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Large Agglomerations and Economic Growth in Urban India: An Application of Panel Data Model

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LARGE AGGLOMERATIONS AND ECONOMIC GROWTH IN URBAN INDIA: AN APPLICATION OF PANEL DATA MODEL

Sabyasachi Tripathi*

Abstract

This paper investigates the impact of urban agglomeration on urban economic growth, using static and dynamic panel data approach, based on data of 52 large cities in India from 2000 to 2009. The results show that agglomeration has a strong positive effect on urban economic growth and support the 'Williamson hypothesis' that agglomeration increases economic growth only up to certain level of economic development. The critical level per-capita city income is estimated to be about Rs 37,049 at 1999-2000 constant prices. In addition, the results indicate that human capital accumulation promotes urban economic growth.

Key Words: Agglomeration, Economic Growth, Panel Data Approach, Urban India.

JEL Classification: O4, R11, R12

Introduction

Recent research on urban economics (specifically related to developing countries) focusing on the most important feature of within-country differences in income, productivity and population density has found a strong positive link (or high correlation) between urban agglomerations and economic growth. The occurrences of these differences are due to two main reasons: First, the transformation of agriculture-based economy into industrial- service-based economy, which is an inevitable stage in the development process of a country; and second, the advantage of higher productivity due to the concentration of manufacturing and provision of services in the large city.

Urban India is also experiencing a similar pattern of transformation as evidenced by the increase in economic growth and demographic size. For instance, the share of urban NDP in the national NDP increased from 37.65 per cent in 1970-71 to 52.02 per cent by 2004-05. On the other hand, urban population as percentage of total population increased from 19.9 per cent in 1971 to 27.8 per cent by 2001.

Why does spatial concentration (or urban agglomeration) promote economic growth? This has been studied in terms of the new economic geographic (NEG) models pioneered by Krugman (1991). The theoretical models and ensuing literature of NEG that are described in Fujita *et al* (1999) seek to measure agglomeration effect (or realization of higher productivity) derived through the interaction of market size, transportation costs and increasing returns at the firm level, i.e., the lowered average costs

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due to the sharing of fixed costs with consideration of general equilibrium framework through imperfect competitive market structure.

However, at any point of time, there may be over- (or excessive) concentration of resources in a few cities or insufficient concentration in certain cities. The over- concentrated cities face problem of higher commuting, congestion and living costs which together increase the production cost of goods and lower the quality of urban service provision. On the other hand, under-concentration also may not be good in terms of productivity growth due to under-utilization of resources. Therefore, there is an optimal degree of urban concentration that is achieved by a trade-off between social marginal benefit and cost of increasing urban concentration. The optimal degree of urban concentration varies with the level of development and country size (Henderson 2003).

The non-linear relationship between spatial concentration and economic growth has been highlighted by Williamson (1965). He suggests that large agglomerations contribute positively to economic growth in the early stage of development when transport and communication infrastructure is scarce; but in the later stage of development when infrastructure improves, large agglomerations contribute negatively to economic growth (see for details explanation in Brülhart and Sbergami 2009; Henderson 2003).

New economic geography literature (for example, Martin and Ottaviano 1999; Fujita and Thisse 2002; Baldwin and Martin 2004) and urban studies (Bairoch 1993; Hohenberg and Lees 1985; Hohenberg 2004; Bertinelli and Black 2004; Crozet and Koeing 2007; Glaeser and Gottlieb 2009; Henderson 2010; Leitão 2012) find a strong positive relationship between agglomeration and growth. However, a number of authors had earlier found a pattern of initially increasing and subsequently decreasing urban concentration across countries corresponding to rise and fall of incomes, (Wheaton and Shishido 1981; Junius 1999; Davis and Henderson 2003), Henderson's (2003) later to measure the non-linear effect of agglomeration on growth support the Williamson hypothesis. Brülhart and Sbergami (2009) have extended Henderson's (2003) study and revalidated Williamson hypothesis.

Most Indian literature (Sridhar 2010; Mathur 2005; Mills and Becker 1986; Narayana, 2009) has mainly focused on finding the determinants of urban population concentration and seeing whether urban concentration has declined or increased over the period, in different classes of cities. Also, some studies (Lall and Mengistae 2005; Lall and Rodrigo 2001; Lall *et al* 2004) explore the determinants of urban agglomeration and urban economic development in India through the indices of industrialization. Sridhar (2010) analyzes and estimates determinants of city growth and output at the district level as well as the city level in India. In city level analysis, the study finds that proximity to a large city, or turning away from agriculture towards manufacturing by its populace encourages a city to become larger. In addition, the author finds that existence of the urban land ceiling act deters city growth by artificially creating scarcity of urban land.

Given the insight provided by the above studies, what should engage the attention of researchers in the Indian context are the impact of urban agglomeration on urban economic growth and the empirical research on non-linear relationship between them. Therefore, these issues form the main focus and objective of this paper. To our knowledge, this paper is a beginning to analyze the non-linear relationship between urban agglomeration and urban economic growth using sub-national level (i.e., state and urban levels) data in the Indian context.

Urban agglomeration is defined by geographic concentration of urban population and related economic activities. Here, cities with 750,000 or more inhabitants in 2005 are defined as large urban agglomerations. The reasons behind the selection of these large agglomerations as unit of analysis are the following: First, World Urbanization Prospects provides updated data for the cities with 750,000 or more inhabitants from 1950 to 2025 with a five-year interval, whereas Indian census data only provides data up to 2001 census (as the latest census 2011 data are yet to be published) with a 10-year interval. Second, due to unavailability of city-specific data for a number of variables (e.g., city income data) used in this study, the city district (where the sample city is located) is used as proxy of a city.

The earlier studies (such as, Henderson 2003; and Brülhart and Sbergami 2009) had also applied the 'Williamson hypothesis'. However, what differentiates this study from earlier studies is that all previous studies had considered that the urbanization process might have impacted national-level economic development. Nevertheless, in line with what Glaeser *et al* (1995) argued, "In many respects, however, the story of growth cities is similar to that of the growth of countries", we also consider urban economic growth rate as a proxy of national-level economic development. In fact, in 2004-05, urban GDP contributed around 52.02 per cent to India's overall GDP. Moreover, Indian states represent a fairly high degree of political autonomy and indicate state-wise variability or heterogeneity among them. Cities located in different states also show different characteristic across them. Therefore, Indian individual cities are considered as a representative of national-level development.

The paper is organized as follows: Section 2 presents the theoretical framework of agglomeration and economic growth, and Section 3 discusses methodological issues regarding the specification and estimation of empirical growth models with description of data and variables for estimation. Estimated results are reported in Section 4. Major conclusions and implications are summarized in Section 5.

Theoretical framework

To measure the effect of urban agglomeration on urban economic growth, the endogenous growth theory (Romer 1990) is considered in the following reduced form specification.[1]

$$\log y(t_2) - \log y(t_1) = -\left(1 - e^{-\beta\tau}\right) \log y(t_1) + X\,(t_1)\,\gamma + f + \varphi_{t2} + \epsilon_{t2} \text{ -------- (1)}$$

Where β is the rate of convergence to the steady state, $X\,(t_1)$ is the vector of determinants of country growth rate, φ_{t2} are the time dummies, f is the time invariant characteristic, and ϵ_{t2} is random disturbance.

Additionally, to incorporate the nonlinear effect of urban agglomeration on urban economic growth, the following specification initially used in Henderson (2003) is considered by adding to equation (1).

$$+\text{urban agglomeration } (t_1)[\gamma_0 + \gamma_1 \log y(t_1) + \gamma_2(\log y\ (t_1)^2] \qquad \text{-------- (1a)}$$

The predicted sign of γ_1 is positive (i.e., $\gamma_1 > 0$) and γ_2 is negative (i.e., $\gamma_2 < 0$), so that the positive effect of urban agglomeration initially increases with income, up to certain income level and then with further increase in income, agglomeration becomes increasingly disadvantageous.

Empirical framework

1. Panel regressions

The econometric model for capturing urban agglomeration effect on economic growth takes the following form:

$$y_{it} = \delta y_{i0} + \delta_1 A_{it} + \boldsymbol{\delta_2 X_{it}} + \partial \text{t} + \eta_i + \epsilon_{it} \text{ ,} \quad \text{-------- (2)}$$

where A_i is an agglomeration variable and $\boldsymbol{X_i}$ is a matrix of the control variables. Additionally, t denotes one year intervals; η_i is the unobserved time-invariant specific effects; ∂t captures a common deterministic trend; ϵ_{it} is a random disturbance assumed to be normal, and identically distributed (IID) with E (ϵ_{it}) = 0 ; Var(ϵ_{it})= σ^2 > 0.

For a dynamic setting, equation (2) can be written in the following form:

$$y_{it} - y_{i,t-1} = \delta y_{i,t-1} + \delta_1 A_{i,t-1} + \boldsymbol{\delta_2 X_{it}} + \partial \text{t} + \eta_i + \epsilon_{it} \text{ ,} \quad \text{-------- (3)}$$

The equation (3) can be written the in following AR (1) specification:

$$y_{it} = \delta' y_{i,t-1} + \delta_1 A_{i,t-1} + \boldsymbol{\delta_2 X_{it}} + \partial \text{t} + \eta_i + \epsilon_{it}, \quad \text{-------- (4)}$$

with $\delta' = (\delta + 1)$.

The η_i component of equation (2) represents a city-specific effect of time-invariant determinants of income per capita that may or may not be correlated with agglomeration. In the presence of such effects, any cross section estimate based on lags of the same variables as instruments will be a biased estimation.

Following the empirical literature review, urban agglomeration, state land area (or geographic size), human capital accumulation, investment on urban development, and trade openness are used as explanatory variables to assess the relationship between agglomeration and economic growth.

We employ two proxies to assess the urban agglomeration; first, population in the large agglomeration, and second population density of the large agglomeration. Accordingly, we formulate the main hypothesis and expect that urban agglomeration tends to promote the economic growth (Martin and Ottaviano 1999; Fujita and Thisse 2002). However, as per Williamson (1965) hypothesis, we expect that agglomerations promote economic growth at an early stage of development. Following the basic empirical growth model of Barro (1991) and Mankiw, Romer and Weil (1992), a positive effect of city-wise investment rate on city economic growth is assumed. As empirical works (Brülhart and Sbergami 2009; Henderson *et al.* 2001) find a strong positive effect of human capital on urban economic growth rate, we also expect to see a positive relationship between human capital accumulation and urban economic growth rate. Large city urban concentration declines with increase in the state's land area (or geographic size) because of the positive link between the bigger state size, dispersion of state resources and formation of more cities as assumed by Henderson (2003) which adversely affect economic growth. Therefore, we expect a negative relationship between geographic size of a state and urban economic growth. In relation to the degree of state trade openness with urban economic growth, a negative effect is expected because when a country trades less with the rest of the world, the domestic transaction becomes more important and these transactions can, in general, be conducted more cheaply over shorter distances. This process is reversed when more countries trade with the rest of the world (or have more liberalized trade norms), as theoretically predicted by Krugman and Elizondo (1996) and elaborated by Brülhart and Sbergami (2009). Therefore, greater trade openness reduces the growth-promoting effect of urban agglomeration.

2. Technique of estimation

Earlier studies had used static panel data, pooled OLS, fixed-effects (FE) and random-effects (RE) estimator for finding the link between agglomeration and economic growth. In view of that, we have estimated basic growth equation (2) with augmenting equation (1a) by using the static panel data model. Diagnostic tests such as Breush and Pagan Lagrange Multiplier (LM) Test and the Hausman (H) Specification diagnostic test are used to choose between panel data models. LM test is used to test the null hypothesis of non-random individual effect. A high value of LM favours fixed effect model or random effect model, over pooled regression model. Hausman specification test is used to test null hypothesis of zero correlation between city- specific effects and the explanatory variables. The significance of LM test statistics indicates that the model estimated by using RE model or FE model give better estimates than pooled regression model. Further, the statistical significance of Hausman (h-test) specification test suggests that estimation by using FE model is preferable to RE model. However, FE model is found efficient to capture time- invariant country characteristics such as geography and culture, but this model is not efficient to eliminate the cross-period correlation between the variables and error terms. In this case, there may be cross-period correlation so that the base-period variables such as income or agglomeration may be correlated with ϵ_{it} from the growth period. To deal with these problems, we have used the Arellano-Bond (1991) difference Generalized Method of Moments (GMM) estimator first proposed by Holtz-Eakin, Newey and Rosen (1988).[2] The first difference of the regression equation is considered for the estimation process in order to remove the unobserved country-specific time-invariant effects, so that there will be no omitted variable bias across time-invariant factors. The lagged values of the explanatory variables (i.e., $y_{i,t-1}$, $A_{i,t-1}$, $\boldsymbol{X}_{it}$) are used as instruments to tackle the inconsistency problem which comes from the endogeneity of the explanatory variables. Further, the difference GMM estimator provides a consistent estimator as long as the following identifying assumptions are satisfied: first, the initial conditions are predetermined, so that $E[y_{it}\varepsilon_{it}] = E[A_{it}\varepsilon_{it}] = E\left[x_{it}^{k}\ \varepsilon_{it}\right] = 0$, for t = 2,…, T, i = 1, ..., N, and *k* = 1, ... , *K* and it is consistent in *N*, the number of cities, given *T*. Second, lagged values of the dependent variable and other explanatory variables in level are valid instruments.

Moreover, we have used two-step estimation procedure to utilize a (within year) heteroskedastic consistent estimate of the covariance matrix of moments. Instruments are all predetermined values of right hand side variables. Moreover, we treat all the time dependent regressors are potentially endogenous. The assumptions on serial correlation are tested and hold (strongly) in all the estimations. We limit the number of instruments by including a maximum of three lags, in order to avoid rejection of the null hypothesis for the validity of over-identifying restrictions.

We also report robust standard errors and Sargan or Hansen test statistics for over-identifying assumption. Estimations are performed using the *xtabond2* package for Stata 11.0 written by Roodman (2009).

3. Source and Description of the Data

Table 1: Measurement and data sources of the variables

Variables descriptions	Measurement	Data Sources
Dependent variables:		
City output and its growth	Non-primary district domestic product (DDP) is measured in terms of the city output and growth rate of DDP over the period 1999-00 to 2008-09 at 1999-2000 constant prices is a measure of urban economic growth.	Directorate of Economics and Statistics (DES), various State Governments, Government of India (GOI).
Independent variables:		
Large city population	52 urban agglomerations with 750,000 or more inhabitants over the period 2000 to 2009. Population figures are available for 2000, 2005, and 2009. Interpolation has been done to generate population data for intervening years.[3]	UN, World Urbanization Prospects, 2009 Revision.
Large city population density	City population density over the period 2000 to 2009. Population data is divided by the city area as per 2001 census.	UN, World Urbanization Prospects, 2009 Revision and Town Directory, Census of India 2001, GOI
State trade openness	Ratio of state export value to the value of Gross State Domestic Product (GSDP) at current prices for 2002-03, 2005-06, and 2006-07.	www.indiastat.com (2011) and DES, various state Government
Human capital accumulation	The effect of education which is proxied by upper primary gross enrollment ratio (Grades VI-VIII) for the period of 2002-03 to 2008-09.	District Information System of Education: District Report Cards published by National University of Educational Planning and Administration (NUEPA), New Delhi, and Census of India 2001.
Size of the state	State land area in 2001.	Statistical Abstract of India 2007, GOI.
City-wise investment rate	Proxied by city wise sanctioned per capita urban capital expenditure over the period 1999-00 to 2008-09, generated by allocating state capital expenditure on urban development to each city over the period 1999-00 to 2008-09 in proportion of their share in total population in 2001.	State Finance: A study of Budget over the period 1999-00 to 2008-09, published by the Reserve Bank of India. Town Directory, Census of India 2001, GOI

Source: Author's compilation

Estimation results: Agglomeration and urban economic growth

Table 4 presents the estimated results of equation (4) augmented with equation (1a). As the estimated results show that LM test is significant for regression (2) to (6), we go for estimation of panel model. The null hypothesis in the LM test is that the variance across entities is zero. This means no significant difference across units (i.e., no panel effect). As Hausman test turns out be significant, we go for fixed effect model estimation for regression (2) to (6). However, as regression (1) shows insignificant LM test, we run OLS regression estimation.

To analyze the non-linear effect of agglomeration on urban economic growth, we run regression (1) to (3). In the first specification in regression (1), both the proxy variables of urban agglomeration (i.e., population in large city and population density of the large city) in the nonlinear form are considered. Regression (2) and (3) consider the non-linear form of the two proxy variables of urban agglomeration separately, as the estimated coefficient of these two models show higher level of significance with expected sign from regression (1). To analyze the effect of urban agglomeration on urban economic growth, regression (4) and (5) have been considered separately for two proxy variables of urban agglomeration. Finally, due to availability of limited data for other explanatory variables we run regression (6) separately by considering other important explanatory variables that may affect urban economic growth.

The results of regression (1) confirm the non-linear effect of urban agglomeration proxied by population of large city, even though, the result is not statistically significant. The non-linear effect of urban agglomeration, as proxied by population density of large city, does not show the expected sign. For that reason we run regression (2) and (3) considering them separately. Results of the fixed effects estimator of regression (2) and (3) are consistent with the Williamson hypothesis, i.e., while the interactions of both the agglomeration variables (i.e., large city population and large city population density) with initial year per capita city output are positive (i.e.,$\gamma_1 > 0$) and interactions of both the agglomeration variables with square of initial year per capita city output are negative (i.e., $\gamma_2 < 0$). Both the coefficients are statistically significant at 10 per cent (or 5 per cent) level in regression (2) [or in regression (3)]. These findings strongly support for the Williamson hypothesis that positive effect of agglomerations initially increase with income, up to a certain income level. Then, with further increase in income, agglomeration becomes increasingly disadvantageous.

Table 2: Large agglomeration and urban economic growth: FE Effects

Independent variables	Dependent variable: growth rate of per-capita city output, 2000 to 2009					
	OLS (1)	**FE (2)**	**FE (3)**	**FE (4)**	**FE (5)**	**FE (6)**
Constant	1362.19*** (106.44)	-173.19 (2432.74)	-4923.72** (2426.69)	-8354.19*** (1029.48)	-3071.47*** (884.51)	-6020.56*** (2044.91)
City population	-9.48 (8.17)	-112.58*** (35.37)			1.561*** (0.337)	
City population* $logyt_1$	1.58 (1.62)	21.07*** (6.34)				
City population* $(logyt_1)^2$	-0.066 (0.079)	-0.975*** (0.287)				
City population density	2.85 (1.83)		-6.23** (2.91)	0.644*** (0.071)		
City population density* $logyt_1$	-0.658* (0.372)		1.22** (0.512)			
City population density* $(logyt_1)^2$	0.037** (0.019)		-.055** (0.023)			
City population* log of state land area						0.23*** (0.076)
UPGER						12.53*** (4.54)
Urban capital expenditure						0.265 (0.869)
City population* state trade openness						-0.395 (0.446)
LM(chi^2)	2.40	50.59***	12.99***	64.70***	53.85***	10.49***
H(chi^2)		42.46***	62.98***	118.73***	66.44***	12.03**
R^2	0.39	0.39	0.46	0.31	0.32	0.33
F Model test		70.96***	31.71***	83.12***	21.51***	12.05***
Year effects		YES	YES	YES	YES	YES
N	340	340	340	340	340	115

Note: Figures in parentheses represent robust standard errors. ***, **, and * indicate statistical significance at 1%, 5%, and 10% level, respectively.
Source: Estimated by using equation (4) and (1a).

The result of regression (4) shows that the large city population density (used as a proxy of urban agglomeration) has a positive and significant effect on urban economic growth. This positive impact of agglomeration on growth matches with our main working hypothesis. In particular, a 10 per cent increase in urban agglomeration increases urban economic growth by 6.4 per cent. In regression

(5), the coefficient of large city population agglomeration is positive and significant (at 1 per cent level) and indicates that a 10 per cent increase in large city population agglomeration is associated with an increase of 16 per cent urban economic growth, which supports the predicted hypothesis.

Due to availability of limited data, we run regression (6) by considering other explanatory variables separately. The results of regression (6) show that the human capital accumulation variable (i.e., UPGER) has a positive and statistically significant effect (1 per cent level) on urban economic growth. The result indicates that human capital accumulation promotes urban economic growth. An increase of 1 per cent UPGER would generate 13 per cent increase in growth. The coefficient of state trade openness reduces the growth-promoting effect of urbanization, which is in line with our working hypothesis. However, the value of estimated coefficient is not significant. The result also shows that the annual average rate of investment (proxied by state government urban capital expenditure) raises economic growth which is in line with our working hypothesis, even though the result is not significant. In particular, a 10 per cent increase in average investment rate is associated with 2.7 per cent increase in city economic growth and supports the positive effect of government policy on urban agglomeration. Finally, we account for state size effects, where we expect large population agglomeration to decline as state land area increases. The result show that the coefficient of log of state land area interacted with urban population agglomeration has a positive and statistically significant effect on urban economic growth rate. The result runs counter to the expected hypothesis. The general performances of the FE regressions estimation are satisfactory. The explanatory power of the urban agglomeration and urban economic growth regressions are high (R^2 values lies between 0.31 and 0.39).

Table 3 reports the regression results based on GMM-Differenced regression estimation based on the two-step estimation procedure. The test for AR2, which detect autocorrelation in levels, shows satisfactory results. Except for regression (11), the Hansen test shows that there are no problems with the validity of instruments used.[4] Moreover, we treat all time dependent regressors as potentially endogenous; hence, we instrument their first differences with past levels by limiting the number of instruments by considering a maximum for three lags.

Table 3: Large agglomeration and urban economic growth: GMM-First-differenced

Independent variables	Dependent variable: growth rate of per-capita city output, 2000 to 2009 – First- differenced GMM (DIF-GMM) estimation				
	(7)	**(8)**	**(9)**	**(10)**	**(11)**
City population	-22.08 (41.1)	-86.28*** (22.95)		2.33*** (0.479)	
City population* $logyt_1$	4.82 (7.18)	16.82*** (4.182)			
City population* $(logyt_1)^2$	-0.246 (0.321)	-0.799*** (0.195)			
City population density	-2.69 (7.003)		-6.94* (3.51)		0.639*** (0.114)
City population density*$logyt_1$	0.527 (1.24)		1.31** (0.629)		
City population density* $(logyt_1)^2$	-0.023 (0.057)		-.059** (0.029)		
Hansen	34.60 (0.628)	21.94 (0.344)	19.89 (0.280)	10.26 (0.174)	15.03 (0.020)
AR1	-2.80 (0.005)	-2.74 (0.006)	-2.78 (0.005)	-2.76 (0.006)	-2.87 (0.004)
AR2	0.89 (0.374)	0.92 (0.357)	0.95 (0.344)	1.03 (0.305)	0.95 (0.343)
N	288	288	288	288	288

Note: Figures in parentheses represent robust standard errors. ***/ **/*- statistical significance at 1%, 5%, and 10% levels. Instruments used for all the equations in first differences are past levels of each time varying variable from t−1 for predetermined variables and from t−2 for the others up to the third lag. P -values for the null hypotheses of the usual diagnostic tests are reported in parentheses at the end of the table.

Source: Estimated by using equation (4) and (1a).

Regression (7) considers both the agglomeration variables together and shows the statistically insignificant non-linear effect of urban agglomeration on large city output growth rate. However, regression (8) and (9) show the statistically significant coefficient of the agglomeration variables in the non-linear form. The coefficients again have their expected sign and the results confirm the Williamson hypothesis. In the GMM-Differenced estimation of regression (8) the (log) income point that maximizes any positive effect of urban agglomeration on urban economic growth $(-\gamma_1/(2\gamma_2))$ equals 10.52, which is the city output per capita at 1999-2000 constant prices of about Rs 37049. The result indicates that increases in urban agglomeration are harmful, but just less so for a city output per capita of about Rs 37049 at 1999-2000 constant prices.

As expected the coefficient of the large city population agglomeration in regression (10) has a positive and statically significant effect on city output growth rate. In particular, a 10 per cent increase in urban agglomeration increases urban economic growth by 23 per cent. Moreover, second proxy variable of urban agglomeration (i.e., large city population density) has a significant and positive effect. These results validate the hypothesis of positive effects of large urban agglomeration on urban economic growth. However, due to availability of a limited number of observations for other explanatory variables, we are unable to get satisfactory results (results are not reported here) by including them as explanatory variable in the GMM-Differenced regression estimation.

The positive effect of urban agglomeration on economic growth supports the findings of earlier urban studies, such as by Martin and Ottaviano (1999) and Fujita and Thisse (2002). The non-linear effect of agglomeration on growth (i.e., Williamson hypothesis) supports the findings of Brülhart and Sbergami (2009) and Henderson (2003). The positive effect of human capital accumulation on economic growth supports Brülhart and Sbergami (2009) and Henderson *et al* (2001).

Conclusions and Implications

This paper has explored the relationship between urban agglomeration and urban economic growth by using static and dynamic panel data approach for the period 2000 to 2009, based on data for 52 large cities in India. Urban agglomeration is measured alternatively through size of urban population and through urban population density, while urban economic growth is measured by growth rate of city output. From the estimated results, we can infer the following: first, urban agglomeration has a strong (or statistically significant) positive effect on urban economic growth; second, the results support for the 'Williamson hypothesis' that agglomeration boosts GDP growth (proxied by urban economic growth) only up to a certain level of economic development with the estimated critical level of per-capita city income at around Rs. 37049 at 1999-2000 constant prices; third, human capital accumulation promotes urban economic growth; fourth, annual average rate of state government investment has a positive weaker impact on city economic growth rate, while state trade openness reduces the growth-promoting effect of urbanization, and firth, urban agglomeration increases with state size (land area).

The results support the logic of the recent urban development programme by the government, for example, the Jawaharlal Nehru National Urban Renewal Mission, for promotion of urban agglomerations in India. However, considerations of other important factors such as level of higher education, life expectancy, fertility and government consumption that may influence urban economic growth are left for further extension of the model.

Notes

[1] Equation (1) is derived from the following Cobb-Douglas production function:

$$Y = K^{\alpha}(AL)^{1-\alpha} \qquad \text{----- (i)}$$

Where Y is national output, K = physical capital, L = human capital (or labour); The technical progress is embedded in human capital.
A linear expansion in natural logs of the equation of motion about its steady state value and using Taylor series expansion equation of equation (i), equation (1) is derived. For more details see Henderson (2003).

[2] The difference-GMM suffers from considerable finite-sample bias and system-GMM overcome that problem and has the smallest bias of the dynamic GMM estimator [Bun and Windmeijer 2007]. However, as system GMM uses more instruments than difference GMM it may not be appropriate to use system GMM for a dataset with a small number of observations. Due to availability of limited data set used in our study, we find more satisfactory result for difference GMM than system GMM and we produce the results based on difference GMM estimation.

[3] Estimation of the population in each city for the year 2001, 2002, 2003, 2004, 2006, 2007, and 2008 from the projection method given by the United Nations Population Fund, New Delhi, and International Institute for Population Sciences (UNPFA-IIPS) in 2009, Mumbai.
Suppose we are going to interpolate city population data for 2006 given the city population data for 2009 and 2005.

Annual growth rate (r) of population = $ln(P_1/P_0)/t$

P_1 = Projected population of 2009

P_0 = Projected population of 2005

t = Time interval between the projected years

i.e., [ln (total population of 2009/Total population of 2005)]/4
Then estimated population for 2006: $P_t = P_0 e^{rt}$
Where, P_t = City population at time t (where t = 2006)
P_0 = Population for 2005
r = Growth rate
t = Years between P_0 and P_t

[4] As the results are based on robust estimation, we report Hansen J statistics instead of the Sargan statistics for the same null hypothesis.

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Appendix 1

Table 1: Name of cities used in regression analysis

Agra (Agra), Aligarh (Aligarh), Allahabad (Allahabad), Amritsar (Amritsar), Asansol (Barddhaman), Aurangabad (Aurangabad), Bangalore (Bangalore Urban), Bareilly (Bareilly), Bhiwandi (Thane), Bhopal (Bhopal), Bhubaneswar (Khordha), Chandigarh[@], Chennai (Chennai). Coimbatore (Coimbatore), Delhi[@], Dhanbad (Dhanbad), Durg-Bhilainagar (Durg), Guwahati (Kamrup), Gwalior (Gwalior), Hubli-Dharwad (Dharward), Hyderabad (Hyderabad), Indore (Indore), Jabalpur (Jabalpur), Jaipur (Jaipur), Jalandhar (Jalandhar), Jamshedpur (Purbi-Singhbhum), Jodhpur (Jodhpur), Kanpur (Kanpur Nagar), Kochi (Eranakulam), Kolkata (Kolkata), Kota (Kota), Kozhikode (Kozhikode), Lucknow (Lucknow), Ludhiana (Ludhiana), Madurai (Madurai), Meerut (Meerut), Moradabad (Moradabad), Mumbai (Mumbai), Mysore (Mysore), Nagpur (Nagpur), Nashik (Nashik), Patna (Patna), Pune (Pune), Raipur (Raipur), Ranchi (Ranchi), Salem (Salem), Solapur (Solapur), Thiruvananthapuram (Thiruvananthapuram), Tiruchirappalli (Tiruchirappalli), Varanasi (Varanasi), Vijayawada (Krishna), Visakhapatnam (Visakhapatnam).

Note: Name in the bracket indicates the name of the district in which city is located.

[@] Delhi and Chandigarh were considered as a whole proxy of a city district.

Table 2: Summary statistics for the main variables

	Observations	Mean	Standard Deviation	Minimum	Maximum
City output per capita, (in Rs)	392	20247.45	11800.67	733.4	77395.4
Log (State land area, in sq km)	520	11.79	1.35	4.74	12.74
City population (in thousands)	520	2510.01	3882.41	603	21720
City population density	520	14768.83	13143	807	82124
UPGER	355	62.81	30.86	0	212.19
State Trade Openness	156	0.13	0.14	0.003	0.69
Per capita capital expenditure (in Rs)	520	73.24	153.62	0	861.05

Source: Author's Computation

Appendix 2:

Theoretical derivation: Agglomeration and economic growth

To incorporate urban agglomeration in to an economic growth framework, first we derive the standard empirical growth model in Durlauf and Quah (1998) and Henderson (2003).

The aggregate Cobb-Douglas production function in the following form is used:

$$Y = (K(t))^{\alpha} (A(t)L(t))^{1-\alpha} \quad \text{------------ (1)}$$

Where *Y* is national output, *K(t)* = physical capital, *L(t)* = human capital (or labour), *A(t)* = level of technology; the technical progress is embedded in human capital. Labour and technology grow at rates *l* and *g* , so $\dot{L}/L = l$,$\dot{A}/A = g$. As in Solow model capital depreciates at the rate δ, and s is the fraction of output saved and invested. The output and capital per effective are defined as $y = Y/AL$ and $k = K/AN$, respectively.

Now we can write equation (1) in the following intensive form

$$y = k^{\alpha} \quad \text{------------ (2)}$$

The steady state condition (it is a situation in which the various quantities grow at constant rates) imply that $\dot{k}/k = 0$.

Therefore, using the capital accumulation equation, we get the following:

$$\dot{k} = sf(k) - (n + g + \delta)k \quad \text{------------ (3)}$$

The steady state value of *k* is the following:

$$k^{*} = (s/n + g + \delta)^{1/_{1-\alpha}} \quad \text{------------ (4)}$$

Dividing by *k* in equation (3), we get

$$\gamma_k = \dot{k}/k = sk^{-(1-\alpha)} - (n + g + \delta) \quad \text{------------ (5)}$$

The logarithm linearization consists in applying a first order Taylor expansion of *log (k)* around *log (k*)*.

Let we write the equation motion

$$\frac{dk/dt}{dk} = sk^{\alpha-1} - (n + g + \delta) \quad \text{------------ (6)}$$

Taking logarithm, we get

$$\frac{dlogk(t)}{dt} = s\ e^{-(1-\alpha)logk(t)} - (n + g + \delta) \quad \text{----------- (7)}$$

we define,

$$g[logk(t)] = s\ e^{-(1-\alpha)logk(t)} - (n + g + \delta) \quad \text{----------- (8)}$$

Now, we approximate this function at its steady state value as following:

$$g[logk(t)] = g[logk^*] + \frac{\partial g[logk(t)}{\partial logk(t)} \;\; .(logk(t) - logk^*) \qquad \text{----------- (9)}$$

logk(t)=logk*

Then we get the log-linear form of the growth rate function as

$$\frac{glogk(t)}{y(t)} = -(1-\alpha)(n+g+\delta)(logk(t) - logk^*) \qquad \text{---------- (10)}$$

and $\frac{d\{logk(t)/dt}{dlogk(t)} = -(1-\alpha)(n+g+\delta)$ ---------- (11)

where $\beta = -\frac{d\{dlogk(t)/dt\}}{dlogk(t)} = (1-\alpha)(n+g+\delta)$ ---------- (12)

β is called the speed of convergence in the economic growth literature. When the production function is Cobb-Douglas, 1 % deviation from k^* yields a percentage change in the growth of k equal to $-(1-\alpha)(n+g+\delta)$.

In the same way, the derivations for growth rate of income per-capita can produce the following equation:

$$\frac{dlogy(t)}{dt} = -\beta\,(logy(t) - \log y^* \qquad \text{---------- (13)}$$

The speed of convergence is the same for the income per-capita as for the capital-labour ratio.

Equation (13) is a first order differential equation of the type:

$$logy'(t) + \beta log\, y(t) = \beta log\, y^* \qquad \text{---------- (14)}$$

where $y'(t)$ is the time derivative of log $y(t)$.

The solution of the differential equation (14) is the following:

$$logy(t) = \left(1 - e^{-\beta t}\right) log\, y^* + e^{-\beta t} \log y(0) \qquad \text{---------- (15)}$$

where $\beta = (1-\alpha)(n+g+\delta)$ and $y^* = (k^*)^\alpha$ ---------- (16)

Then combining for the two time period t_2, and t_1 we get

$$logy(t_2) - logy(t_1) = -\left(1 - e^{-\beta\tau}\right) log\, y^* - \left(1 - e^{-\beta\tau}\right) \log y(t_1) \qquad \text{---------- (17)}$$

where $\tau = t_2 - t_1 > 0$

To convert equation (17) to observable magnitudes, we substitute in for $y(t) = \frac{y(t)}{A(t)}$, then we get the following:

$$logy(t_2) - logy(t_1) = -\left(1 - e^{-\beta\tau}\right) logy(t_1)$$

$$+\left(1 - e^{-\beta\tau}\right)(\alpha/1-\alpha)\log(s/n+g+\delta)) \;\; \left(1 - e^{-\beta\tau}\right) logA(t_1) + g\tau \qquad \text{---------- (18)}$$

However, the most recent empirical approaches, formulations typically reduce for country i to

$$\log y(t_2) - \log y(t_1) = -\left(1 - e^{-\beta\tau}\right) \log y(t_1) + X\,(t_1)\,\gamma + f + \varphi_{t2} + \epsilon_{t2} \quad \text{---------- (19)}$$

Where β is the rate of convergence to the steady state, $X\,(t_1)$ is the vector of determinants of country growth rate, φ_{t2} are the time dummies, f is the time invariant characteristic, and ϵ_{t2} is random disturbance.

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