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SPATIAL DURBIN MODEL OF REGIONAL INCOMES IN INDIA: THE ROLE OF PUBLIC, PRIVATE AND HUMAN CAPITAL

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Abstract

Most regional income studies in India examine only the convergence of regional per capita incomes with a limited number of studies analyzing the relative role of its determinants. Spatial Durbin model of regional income and growth based on the augmented Mankiw-Romer-Weil (MRW) -with public, private, household and human capitals as the determinants - is estimated using the 2015 Indicus data on per worker incomes for 103 regions (clusters of districts) of India. The results of the spatial model support spillover effect of public, human and private capital from neighbouring regions on per worker Gross Regional Domestic Product (GRDP) as found in several studies for European regions. We additionally find that public capital, which is not accounted for separately in the developed country regional models, is a relatively more important determinant for a developing country like India than private capital or human capital for this data. In the spatial growth model of per worker GRDP, none of the determinants except the state capital dummy variable have significant impact on the regional growth rate between 2001 and 2015. This may be a data limitation and perhaps a panel data model may be more suited for such an analysis.

Keywords: *Public capital, Regional Income, Spatial Durbin Model, Augmented MRW model.*

JEL Codes: *O47, R12, R53, C21*

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INTRODUCTION

Neoclassical theories[1] explain the role of physical capital in determining income level with technological progress as exogenously determined. On the other hand, theories of disequilibrium (Myrdal, 1957; Hirschman, 1958; Williamson, 1965) and the new endogenous theory account for the spillover impact of either capital or technology on growth. Such spillover aspects gain significance while analysing changes in income or its growth at a regional level for a large country or a group of countries that have common boundaries. The federal polity of a country like India or the institutional arrangements between geographically contiguous nations within a continent like Europe would have less barriers to spatial spillovers in factors of production or technology. However, the spillovers may not be uniform between any two contiguous regions due to inherent disparities arising from social, political, and agro-climatic differences. Thus, ignoring the spillover effects while analysing the determinants of income or growth at a regional level would lead to a mis-specified model in the empirical analysis.

The spillover effects are modelled by accounting for the spatial interconnectedness between contiguous regions and has spawned off a new set of studies. For instance, the spatial spillover effects are incorporated in the Solow's model (Solow and Swan, 1956) by Ertur and Koch (2007) and by Fischer (2011) in the model of Mankiw-Romer-Weil (1992- henceforth MRW) to analyse the spatial aspects of regional income after accounting for different forms of capital at a regional level. Dominicis (2014), Panzera and Postiglione (2022) modify the spatial MRW model to assess Beta-convergence[2].

[1] Martin and Sunley (1998) point out that, taking a departure from exogenous neoclassical theories, physical and human capital are included in the augmented neoclassical model. In an endogenous broad capital model, returns through knowledge spillovers as well as government spending are incorporated. Schumpeterian endogenous innovation theory points out the importance of technological diffusion, transfer, and restrictions in the convergence process. These theories are referred to as "New Endogenous Growth Theories."

[2] Sala-i-Martin (1996) provides two types of convergence. Sigma convergence refers to a reduction in differences in income levels among regions, while in Beta convergence the focus is on income growth wherein poor regions grow faster than rich regions.

The empirical analysis has firmly established that spillover effects have to be accounted for while analysing the determinants of regional income or growth. However, such studies are largely for developed countries like Brazil (Lima and Silveira Neto, 2016) or for European Union (Arbia, et al 2010, Fischer, 2011). Developing countries like India with diverse social, demographic, and agro-climatic features alongside historical inequities has resulted in leading and lagging regions within the nation (Ghani, 2010). For several decades, the endeavour of public policy has been to address the uneven pace of regional growth and development (Fifteenth Finance Commission 2020). On the one hand, this happens through allocation of public capital for an equitable access to public goods including social and physical infrastructure. On the other hand, policy regulations attempt to improve the business environment to ensure that neither the flow of private capital is limited only to the leading regions and nor is there a restriction to labour mobility due to social or political reasons. All these policies aim to ensure that human capabilities improve for the citizens to participate in economic development.

In this context, the first objective of the study is to formulate a regional model of income and growth that accounts for spatial spillovers with public and private capital as separate determinants. Empirical estimates from such regional models provide insights for improvements in regional income for (ex ante) policy planning and (ex post) policy evaluation. The second objective is to fill this gap, as such spatial empirical models are nearly absent in the Indian context at a more disaggregated geographic (or administrative) level beyond the states of India. One of the reasons for this could be the paucity of resources posing difficulties in making district level data publicly available on income and its determinants for a developing country like India. The third objective of this study is to estimate a sub-state income model with the scale of geographical unit that is intermediate between the states and districts. The sub-state (henceforth, regional) model enables to overcome certain data limitations (in particular the unavailability of district level private capital), as will be discussed later in the paper. Thus, this study makes the following contributions to the literature on regional growth and inequality.

In this study the private and public capital are considered as two separate determinants of regional income instead of a composite of these two types of capital in order understand their relative role in directly or indirectly (spillover) influencing regional incomes. However, data on private capital, at a disaggregated level of geographical unit beyond the states is difficult to obtain in the Indian context. Following earlier studies, we use regional income inequality measured by population adjusted and spatially weighted Gini coefficient based[3] on the domestic products of the districts that comprise a region.

Thus, for the first time a regional study in the Indian context, uses two different determinants for private and public capital and this is facilitated largely by the choice of sub-state regions of India as the unit of analysis that enables the calculation of regional Gini coefficient. With districts as the unit of analysis, it may not have been possible to arrive at this type of proxy for private capital. In the data section of this study, we discuss the justification for the use of intra-regional inequality as a proxy for private capital based on earlier studies.

Most studies in India analyse regional disparities in income at the state level (the second tier in the federal administration) and only in a few studies, the unit of analysis is the districts (third tier of federal administration). For the first time in the Indian context, this study uses cluster of contiguous districts called regions at the sub-state level to analyse the determinants of regional growth. Data limitations apart, this intermediate scale of geographical unit between a state and a district is preferred as one expects agglomeration effects to be more prominent at the sub-state level of geographical disaggregation (Panzera and Postiglione, 2022).

[3] Gini (1912) gives Gini Coefficient which is used to measure inequality

This study estimates a spatial auto correlated sub-state model to account for spillover effects that are ignored in the more aggregated state level models. The econometric model accounts for spatial spillovers not only via the error term but also in the deterministic part of the model. For this, we extend different versions of spatial models of income derived in Ertur and Kosch (2007), Fischer (2011) and Panzera and Postiglione (2022), to include two other forms of capital: public capital and household capital as determinants of regional income alongside private and human capital as in the original model. Unlike the few previous Indian studies by Banerjee and Banik (2014), Sanga and Shaban (2017) and Hazrana et al (2019) which use spatial econometric models to account for spatial spillovers in regional incomes, the spatial model of regional income used in this study has a theoretical underpinning for spatial spillover effects of the determinants of capital. Thus, the empirical model in this study accounts for: (a) the direct effect of different types of capital as in any standard model of income; (b) the spatial spillover or indirect effects of these capitals; and (c) any other unobserved spatial spillover effects accounted in the residual term of the econometric model.

On the one hand, the spatial models of regional income mentioned above seldom include public capital separate from private capital. On the other hand, the few theoretical models that include public capital separate from private capital as in Barro (1990) and Roy and Raychaudhuri (2009) derive an aggregate model for the whole economy and hence has less scope to account for spatial spillover effects. The theoretical framework used in this study bridges the gap between these two strands of research.

In the absence of regional data on public expenditure, the regionally disaggregated data on public goods is used to construct an index as a proxy for public capital. However, we further distinguish between public goods at the community level and at the household level and refer to this as public and household capital respectively. The index of public capital includes transport and communication facilities, road length, health centers, and irrigation rate. The household capital index consists of household amenities like sanitation, clean drinking water and cooking fuel which is shared by all the members of the household and are thus public goods within the household. We observe that in most studies on regional income in India where such amenities are usually included individually, (and not as an index) there is a differential impact of the community and household level public goods on income. Given this evidence, the aim is to understand the effect of these two forms of capital separately.

The household level public goods improve the health and reduce the drudgery of household members leading to a more efficient use of their time for other productive purposes including human capital formation. Thus, the inclusion of household capital also allows us to control such unobserved aspects of human capital separating it from the observed aspect of human capital measured as years of schooling in a typical endogenous growth model as in MRW. In this study, the fourth determinant of regional income is human capital measured as share of individuals in a region with tertiary education. Thus, there are four types of capital used as observed determinants of regional income as compared to two determinants of broad physical capital and human capital in the earlier studies based on spatial MRW models.

Some of the public expenditure is financed by taxes and tax revenue would depend on how much income or output is generated in the economy. This could lead to potential endogeneity of the public and household capital in the econometric specification. However, the theoretical model used in this study is derived for the steady state level of income. This allows the empirical model to be specified in such a way that the year of regional income is for a later year and the determinants are all at an earlier year (lagged data). Thereby the specification avoids the problem of endogeneity between public capital inputs in a model of regional income.

A sub-state level analysis in this study is made possible due to the access to Indicus district level data[4]. The augmented spatial MRW model is specified for per worker regional income and Indicus district level data provides both per worker and total domestic product for district income at constant prices. This data is available to us for the period 2001 to 2015 that coincides with the period of highest (until date) per capita growth rate in India's post independent period. The steady state regional income model is estimated with income for the terminal year of 2015 and the capital inputs are for the initial year of 2001.

The results of this study show that the spatial econometric model explains the variation in per worker regional income compared to the non-spatial specification. The results highlight the direct role of public and household capital in improving regional growth for India. Further, the spatial models highlight the spillover effect of public capital and household capital on regional income.

This paper is divided into 4 sections. The first section discusses the theoretical and empirical framework for augmented spatial MRW model followed by the data and methodology section. The third section discusses the results and the fourth is the concluding section.

CAPITAL, GROWTH AND SPILLOVER EFFECT

Modern growth theory literature begins with Solow's (1956) explanation of per worker growth driven by the accumulation of per worker physical capital allowing for productivity improvements from exogenous technological progress. An important feature of Solow's model is that physical capital influences the level of income but not growth[5]. In addition to physical capital, later studies also note the role of human capital in determining income (Siggel, 2001; Pistorius, 2004; Horwitz, 2005) and growth (Mankiw, Romer, and Weil, 1992; De la Fuente and

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[4]The access to this data was from DFID research grant on an earlier project and the authors would like to thank the project investigators for being generous in sharing it for further academic research (Vepa *et. al.*, 2015; 2016; 2020 and Ganapati and Vepa, 2020).

[5]In this review and the following empirical analysis, we maintain a distinction between income level and income growth while discussing their determinants.

Domenech, 2006) through labour productivity and technology diffusion. In the neoclassical framework, productivity is considered as exogenous, therefore the influence of characteristics such as education and knowledge acquired by labour on income and growth is overlooked (Pelinescu, 2015). Funke and Strulik (2000) suggest that physical capital has a significant impact on per capita income in the early stages of growth, whereas human capital plays a crucial role in the later stages. In this context very few studies have either emphasized or examined the role of public capital (investment) in the income/growth model with (Barro, 1990; Milbourne et al., 2003; and Roy and Raychaudhuri, 2009). In this study, we review the literature in some detail to highlight the role of public capital and also examine its relevance in an empirical model for regional growth in the Indian context.

According to Bassanini and Scarpetta (2002), the human capital represented by education contributes to the growth of per capita GDP. Recent studies, such as Iacopetta (2010), Gomez (2011), Sequeira (2011), and Chen and Funke (2013), emphasize the significance of human capital to economic growth. While schooling and education levels, which serve as proxies for human capital, have a significant effect on income and growth, these proxies, including education, may not reflect true human capital (Oxley *et. al.*, 2008). Education-based proxy does not incorporate the individual's job ability or health, both of which are essential for employment. Very few studies have paid attention to separating the influence of the role of education and other aspects of human capital, such as health-related amenities, on income levels. Thus, alongside education as human capital, access to basic household amenities, such as drinking water, toilets, and cooking facilities, which play a crucial role in an individual's health and assist in the working capacity and ability are included in this study. An index based on a household's access to such amenities is referred to as household capital in this study.

While it is vital to recognize the roles that physical and human capital play in determining income, it is equally crucial to note that the public sector infrastructure and public capital also play a significant role (Barro, 1990). Public capital has an effect on economic development (Arslanalp et. al., 2010) in two ways: first, it influences productivity (Agénor and Neanidis, 2010); second, it influences the accumulation of human capital (Agénor, 2012). Public capital, human capital via productivity and innovation can affect income level and growth along with physical capital. A few studies in the context of India that include public capital along with human capital and physical capital in a growth model are at the state level and find that it does play an important role in economic growth and human development indicator (Pradhan and Abraham, 2002; Roy and Raychaudhuri, 2009; Viswanath *et. al.* 2009; Halder and Mallik, 2010; Banerjee and Banik, 2014). Compared to regional inequality in incomes measured at an aggregated state level, the inequality assessed at a more disaggregated geographic level of districts is higher. Thus, it is even more relevant to understand the role of public capital in economic growth in a model estimated at a sub-state level of a region that are formed from a cluster of districts. In this study, public capital is an index based on district level public infrastructure such as health centers, roads, post offices, irrigation. However, public capital is not adequate to capture physical capital as it would omit the private investment.

Arbia et. al. (2005) suggests that higher regional inequality results in higher investment in higher income regions and is shown to increase economic growth. Following this Arbia, et. al. (2005), De Dominicis (2014) and Panzera and Postiglione (2022) assume that the investment for physical capital is a function of regional inequality at initial period. Thus, as specified in all these models, regional inequality (proxy for private physical capital) calculated at the study period's starting year is included as a determinant of income or growth.

Physical capital will be created by investment from private and public capital. However, the regional inequality that proxies for physical capital would include only the investment from private capital and not public capital. This is because public investment will happen to any region regardless of regional inequality, as efficiency from the return to investment is not the criteria for public investment unlike private investment. As the role of public investment is to reduce the regional differences in physical capital to foster equitable growth and more so in developing countries, the growth model in this study takes into account public capital in addition to regional inequality which takes into account private capital.

Unlike cross-country models explaining income or growth, spatial externality and spillover effect of technology and capital on income and growth cannot be ignored in a model estimated based on intra-national income. One expects that most determinants, particularly technology and may have spillover effects as political barriers to movement of factors of production or technology may not be there within a country (Quah, 1996; Ertur and Koch, 2007; Fischer, 2011) In order to explain how spatial agglomeration influences development, Ertur and Koch (2007) developed the Spatially Augmented Solow Growth model. The growth model incorporates spatial externalities to capture technological spillover effect. Fischer (2011) presents the spatial MRW model, which takes into consideration the effects of the neighbouring environment. In contrast to spatial augmented Solow growth, spatial MRW takes human capital into account. The growth model developed by Ertur and Koch (2007) is adapted by De Dominicis (2014), while Panzera and Postiglione (2022) expand Fischer's (2011) spatial MRW model. These spatial models determine the direct influence of the physical and human capital on regional income as well as the indirect effect due to spillover from the neighbouring regions.

DEFINING INDIAN REGIONS

India’s federal democracy has three tiers of administration of which the union government at the center and the governments at the state- the first and second tier respectively- formulate policies for an equitable growth and development. A further segregation of states into smaller geographical units called districts form the third tier of governance with very limited administrative jurisdiction for policy formulation. The third tier plays the key role to administer the policies at the ground level and hence is closest to the population that lives in a district. Further, Indian states can be as large as a country in Europe in geographical area or as populous as a country in Latin America or with comparable per capita domestic product in an African country (Ahluwalia, 2002; Nagaraj et. al., 2000). Thus, the districts within a state would be equivalent to the regions within countries of the European Union. Drawing upon this geographical similarity this study analyses the regional incomes and growth for a developing country like India analogous to the analysis based on spatial models of regional growth in European countries mentioned earlier.

The challenge however for a developing country lies in the availability of data on district level incomes as well as the different forms of capital (mentioned earlier) for at least a decade in order to use the empirical framework suggested in the spatial growth models. There are however a few private and public sources of data at the district level, which has made it possible for us to examine regional incomes and its determinants. However, the theoretical structure of the spatial models is such that regional inequality (proxy for private capital) for the initial year is also an important determinant as indicated before. This would require data on intra-district inequality in incomes for the estimation of district level models for income or its growth. To assemble a time series of financial and physical data at the district level is in itself a daunting task for developing countries like India. Data at an urban administrative block or a rural village is nearly absent[6] and hence, it is not possible to arrive at intra-district inequality for each district in India. Thus, instead of the third tier of geographical unit of administration, the analysis is carried out at what we refer to as regiona which are a combination of a few contiguous districts within each state. Such regions within states enable us to arrive

[6]Except through the decennial censuses for some of the household amenities, public infrastructure and demographic data.

at an income inequality value for each region using the unit of districts within each region.

Therefore, in the context of this study, a region refers to a set of districts that have similar characteristics and come together to create administrative divisions. The formation of regions within a district is not done arbitrarily but we find that for all the large states of India with the exception of one state (Tamil Nadu), the state governments have formed regions based on a few contiguous districts within each region that have economic and political similarity (Hirway, 2000; Eapen and Kodoth, 2002; Gupta, 2005; Shaban, 2006; Kelkar, 2013)[7]. Jadhav and Viswanathan (2022) give details regarding the 103 regions and districts forming these regions. Apart from the lack of data at sub-district level as mentioned earlier there is another advantage of using regions instead of districts. While all of these regions are located in the same state, there exists disparity between them. To understand how spillover effect works, regional level is more appropriate than district level as districts within region may be more similar in terms of economic, political and geographical features.

Sub-national analysis in India is largely restricted to state level analysis focusing mostly on convergence or lack of it while very few studies have analysed district level incomes but based on a single state and once again focus on spatial convergence (Shaban, 2006; Kocornik-Mina, 2009; Singh, et al, 2010; Kalra and Thakur, 2015; Sanga and Shaban, 2017). Hazrana, et al (2019) implements spatial model to understand the sector-wise spillover effect on growth using district level data. However, none of these studies consider the role of spillover effects of either technology or forms of capital in analysing regional models and the different types of capital, particularly public capital that would reduce inequities across regions. A few studies, including Roy and Raychaudhuri (2009) and Banerjee and Banik (2014), examine the role of public capital and public services in economic development. However, these studies are limited to either the state level (Roy and Raychaudhuri 2009) or the

[7]Thus, the use of a generic term 'region' for a group of districts is based on its administrative usage in India.

district level (Banerjee and Banik 2014). In this sense our study not only differs in terms of using sub-state level disaggregated data on incomes but equally importantly focuses on spatial correlation across regions that would indirectly capture the spillover effects of different forms of capital while also controlling for direct effects of those capitals by including it directly as in Panzera and Postiglione (2022).

EMPIRICAL STRATEGY

Structural Model

The theoretical framework and the derived empirical models to analyse regional incomes is primarily based on Ertur and Koch (2007), Fischer (2011), and Panzera and Postiglione (2022). An important difference from these earlier models is that this augmented version of the spatial MRW model now incorporates two more capitals: public and household as given below in equation 1.

$$\begin{aligned}
&\ln(\text{per worker GRDP})_{r2015} = \beta_{1_0} + \beta_{1_1}\ln\left(s_{K_1}\right)_{r2001} + \beta_{1_2}\ln\left(s_{H_1}\right)_{r2001} + \\
&\beta_{1_3}\ln\left(s_{H_2}\right)_{r2001} + \beta_{1_4}\ln\left(s_{K_2}\right)_{r2001} + \beta_{1_5}\ln(\delta + g + n_r) + \tau_{1_1}D_{1_{r2001}} + \\
&\tau_{1_2}D_{2_{r2001}} + \textstyle\sum_{r=2}^{n}\theta_{1_r}S_r + \beta_{1_6}\sum_{s=1}^{N} w_{rs}\ln\left(s_{K_1}\right)_{s2001} + \\
&\beta_{1_7}\textstyle\sum_{s=1}^{N} w_{rs}\ln\left(s_{H_1}\right)_{s2001} + \beta_{1_8}\sum_{s=1}^{N} w_{rs}\ln\left(s_{H_2}\right)_{s2001} + \\
&\beta_{1_9}\textstyle\sum_{s=1}^{N} w_{rs}\ln\left(s_{K_2}\right)_{s2001} + \beta_{1_{10}}\sum_{s=1}^{N} w_{rs}\ln(\delta + g + n_s) + \\
&\tau_{1_3}\textstyle\sum_{s=1}^{N} w_{rs}D_{1_{s2001}} + \tau_{1_4}\sum_{s=1}^{N} w_{rs}D_{1_{s2001}} + \\
&\rho_{1_1}\textstyle\sum_{s=1}^{N} w_{rs}\ln(\text{per worker GRDP})_{s2015} + u_{1_r} \qquad (1)
\end{aligned}$$

Where for region r,

$\ln(\text{per worker GRDP})_{r2015}$ – Log of per worker GRDP of 2015 which is the terminal year for the period of analysis.

$s_{K_{1_r}}$ – Saving rate for public capital,

$s_{K_{2_r}}$ – Saving rate for private capital,

$s_{H_{1_r}}$ – Saving rate for human capital,

$s_{H_{2_r}}$ – Saving rate for household capital,

δ – Rate of depreciation,

g – Balanced growth rate,

n_r – Population growth rate,

D_1 – Dummy variable for state capital where it is 1 for regions which have state capital and zero otherwise,

D_2 – Dummy variable for border region where it is 1 for regions which have external border including ocean border and zero otherwise.

S_r – A state dummy variable for regions belonging to state 'r'

Equation 1 is empirical representation for income level. A similar model for growth rate is in equation 2 below:

$$\text{Growth Rate}_r = \beta_{2_0} + \beta_{2_1} \ln\left(s_{K_1}\right)_{r2001} + \beta_{2_2} \ln\left(s_{H_1}\right)_{r2001} + \beta_{2_3} \ln\left(s_{H_2}\right)_{r2001} + \beta_{2_4} \ln\left(s_{K_2}\right)_{r2001} + \beta_{2_5} \ln(\delta + g + n_r) + \tau_{2_1} D_{1_{r2001}} + \tau_2 D_{2_{r2001}} + \sum_{r=2}^{n} \theta_{2_r} S_r + \beta_{2_6} \sum_{s=1}^{N} w_{rs} \ln\left(s_{K_1}\right)_{s2001} + \beta_{2_7} \sum_{s=1}^{N} w_{rs} \ln\left(s_{H_1}\right)_{s2001} + \beta_{2_8} \sum_{s=1}^{N} w_{rs} \ln\left(s_{H_2}\right)_{s2001} + \beta_{2_9} \sum_{s=1}^{N} w_{rs} \ln\left(s_{K_2}\right)_{s2001} + \beta_{2_{10}} \sum_{s=1}^{N} w_{rs} \ln(\delta + g + n_s) + \beta_{2_{11}} \sum_{s=1}^{N} w_{rs} \ln(\text{per worker GRDP})_{r2001} + \tau_{2_3} \sum_{s=1}^{N} w_{rs} D_{1_{s2001}} + \tau_{2_4} \sum_{s=1}^{N} w_{rs} D_{1_{s2001}} + \rho_{2_1} \sum_{s=1}^{N} w_{rs} \ln(\text{per worker GRDP})_{s2015} + u_{2_r} \qquad (2)$$

Where for region r,

Growth rate_r – Growth rate of per worker GRDP for time period 2001 to 2015,

$s_{K_{1_r}}$ – Saving rate for public capital,

$s_{K_{2_r}}$ – Saving rate for private capital,

$s_{H_{1_r}}$ – Saving rate for human capital,

$s_{H_{2_r}}$ – Saving rate for household capital,

δ – Rate of depreciation,

g – Balanced growth rate,

n_r – Population growth rate,

D_1 – Dummy variable for state capital where it is 1 for regions which have state capital and zero otherwise,

D_2 – Dummy variable for border region where it is 1 for regions which have external border including ocean border and zero otherwise.

S_r – A state dummy variable for regions belonging to state 'r'

ln(per worker GRDP)$_{r2001}$ – Log of per worker GRDP of 2001 which is the initial year for the period of analysis.

The MRW model in equation (1) and equation (2) is the long term per worker income (GRDP) and per worker growth rate respectively as determined by the saving rate of different forms of capital[8].

Data and Variables

The dependent variable in the model for income level is per worker Gross Regional Domestic Product (PWGRDP) for the year 2015 (the latest year for which the data is available). For the r^{th} region the incomes and worker populations are summed up using the values of the districts that constitute the region in 2015. The district level data on domestic product and per worker domestic product for the years 2001-2015 have been sourced from Indicus Analytics (2015)[9]. This private firm has used data from government sources and a method of estimation suggested by the Central Statistical Office of the Government of India (Bhandari and Roychowdhury, 2011).

The data on worker population (total population) is not separately available from Indicus data. So we calculate it as the ratio of GDDP for each district to per worker (capita) GDDP for each district and then sum up to arrive at worker population (total population) for that region. The gross district product and number of workers are aggregated for the districts that belong to a given region to calculate the per worker gross regional domestic product.

[8]These models are the modified version of the empirical models proposed by Ertur and Koch (2007), Fischer (2011) Dominicis (2014) and, Panzera and Postiglione (2022). It may be noted that the derivations are such that the determinants in the both the equations are the same except that in equation (2) for per worker growth rate, the initial level of per worker GRDP is an additional determinant.

[9]Das, et al (2015) and Hazrana, et al (2019) use Indicus district level data to analyse the convergence and sectoral spillover effect at the district level.

Given the pervasive use of real income in all neoclassical models, GDDP (constant price at base 2004) is aggregated to compute GRDP. As the number of workers data per districts is not directly reported in this database, we use the ratio of GDDP to GDDP per worker to determine district level worker population. This district level worker population is summed up to obtain worker population at the regional level. The per worker GRDP at constant prices (base year 2004) is obtained by dividing Gross Regional Domestic Product by total workers. The process of calculating the per worker GRDP is explained below.

$$\mathrm{GRDP_r} = \sum_{\mathrm{i=1}}^{\mathrm{n_r}} \mathrm{GDDP_i} \quad (3)$$

$$\mathrm{Worker_r} = \sum_{\mathrm{i=1}}^{\mathrm{n_r}} \frac{\mathrm{GDDP_i}}{\text{per worker } \mathrm{GDDP_i}} \quad (4)$$

$$\text{Per Worker } \mathrm{GRDP_r} = \frac{\mathrm{GRDP_r}}{\mathrm{Worker_r}} \quad (5)$$

Where i=1, 2,3, n are districts in region r.

$$\text{Per Worker GRDP Growth } \mathrm{Rate_r} = \frac{\ln(\text{Per Worker GRDP}_{r2015}) - \ln(\text{Per Worker GRDP}_{r2001})}{14} \quad (6)$$

Similarly, the regional population is calculated by aggregating the population of the districts in 2001 and 2015 that belong to a region which are then used to calculate population growth rate for a given region.

$$\mathrm{n}_r = \frac{(\ln(\mathrm{populationr}_{2015}) - \ln(\mathrm{population_{r2001}}))}{14} \quad (7)$$

$\mathrm{w_{ij}}$ is an element from binary spatial weights matrix which represents the neighbour relationship between regions i and j. It has zero at diagonal which means region can’t be considered as neighbouring to itself $(\mathrm{i.e.\,w_{ii}} = 0)$. Since these regions are formed manually using district level information, it is difficult to have information related to co-ordinates and other spatial aspects. Therefore, with 103 regions the spatial matrix is **W** (103×103) is binary matrix is formed based on the location of districts in the regions by visually inspecting the Indian Map. There are two broad categories of weight matrix: Contiguity matrix (simple form is binary weight matrix)[10] and Distance based matrix (K- nearest neighbour, inverse distance, exponential distance matrix). In this empirical analysis, binary spatial weight matrix is used. The decision not to use the distance-based matrix is rooted in the nature of the sub-state regions, which are formed by contiguous districts and lack of representation by specific geographical location or district. Consequently, it becomes challenging to determine the place or district within the region from which distance exerts influence, making the formation of a distance-based matrix theoretically intricate. However, it is row-normalized to avoid the overestimation of coefficient of spatially lagged variables.

$\beta_{m_1}, \beta_{m_2}, \beta_{m_3}, \beta_{m_4}$ (m=1 for the income model in equation (1) and m=2 for the growth model in equation (2)) represent the coefficient of public capital, human capital, regional inequality (or private capital) and household capital respectively whereas $\beta_{m_6}, \beta_{m_7}, \beta_{m_8}, \beta_{m_9}$ (m=1 or m=2 as mentioned earlier) show the coefficient of their spatial lag. These capital variables are discussed in brief below with detailed definitions in Appendix A. As indicated in equation (1) all these capital variables are for the year 2001 and available at the district level which are summed up to the regional level for estimating the equations.

Public Capital: This is an index representing the stock of public goods. While underlining the role of public policy for public goods, Banerjee, et al. (2007) highlight the scarcity of public goods in rural areas which had 72.2% population in 2001. Village level infrastructure, education and health are important component of public goods (Banerjee, et. al. 2007) and these were emphasized in the Minimum Needs Programme of 5th five-year plan as early as in 1974 and continues

[10] There are three types of contiguity matrices: Rook Contiguity, where regions sharing a common boundary are considered neighbors; Bishop Contiguity, where regions with a common meeting point or very small boundary are regarded as neighbors; and Queen Contiguity, which considers regions as neighbors if they share any part of their boundaries, regardless of the boundary's size (either defined as neighbour by Rook contiguity matrix or defined as neighbour by Bishop contiguity matrix). This thesis uses Queen Contiguity Spatial Weight Matrix.

to be in the focus even in the most recent Economic Survey (2021) as Bare Necessities.

The public capital index here comprises of: (i) bus services, (ii) post offices and telecommunication services, (iii) health services, (iv) paved roads and (v) irrigation. For health services, the number of primary health centres (PHC) are considered as important public services which are cornerstone of public health system. It is also known as the first port to qualified doctor in rural areas. The paved roads are important public infrastructure at district level. Except irrigation, district data from Census 2001 is used for all indicators and are in numbers per one lakh population (Census of India, 2001). Irrigation for the year 2001 is percentage of area irrigated in the total area for a region 'i' as provided by the Directorate of Economics and Statistics (DES), Ministry of Agriculture Co-operation and Farmers Welfare for district wise and source-wise irrigation in terms of net and gross irrigation. The sources of irrigation are canals, tanks, wells and other sources. Under canals, there are two categories[11]: government and private. The irrigation in hectare due to government canals represents public investment. DES also provides data related to total area reported in hectares. Based on the district level data, the irrigation land via government canals and total area are calculated for each region and then the ratio of irrigation via government canals to total area is calculated. The details of the index calculations are in Appendix A.1.

Household Capital: This is an index that includes percentage of households with access to: (i) electricity; (ii) improved drinking water from a protected or covered source (like, tap, hand pump, tube well or well) situated within or outside the premise; (iii) toilet, (iv) a separate bathroom within the house; and (v) use of LPG as the (clean) source of cooking fuel due to less indoor pollution. The details of the index calculations are in Appendix A.2.

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[11]Although DES reports irrigation via government canals and private canals, in 2001, the districts have only government canals irrigation.

Human Capital: This variable is the proportion of population having tertiary education (defined in Appendix A.3). District Census Handbook for Census 2001 provides the district level data of the population completed under-graduation and above. This is aggregated to the regional level and along with the population of the region the proportion of those with tertiary education is the measure of human capital.

Regional Inequality as a Proxy for Private Capital

Among the four types of capital used as determinants of regional income, related data is available at the district level for three of them except for private capital. Incidentally, there is a small literature that considers physical capital as a function of relative income inequality (Arbia, et. al., 2005; De Dominicis, 2014; and Panzera and Postiglione, 2022). However, such a relationship between physical capital and regional inequality may perhaps be more appropriate to private investment. This may be because private investment would be efficiency seeking that is, where expected an optimal returns to investment are good and hence such investments would seek regions that have a high level of PWGRDP. In contrast, public investment in a developing country would happen in one or the public infrastructure regardless of the region's level of development, which could make regional inequality a weak proxy for public capital.

Rey and Smith (2013) suggest the Gini Index to measure the regional inequality, and which can be decomposed spatially into neighbouring and non-neighbouring regional inequality. A spatial autocorrelation is positive when areas which are close to each other tend to have similar values which suggests low neighbouring regional inequality and high non-neighbouring regional inequality. On the other hand, negative spatial autocorrelation suggests a high neighbouring regional inequality and low non-neighbouring regional inequality. Therefore, neighbouring regional inequality is non-spatial component of regional Gini coefficient which is calculated by using the border sharing district's per capita district product. Non-neighbouring regional inequality is spatial component of regional Gini coefficient which is calculated by using per capita district product of non-neighbouring districts.

Neighbouring regional inequality shows the inequality in geographical clusters within a region where non-neighbouring regional inequality shows the inequality in disconnected district (sub-region) within a region. Neighbouring regional inequality becomes a relevant measure of regional inequality if neighbouring districts in a region are heterogeneous in terms of its economic features. In contrast, non-neighbouring regional inequality becomes a relevant measure of regional inequality if districts with no common boundary in a region are heterogeneous in terms of its economic features. Therefore, regional inequality is additively decomposed into neighbouring and non-neighbouring component to better understand its relative impact on regional income (Appendix A.4 provides the detailed derivation and discussion on the regional inequality). Based on these three different measures of regional inequality, Equation (1) is estimated in three separate variants: overall regional inequality, neighbouring regional inequality and non-neighbouring regional inequality as a proxy for private capital.

A region's inequality is measured using the Regional Gini Index with districts as the sub-regions and per capita district domestic product as the sub-region's income level. The Gini Index is suitably modified to account for the district population and separate Gini Indices for neighbouring and non-neighbouring districts is calculated as shown in Appendix A.4.

State capitals and international border regions could have an impact on regional growth (Panzera and Postiglione, 2022). The regions with state capital can help the neighbouring region to grow in terms of PWGRDP. Therefore, the model incorporates dummy variables for state capital and international border regions.

Time-Period of Analysis

The district level data of Indicus is available from 2001 to 2015 while the census data are available for 2001 and 2011. In Equation (1) above PWGRDP is for 2015, the terminal year in the data set and all other variables are for the year 2001. It may be noted that Equation (1) is derived as a steady state model of income, and this implies that the different capitals will have the impact on income level in long run. Consequently, the year of investment in different forms of capital and the year of income is not contemporaneous but that past investments will fructify into current income level. The gestation period for returns to investments in various capitals is expected to be longer in a developing country, so 2001 is chosen compared to 2011 for the different capitals, as the gap is relatively longer with 2015, the year of income level.

Barro (1991) while incorporating the government spending in the growth model raises the issue of endogeneity in its empirical implementation. The endogeneity arises from the responsiveness of government consumption spending and initial level of per capita GDP. Hauk (2017) addresses the endogeneity of the determinants of growth using simulations techniques in a panel data framework that may not be applicable here. To address the endogeneity problem in cross-sectional setup, Cuaresma et. al. (2014) suggest considering the explanatory variables at beginning of the period or close to the beginning of the period to help solve the problem of endogeneity. Therefore, the choice of 2001, which is the initial year for the analysis, helps to address the possible endogeneity of the explanatory variables.

It may not be possible to collect and report several explanatory variables at a disaggregated level of counties or districts within a state or province to estimate a regional output or regional income model.

Spatial Econometric Model

The empirical Equations 1 and 2 represent the Spatial Durbin Model (SDM). The commonly used matrix represented for SDM is given below:.

$$\mathbf{Y} = \rho\mathbf{WY} + \mathbf{X\beta} + \mathbf{WX\theta} + \boldsymbol{\varepsilon} \qquad (8)$$

where **Y** (n×1) is the dependent variable for a sample of size n, **X** (n×k) is the matrix with k explanatory variables, and $\varepsilon = (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n)^T$ is a vector of disturbance terms, where ε_i is independently and identically distributed. Halleck Vega and Elhorst (2010) provide seven different

spatial models for cross sectional data based on different types of spatial dependence, with different combinations of spatial lag of dependent variable (WY), spatial lag of independent variables (WX), and spatial dependence of error, which are discussed in detail in Section 4.4. However, LeSage and Pace (2009) and Elhorst (2014) suggest using the SDM over all other variants of spatial models if there is any spatial dependency based on its statistical LM tests[12]. The reason behind preferring the SDM is that it produces unbiased and consistent estimations. Moran's I is also used to test for spatial dependence. Hazrana et al. (2019) also find that the SDM model fits the data while they investigate the spillover effect of sectors on economic growth in the context of Indian districts. In order to interpret, the coefficients in SDM model, the direct, indirect and total effects have to be calculated (LeSage and Pace, 2009). As there exists a spatial dependence, a change in explanatory variable will change the dependent variable of a given region as well as the dependent variable of other neighbouring regions. Among these two changes, first one is known as direct effect and second one is known as indirect effect (Elhorst, 2014). SDM model for the Equation (1) and direct-indirect effects are estimated in Stata by using SPREGSDM package (Shehata and Mickaiel, 2014).
In SDM model (Equation 8)[13]:

$$\mathbf{Y} - \rho\mathbf{WY} = \boldsymbol{\alpha}_{\mathbf{N}} + \boldsymbol{\beta}\mathbf{X} + \mathbf{WX}\boldsymbol{\theta} + \boldsymbol{\varepsilon} \tag{8.1}$$

$$\mathbf{Y} - \rho\mathbf{WY} = \boldsymbol{\beta}\mathbf{X} + \mathbf{WX}\boldsymbol{\theta} + \boldsymbol{\alpha}_{\mathbf{N}} + \boldsymbol{\varepsilon} \tag{8.2}$$

$$\mathbf{Y} = (1 - \rho\mathbf{W})^{-1}[\boldsymbol{\beta}\mathbf{X} + \mathbf{WX}\boldsymbol{\theta}] + \mathbf{R} \tag{8.3}$$

Where R contains error term and intercept. The partial derivative of Y with respect to kth explanatory variable in 1st region to Nth region is expressed as:

$$\left[\frac{\partial E(Y)}{\partial x_{1k}} \; . \; \frac{\partial E(Y)}{\partial x_{Nk}}\right]$$

[12] LM tests are used to identify the spatial dependence of spatial error dependence whereas Moran's I is used to identify the spatial interaction of dependent variable. If any one or both spatial dependences are present in a given data, SDM is preferred (Elhorst, 2014; LeSage and Pace, 2009)

[13] In Equation 8.1, intercept is separately represented by $\boldsymbol{\alpha}_{\mathbf{N}}$ unlike Equation 8 where $\mathbf{X}\boldsymbol{\beta}$ incorporates intercept.

$$
= \begin{bmatrix} \frac{\partial E(y_1)}{\partial x_{1k}} & \cdots & \frac{\partial E(y_1)}{\partial x_{Nk}} \\ \vdots & . & \vdots \\ \frac{\partial E(y_N)}{\partial x_{1k}} & \cdots & \frac{\partial E(y_N)}{\partial x_{Nk}} \end{bmatrix}
$$

$$
= (1 - \rho W)^{-1} \begin{bmatrix} \beta_k & w_{12}\theta_k & . & w_{1N}\theta_k \\ w_{21}\theta_k & \beta_k & . & w_{2N}\theta_k \\ . & . & . & . \\ w_{N1}\theta_k & w_{N2}\theta_k & . & \beta_k \end{bmatrix} \qquad (4.6)
$$

Where w_{ij} is an element of matrix W. From equation (4.6), the direct effect is the diagonal elements of matrix whereas the off-diagonal elements denote the indirect effects[14]. LeSage and Pace (2009) suggests that direct, indirect and total effect (which is a sum of direct and indirect effects) should be calculated in order to explain the coefficients of SDM model. In this thesis, when SDM model is appropriate among all other spatial models, direct, indirect and total effect is discussed.

Empirical Analysis

Table 1 reports the summary statistics of the dependent and explanatory variables. The minimum and maximum values of logarithm of per worker GRDP highlights the wide range in its values across regions of Indian in 2015. Since all the explanatory variables are indices with values between zero and one and hence the logarithms are all negative values. Among the three capital indices, the human capital has least mean value and least value of standard deviation. Public capital index has mean, standard deviation and range higher than human capital values while household capital has a low mean index value but the largest range and standard deviation. Between the three Gini Indices, non-neighbouring has the least mean but largest range and standard deviation. Neighbouring Gini has the next highest mean but has lower standard deviation compared to over Gini. Out of 103 regions, 17 regions (about 17% regions) have a state capital whereas 38 regions (around 37% regions) have international borders. Thus, the differences in mean and dispersion for the different

[14] These are discussed in detail in LeSage and Pace (2009) and Elhorst (2014). There can exist a small difference between direct impact and parameter estimated in the regression due to feedback effect (LeSage and Pace, 2009; Elhorst, 2014).

explanatory variables would result in different values of estimated coefficients and its standard error.

Table 1: Summary Statistics

Variables	Mean	Std. Dev.	Minimum	Maximum
ln(Per worker Gross Regional domestic product 2015) (constant prices (2004 year) in 1000 Rs)	4.52	1.02	-0.540	6.411
ln(Per worker Gross Regional domestic product 2007) (constant prices in 1000 Rs)	3.98	1.01	-0.460	5.725
Growth rate for 2001-2015	0.08	0.03	-0.003	0.189
Growth rate for 2001-2007	0.09	0.09	-0.516	0.663
ln(Human Capital Index)	-3.49	0.38	-4.371	-2.559
ln(Public Capital Index)	-3.65	2.89	-10.199	-1.151
ln(Household Capital Index)	-0.97	1.12	-8.167	-0.158
ln(Non-Neighbouring Gini)	-3.69	1.53	-6.546	-0.915
ln(Neighbouring Gini)	-2.63	0.69	-4.478	-1.023
ln(Overall Gini)	-2.18	0.75	-4.385	-0.275
ln(n+0.05)	-2.76	0.24	-3.799	-1.839
State capital Dummy	0.16	0.37	0	1
Border Dummy	0.37	0.48	0	1

Note: Note: Total number of observations is 103; The minimum value for index for household, index for public capital, non-neighbouring Gini coefficient, neighbouring Gini coefficient, overall Gini coefficient is zero. Therefore, before taking log, the minimum positive value is added to all observations for such variables as is the common practice (Cameron and Trivedi, 2009); Summary statistics of log of human capital, public capital, household capital and private capital is provided for 2001 based on 2001 census.

Table 2 reports the OLS estimates and the LM test to compare OLS with the spatial model. The robust $\mathrm{LM}_{\mathrm{error}}$ as well as Moran' I test result favours the spatial model over OLS (test statistics are significant at 1% and 5% levels of significance). Since both tests are in favour of the SDM model over the OLS model. Model 1.1, model 1.2 and model 1.3 incorporate non-neighbouring Gini, neighbouring Gini and overall Gini respectively as a proxy for private capital where per worker GRDP is dependent variable. However, we would like to draw attention to the fact that the OLS coefficient of public capital is statistically significant and positive in all models and so are the coefficients of neighbouring Gini and overall Gini in models 2 and 3 respectively.

Table 2: OLS estimates (non-spatial model) for log of per worker GRDP with all capitals as determinants.

	Model 1.1	**Model 1.2**	**Model 1.3**
ln(Human Capital Index)	0.399*	0.172	0.148
	(0.213)	(0.249)	(0.234)
ln(Household Capital Index)	-0.051	-0.047	-0.063
	(0.059)	(0.052)	(0.058)
ln(Public Capital Index)	0.094*	0.095*	0.091*
	(0.056)	(0.054)	(0.055)
ln(n+0.05)	-0.449	-0.293	-0.349
	(0.427)	(0.408)	(0.403)
State Capital Dummy	0.117	0.0705	0.073
	(0.311)	(0.304)	(0.309)
External Border Dummy	0.027	-0.035	-0.028
	(0.256)	(0.249)	(0.253)
ln(Non-Neighbouring Gini)	0.082		
	(0.059)		
ln(Neighbouring Gini)		0.374***	
		(0.130)	
ln(Overall Gini)			0.362***
			(0.130)
Constant	5.368***	6.043***	5.476***
	(1.678)	(1.596)	(1.592)
Observations	103	103	103
R-squared	0.53	0.55	0.55
Joint test for state specific fixed effect: F statistics	7.72***	6.78***	8.63***
Moran's I	5.48**	5.89**	5.53**
Robust $\mathrm{LM}_{\mathrm{error}}$	5.73**	7.23***	6.38**

Note: 1) Robust standard errors in parentheses: 2) *** p<0.01, ** p<0.05, * p<0.1 3) All the explanatory variables are for initial year 2001. 4) Moran's I tests for spatial dependency from dependent variable and Robust LM_{error} tests for spatial dependency from error term. 5) Models .1, .2, .3 are used different forms of regional inequality which proxies for private capital.

Table 3 gives the OLS estimates and the LM test to compare OLS for spatial dependency. The robust $\mathrm{LM}_{\mathrm{error}}$ as well as Moran's I are not statistically significant. These results indicate that OLS models are preferred over Spatial Models. Similarly model 2.1, model 2.2 and model

2.3 also incorporates these three indices as a proxy for private capital respectively where dependent variable is growth rate of per worker GRDP. In all three models, except for state capital dummy, no other coefficient is statistically significant. These models highlight the fact that the regions having state capital do have, on an average, higher per capita GRDP growth rate compared to other regions.

Table 3: OLS estimates (non-spatial model) for growth rate of period 2001-2015 with all capitals as determinants.

	Model 2.1	**Model 2.2**	**Model 2.3**
ln(Human Capital Index)	0.009	0.013*	0.007
	(0.007)	(0.007)	(0.007)
ln(Household Capital Index)	-0.001	-0.0001	-0.001
	(0.002)	(0.002)	(0.002)
ln(Public Capital Index)	0.0001	0.0003	0.0003
	(0.0009)	(0.001)	(0.001)
ln(n+0.05)	-0.013	-0.010	-0.009
	(0.014)	(0.014)	(0.014)
State Capital Dummy	0.020**	0.020**	0.019**
	(0.009)	(0.009)	(0.009)
External Border Dummy	0.009	0.011*	0.009
	(0.006)	(0.006)	(0.006)
ln(Per worker GRDP)	-0.009	-0.008	-0.009
	(0.007)	(0.008)	(0.007)
ln(Non-Neighbouring Gini)	0.003**		
	(0.001)		
ln(Neighbouring Gini)		-0.001	
		(0.004)	
ln(Overall Gini)			0.006
			(0.004)
Constant	0.116*	0.125*	0.128**
	(0.062)	(0.064)	(0.063)
Observations	103	103	103
R-squared	0.45	0.43	0.44
Joint test for state specific fixed effect: F statistics	7.74***	6.69***	7.29***
Moran's I	0.96	0.82	0.99
Robust $\mathrm{LM}_{\mathrm{error}}$	0.95	0.64	0.82

Note: 1) Same as Table 3 2) Compared to Table 4.7, one more additional variable, per worker GRDP (2001) is included which can be seen Equation 2.

Spatial Models: Result and Discussions

Human Capital and Private Capital as determinants

Table 4 reports the SDM results with only human capital and the three different variants of the regional inequality. Once again, Wald test statistic is significant at 5% so that SDM is preferred over OLS. We estimate this model to understand if regional inequality and human capital along with the spatial econometric specification are sufficient determinants of regional income and provides an analytical comparison with the Panzera and Postiglione (2022) where the public capital and household capital are not considered as relevant for explaining regional income. However, the results in the spatial effect of independent variables except overall Gini coefficient is not statistically significant. The coefficient of human capital is statistically significant in model 1 whereas the coefficient of log of neighbouring Gini coefficient and its spatial lag both are statistically significant at 5% level of significance. Panzera and Postiglione (2022) find the significant negative spillover effect of log of human capital and positive direct impact on regional growth. In this study, the coefficient of ln(human capital index) is positive and statistically significant in model one whereas W×ln(Human Capital Index) is not statistically significant in any model.

Table 4: SDM (Spatial Model) for log of per worker GRDP with private capital and human capital as determinants

	Model 1.1	**Model 1.2**	**Model 1.3**
ln(Human Capital Index)	0.503^{***}	0.324^{*}	0.339^{*}
	(0.193)	(0.197)	(0.195)
ln(n+0.05)	-0.760^{**}	-0.624^{**}	-0.704^{**}
	(0.310)	(0.304)	(0.296)
ln(Non-Neighbouring Gini)	0.028		
	(0.061)		
ln(Neighbouring Gini)		0.256^{***}	
		(0.096)	
ln(Overall Gini)			0.176^{*}
			(0.098)
State Capital Dummy	-0.319	-0.324	-0.283
	(0.283)	(0.259)	(0.269)

	Model 1.1	Model 1.2	Model 1.3
External Border Dummy	0.198	0.194	0.186
	(0.184)	(0.177)	(0.182)
W×ln(Human Capital Index)	0.124	0.122*	0.140*
	(0.079)	(0.064)	(0.072)
W×ln(n+0.05)	-0.213*	-0.198*	-0.199*
	(0.119)	(0.104)	(0.110)
W×ln(Non-Neighbouring Gini)	-0.050		
	(0.042)		
W×ln(Neighbouring Gini)		-0.098**	
		(0.046)	
W×ln(Overall Gini)			-0.131**
			(0.061)
W×State Capital Dummy	-0.183	-0.151	-0.111
	(0.112)	(0.101)	(0.108)
W×External Border Dummy	0.0115	-0.003	0.014
	(0.081)	(0.080)	(0.079)
Constant	5.055***	4.972***	4.808***
	(1.33)	(1.335)	(1.293)
W×log(Per Worker GRDP) (ρ)	-0.074**	-0.077**	-0.077**
	(0.036)	(0.034)	(0.035)
Observations	103	103	103
Wald Test SDM vs. OLS (ρ = 0)	4.159**	5.189**	4.681**
Wald Test (wX's =0)	7.322	10.161*	8.738

Note: 1) Robust standard errors in parentheses: 2) *** p<0.01, ** p<0.05, * p<0.1 3) All the explanatory variables are for initial year 2001. 4) SDM- Spatial Durbin Model. 5) Models .1, .2, .3 are used different forms of regional inequality which proxies for private capital.

All the four capitals as determinants

In a developing country context, regional incomes are perhaps better determined by public investment and basic amenities rather than by tertiary education alone. Exclusion of such relevant variables also leads to omitted variable bias for the other coefficients due to the omission of other relevant variables (Maddala, 1988). Table 5 provides the results for SDM model where all four capitals are incorporated with diagnostic measures. In all three models, Wald test suggests that SDM model is preferred over OLS. The Wald test also suggests that the coefficient of spatial lag of independent variables are jointly significant. Further, AIC values and Wald test for significant of spatial lag of independent variables indicate that, models with log of public capital and log of household capital with models are appropriate compared to those which do not include these two variables and their spatial components. Therefore, not including these variables in model can create a problem of omitted variable bias.

All three models, the coefficient of log of public and log of household capital are statistically significant at 5% level of significance whereas coefficient of their spatial lag is statistically significant at 1% level of significance. They all have a positive sign implying the direct and indirect effect of higher stock of these capitals in regional incomes arising from higher investment or saving rate from these capitals. However, human capital is not statistically significant in any of the models while the coefficient of ln(n+0.05) is significant in models 1 and 3 with the negative sign implying the larger population growth rate along with the fixed depreciation rate adversely affects regional incomes as can be expected. The coefficient of log of neighbouring Gini coefficient and overall Gini coefficient are statistically significant in model 2 and model 3 respectively at 5% level of significance. The positive sign for the regional inequality is to be interpreted as higher private capital is associated with higher regional income but the capital could be invested in a in a region with larger regional inequality and in a district with higher income. At the same time, there is hardly any spillover effect of private capital as the spatial coefficients are largely insignificant unlike what is observed for public and household capital and to some effect for the human capital.

Table 5: SDM estimates (spatial model) for log of per worker GRDP with all capitals as determinants.

	Model 1.1	**Model 1.2**	**Model 1.3**
ln(Human Capital Index)	0.207	0.069	0.048
	(0.177)	(0.204)	(0.190)
ln(Household Capital Index)	0.123**	0.098**	0.109**
	(0.054)	(0.045)	(0.050)
ln(Public Capital Index)	0.085**	0.084**	0.079**
	(0.036)	(0.037)	(0.036)
ln(n+0.05)	-0.680**	-0.534*	-0.593**
	(0.278)	(0.277)	(0.269)

	Model 1.1	**Model 1.2**	**Model 1.3**
State Capital Dummy	-0.009	-0.042	-0.043
	(0.203)	(0.195)	(0.196)
External Border Dummy	0.056	0.057	0.035
	(0.168)	(0.166)	(0.170)
ln(Non-Neighbouring Gini)	0.050		
	(0.052)		
ln(Neighbouring Gini)		0.283***	
		(0.092)	
ln(Overall Gini)			0.244**
			(0.098)
W×ln(Human Capital Index)	-0.069	-0.078	-0.07
	(0.079)	(0.06)	(0.069)
W×ln(Household Capital Index)	0.147***	0.135***	0.145***
	(0.048)	(0.041)	(0.043)
W×ln(Public Capital Index)	0.038***	0.032**	0.034***
	(0.014)	(0.013)	(0.013)
W×ln(n+0.05)	-0.132	-0.142*	-0.140*
	(0.098)	(0.079)	(0.084)
W×ln(Non-Neighbouring Gini)	-0.055		
	(0.034)		
W×ln(Neighbouring Gini)		-0.053	
		(0.037)	
W×ln(Overall Gini)			-0.08*
			(0.047)
Constant	5.990***	5.935***	5.833***
	(1.225)	(1.233)	(1.196)
W×log(Per Worker GRDP) (ρ)	-0.128***	-0.125***	-0.127***
Observations	(0.035)	(0.032)	(0.033)
Wald Test SDM vs. OLS	103	103	103
(ρ = 0)			
Wald Test (wX's =0)	13.510***	15.104***	14.542***
Wald Test (wX's =0)	21.833***	25.255***	25.232***

Note: Same as Table 4

Table 6 reports the direct, indirect and total effects[15] that help to interpret the coefficients in Table 5 above as direct, indirect and total impacts on per worker GRDP.

[15] Total Effect is a summation of direct and indirect effect.

The log of public capital and log of household capital do have positive significant direct, indirect and total impacts on log of per worker GRDP. The log of public capital has a significant positive direct and indirect impact on log of regional income. The positive spillover effect of public capital supports that even if the public investment happens in a prosperous region due to higher absorption capacity, it can increase neighbouring region's income and thus highlights the importance of government intervention for regional development.

Log of household capital has direct, indirect and total positive significant impact on log of regional income. Household capital can be viewed as intervention at household level for basic necessities. The results suggest that intervention for basic necessities is important for regional development. The public policies are also critical for regional income as it can affect regional income through two main channels. They can have visible impact through providing the infrastructures including irrigation, roads, health facilities etc. They can have an 'invisible' impact by providing the basic facilities to household.

Log of human capital has statistically significant impact on log of per worker GRDP but this impact becomes insignificant when log of public capital and log of household capital are included in the model.

From table 6 it is noted that the total effect is the sum of direct and indirect effects. The proportion of spillover effect is higher for log(household capital) compared to log(public capital). The spillover effect of log of public capital in total effect is 34% in model 1, 28% in model 2 and 32% in model 3 whereas it is 52% in model 1, 58% in model 2 and 53% in model 3 for log household capital.

Table 6: Direct, Indirect and Total effect under SDM for log per worker GRDP with all capitals as determinants

	Model 1.1			Model 1.2			Model 1.3		
	Direct Effect	**Indirect Effect**	**Total Effect**	**Direct Effect**	**Indirect Effect**	**Total Effect**	**Direct Effect**	**Indirect Effect**	**Total Effect**
ln(Human Capital Index)	0.177 (0.224)	-0.010 (0.107)	0.167 (0.206)	0.069 (0.204)	-0.078 (0.06)	-0.009 (0.08)	0.047 (0.250)	-0.003 (0.094)	0.044 (0.089)
ln(Household Capital Index)	0.178** (0.225)	0.194*** (0.068)	0.372*** (0.088)	0.098** (0.045)	0.135*** (0.041)	0.233** (0.11)	0.166** (0.074)	0.191*** (0.064)	0.357*** (0.119)
ln(Public Capital Index)	0.104** (0.040)	0.053*** (0.018)	0.157*** (0.048)	0.084** (0.037)	0.032** (0.013)	0.116** (0.051)	0.097** (0.042)	0.046*** (0.016)	0.143*** (0.049)
ln(n+0.05)	-0.565** (0.381)	-0.146 (0.118)	-0.711 (0.641)	-0.533* (0.276)	-0.142* (0.079)	-0.675* (0.430)	-0.483 (0.376)	-0.152 (0.181)	-0.635 (0.469)
ln(Non-Neighbouring Gini)	0.048 (0.063)	-0.063 (0.044)	-0.025 (0.031)						
ln(Neighbouring Gini)				0.282*** (0.092)	-0.053 (0.037)	0.229** (0.108)			
ln(Overall Gini)							0.231** (0.102)	-0.076* (0.047)	0.155** (0.073)

Note: 1) *** p<0.01, ** p<0.05, * p<0.1

CONCLUSION

This study is carried out to analyse the role of public capital and household capital (basic household amenities) on per worker regional incomes. The purpose of these investments is to ensure that everyone benefits from these investments to help build the individual capabilities and in turn improve the productivity and output of the nation. If economic development is left only to market forces during the course of development, some regions tend to grow faster than other regions as private capital will seek efficient outcomes and so would the better endowed individuals. This leads to rising inequality during rising incomes and hence redistribution within and between nations to the less endowed population and less developed regions is an important public policy.

In the Indian context, the central and state finance commissions allocate resources to the less developed regions and to the sectors that would need higher public investments as private investment is inadequate or nearly absent. Very few studies consider the role of public investments in basic infrastructure and basic household amenities on per worker regional incomes beyond the level of states in India. Districts in India form the third tier of government administration and are mainly involved in implementing the state and central policies but has limited scope for revenue generation. Similarly, less emphasis is given to the collection and reporting of district domestic product on an annual basis across all the states of India. Some states have recently started reporting district domestic product but is not for a long enough duration and may not be at regular intervals. Once such exception is the Indicus data on district domestic product including per worker values and its sectoral decomposition. This has enabled the estimation of a regional income model to analyse the role of public capital and to compare its role relative to human capital and private capital.

The regional income model in this study is estimated not at the level of the district but a group of districts referred as regions within a state mainly to account for regional inequality which is also a proxy for private capital. The Gini index based on within a region's district incomes is the measure of regional inequality. The conceptual framework of the spatial MRW model in its steady state form enables us to examine the regional income based on a recent year of 2015 with the determinants of income based on an initial year. The initial year, 2001 is the Census year so that data on several district level public goods like public transportation, basic communication services, primary health service, irrigation and household amenities like sanitation, clean drinking water and cooking fuel are easily available. Intra-country studies on regional incomes are estimated using spatial econometric models to account for spillover (indirect) effects of the determinants of regional incomes as there are less barriers to movement of factors of production and also include direct effects of these factors. The results here show that Spatial Durbin Model gives a better fit and that public capital and household capital are both relevant in explaining regional incomes. The spillover effects are also significant and add to the regional incomes and thereby reduce inter-regional disparities in incomes.

As far as growth of per worker GRDP is concerned, none of the capitals have significant impact on the regional growth rate. The growth rate is calculated for the period of 2001 to 2015 which is fairly a longer duration. The capitals including public capital, household capital do have significant level effect but growth effect is not significant. This supports the argument of significant level effect in long run. Further the regions having state capital have higher growth. This does highlight the importance of having the state capital as it gives an advantage to that region. The importance of growth effect of state capital draws the attention of having capitals or capital-like cities in backward regions.

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Definitions for saving rate of capitals

In this appendix, we define the various measures for saving rate of capitals. There are four types of capitals used in this study, which are determinants of regional income and growth.

A.1 Saving rate of Public Capital

For region i, $s_{K_{1_i}} = \text{f(Index for Public capital}_{i0})$

Where $s_{K_{1_i}}$ is saving rate for public capital for region 'i'. This work assumes that saving rate for public capital is a function of initial index for public capital.

$$\text{Bus}_i = \frac{\big(\text{(Bus services (per one lakh persons) in region i)} - \text{minimum value}\big)}{\text{Maximum value} - \text{minimum value}}$$

$$\text{Post offices and telecom}_i = \frac{\big(\text{(Post offices and telecommunication services (per one lakh persons) in region i)} - \text{minimum value}\big)}{\text{Maximum value} - \text{minimum value}}$$

$$\text{Health center}_i = \frac{\big(\text{(Primary Health centers (per one lakh) in region i)} - \text{minimum value}\big)}{\text{Maximum value} - \text{minimum value}}$$

$$\text{Road}_i = \frac{\big(\text{(Paved road in region i (per one lakh))} - \text{minimum value}\big)}{\text{Maximum value} - \text{minimum value}}$$

$$\text{Irrigation}_i = \frac{\big(\text{(Irrigation (in percentage) in region i)} - \text{minimum value}\big)}{\text{Maximum value} - \text{minimum value}}$$

Therefore,

$$\text{Index for Public capital in region i} = (\text{Bus}_i \times \text{Post offices and telecom}_i \times \text{Health center}_i \times \text{Road}_i \times \text{Irrigation}_i)^{\frac{1}{5}} \quad \text{(A1)}$$

A.2 Saving rate of Household Capital

It is assumed that saving rate for household capital is a function of initial index for household capital.

$$s_{H_{2_i}} = \text{f(Index for Household Capital}_{i0})$$

It is assumed that all the variables used for calculation of household capital are resources shared by all members of the household and will not be restricted to any one member within the household.

To understand the household capital, the index is formed based on the access to water, access to electricity and house infrastructure. The percentage of households having improved drinking water[16], electricity, toilet, bathroom and LPG is considered to calculate the household capital. These indicators are normalized using minimum and maximum values.

For region i,

$$\mathrm{Water_i} = \frac{\left((\text{household having improved water in region i (\%)}) - \text{minimum value}\right)}{\text{Maximum value} - \text{minimum value}}$$

$$\mathrm{Toilet_i} = \frac{\left((\text{household having toilet in region i (\%)}) - \text{minimum value}\right)}{\text{Maximum value} - \text{minimum value}}$$

$$\mathrm{Electricity_i} = \frac{\left((\text{household having electricity in region i (\%)}) - \text{minimum value}\right)}{\text{Maximum value} - \text{minimum value}}$$

$$\mathrm{Bathroom_i} = \frac{\left((\text{household having bathroom in region i (\%)}) - \text{minimum value}\right)}{\text{Maximum value} - \text{minimum value}}$$

$$\mathrm{Fuel_i} = \frac{\left((\text{household having LPG in region i (\%)}) - \text{minimum value}\right)}{\text{Maximum value} - \text{minimum value}}$$

Therefore,

$$\text{Index for Household capital for i}^{\text{th}} \text{ region} = (\mathrm{Water_i} \times \mathrm{Toilet_i} \times \mathrm{Electricity_i} \times \mathrm{Bathroom_i} \times \mathrm{Fuel_i})^{\frac{1}{5}} \quad \text{(A2)}$$

A.3 Saving Rate of Human Capital

$$s_{H_{1_i}} = f(\text{Index for Human Capital}_{i0})$$

Where $s_{H_{1_i}}$ is saving rate for human capital for region 'i'

For human capital, Panzera and Postiglione (2022) uses tertiary education. Therefore, proportion of population having tertiary education can be used to understand s_{1H}.

$$s_{H_{1i}} = f(\text{proportion of population having tertiary education}_{i0})$$

For human capital, proportion of population having tertiary education is used (Graduation and above education level is defined as tertiary education).

[16] Census of India defines household with improved drinking water if the household had access to drinking water supplied from a tap, hand pump, tube well or well (protected or covered) situated within or outside the premises.

$$\text{Index for Human capital for i}^{\text{th}}\text{ region} = \frac{\text{Popualtion having tertiary education in region i}}{\text{Total Population in region i}} \quad \text{(A3)}$$

A.4 Private Capital and Regional Inequality

Gini index is conventionally used for calculating individual inequality based on personal incomes is represented as: $\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{|x_i - x_j|}{2\bar{x}}$; where, x_i is income of individual 'i', x_j is income of individual 'j' and $\bar{x}$ is average income. However, the spatial inequality is based on a region's per capita income which in this study is PWGRDP and is weighted by that regions' population. Rey and Smith (2013) further decompose the spatial inequality as:

$$G_{aw} = \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{p_{ai}\times p_{aj}\times w_{a\,i,j}\times|x_{ai}-x_{aj}|}{2\bar{x}_{aw}} + \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{p_i\times p_j\times\left(1-w_{a\,i,j}\right)\times|x_{ai}-x_{aj}|}{2\bar{x}_{aw}} \quad \text{(A4)}$$

For this study,

x_{ai} is per capita Gross District Domestic Product (GDDP) for ith district in a say, region 'a';

x_{aj} is per capita Gross District Domestic Product (GDDP) for jth district in a region 'a';

p_{ai} is $\frac{\text{Population of i}^{\text{th}}\text{ district in region "a"}}{\text{Total Population in region "a"}}$;

p_{aj} is $\frac{\text{Population of j}^{\text{th}}\text{ district in region "a"}}{\text{Total Population in region "a"}}$;

$\bar{x}_{aw}$ is average district product of region 'a' i.e. $\frac{x_{a1}+x_{a2}+\ldots\ldots+x_{an}}{n_a}$,

n_a is total number of districts in region 'a'

$w_{a_{ij}}$ is an element from binary spatial weights matrix for region 'a' which is assigned *one* if the districts i and j have a common border and *zero* otherwise.

The first term in equation A4 is the neighbour component (NG_i) which is also known as non-spatial component, and the second one is the non-neighbour component (NNG_i), also known as spatial component (Rey and Smith, 2013; Panzera and Postiglione, 2022). Panzera and Postiglione (2022) used neighbouring Gini index as spatial autocorrelation have a less influence on neighbouring Gini index. In this research, all indices are used separately to understand the robustness and to identify whether analysis gets affected or not due to change in index.

$$s_{K_{2_i}} = f(\text{Regional inequality}_{i0})$$

Equation A4 can be rewritten as:

$$\text{Overall regional inequality} = (\text{neighbouring regional inequality}) + (\text{non} - \text{neighbouring regional inequality})$$

Therefore, model specifications have done to incorporate overall regional inequality, neighbouring regional inequality and non-neighbouring regional inequality separately in models.

From per worker gross district product and gross district product data, number of total workers for districts is calculated. The gross district product and number of workers are aggregated for the districts that belong to a given region to calculate the per worker gross regional domestic product. The regional population is likewise calculated by aggregating the population of the districts that belong to a region. And then population growth rate is calculated for a given region.

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