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RESEARCH ARTICLE

Modeling Per Capita Income and Its Dependence on Literacy Rate

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Abstract

This paper challenges the idea that India's economic liberalization in 1991 was solely responsible for the transition in Per Capita Income (PCI). The paper investigates the complex dynamics between educational attainment, economic policies, and their impact on PCI in India. By analyzing the relationship between PCI and literacy rate, the study aims to answer the intriguing question of whether the strong correlation observed between PCI and the literacy rate is a mere coincidence. Additionally, looking at the diode equation's good fit to the data on PCI vs literacy rate, for the period 1980−2020, the study attempts to determine whether or not crossing a certain threshold in literacy rate is necessary for rapid economic development. Based on the statistics available for India, the findings revealed that the literacy rate in India increased with time as a result of sustained efforts by the government to ensure an increase in enrollment in the formal education system, all the while ensuring a low dropout rate through subsidization of education. The findings revealed a significant relationship between PCI and literacy rate. It was found that the increase in PCI post-1991 was due to the hike in female enrollment in the decade 1991−2000. Hence, the transition in PCI can be attributed to the interplay of factors such as government social welfare schemes in the education sector, which have reduced dropout rates and increased enrollment. The analysis also revealed that there is an association between the minimal pay of an illiterate laborer and the strength of the power in the PCI and literacy relationship. When a minimum wage is established, educated workers' pay increases, guaranteeing that the relationship between PCI and literacy is significant.

Keywords: Per Capita Income, Literacy Rate, Development

1. Introduction

It is common knowledge that a literate population is more productive and is more capable of utilizing knowledge and technology to boost production, which in turn leads to enhanced wages. As early as the 1960's, Schultz (1961) investigated whether education was a parameter that increased productivity. As we shall demonstrate in the section of the literature review, other studies were subsequently undertaken to investigate the relation between literacy rate and Per Capita Income. The majority of these studies established a relationship or trend between the two parameters using data from small towns, districts, regions, and even countries. Every study conducted on this subject agreed that there is a relationship between these two indices. However, poor regression values implied that a direct proportionality did not exist between them. Furthermore, no major work was done to establish a model to include other underlying issues like salary, unemployment, etc. While relating the literacy rate to Per Capita Income. The importance of this subject can be easily understood if one views it in terms of the question, “How should the government plan and allocate meager funds in welfare schemes?”. Also, it becomes an essential issue for poverty alleviation.

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Based on data available in India, the present work develops a model based on the first principle, to relate literacy rate with Per Capita Income. The model is not restrictive and should be applicable to other countries too.

2. Literature review

The ability to read and write is commonly referred to as literacy. In today's world, with an information explosion, literacy is crucial. In a democracy, people are supposed to be aware of their rights, stand up for them, and express their opinions. Thus, demanding more literate people. The percentage of the population who is literate is known as the literacy rate, and it serves as a gauge for the level of literacy in a certain country. Literacy rates are typically defined by economists for specific age groups. Most people think that getting an education will help them get better jobs, hence in this study, we investigate the relationship between literacy rate and earning potential. Therefore, we have taken the measure of literacy rate as the percentage of the population enrolled in the formal education system. We also assume the Per Capita Income is an indicative measure of the capacity to earn. Per Capita Income is calculated by dividing a nation's total income by its total population. Thus, it represents the average income earned by every citizen in the country. This figure is used to appreciate the country's citizens' level of living and quantify their overall quality of life. There are certain limitations with PCI. For instance, children who do not work are included in the total population. PCI thus moves downward. Similar to this, a tiny fraction of extremely wealthy people may cause the PCI to rise, creating the illusion of prosperity in the nation. In spite of these shortcomings, PCI remains a valuable metric for comprehending a nation's economic progress. We have used this index to determine whether a higher literacy rate leads to greater economic prosperity due to the simplicity of its calculation.

Schultz (1961) conducted one of the first studies on the relationship between Per Capita Income (in terms of productivity) and the literacy rate. The paper argued that, in the same profession or position, an educated individual would be paid more than an illiterate one.

Dension (1967) was convinced that a country's literacy rate would lead to an increase in GDP, contrary to Schultz (1961), who predicted that education would increase productivity and individual salaries. This suggests that education benefits not just an individual but also a nation as a whole.

Rocha et al. (2011) although did not try to establish a formal relationship between literacy rate and earning, demonstrated that there was a 21.25% rise in income for those who were educated, with an 8.1% increase in the likelihood of finding a job.

Desai (2012) discovered a correlation between GDP and the literacy rate from the statistics he examined for India. Although these studies showed a trend toward a correlation between GDP and literacy, Yeoh (2012) argued that a rise in Per Capita Income with a higher literacy rate was due to investors' interest in investing in highly educated nations.

Rahman made the first attempt to create a model (2013). By computing Pearson's Product Moment Correlation Coefficient, he attempted to demonstrate the existence of a linear link between the literacy rate and per capita GDP.

However, interesting results flowed from Kaur et al.'s (2014) work. The study employed a range of analytical techniques, such as the Johansen-Juselius co-integration test and Vector Error Correction Model, to examine the relationship between education spending and economic development in two of the most populated nations on earth, China and India from 1970 to 2005. Their results show a long-term correlation between GDP per capita and educational spending in both countries. However, the authors concluded that the causal relationship is different in China and India. In China, rising income levels stimulate expenditure on education, whereas, in India, education investment fuels income development.

Studies in other regions of the world, be it regions which are developing or under-developed, have shown a correlation between literacy rate and GDP. Elizabeth N. Appiah's (2017) work focused on Sub-Saharan Africa (SSA). The analysis found that, although the effect is more pronounced outside the SSA, higher investment in education increases per capita GDP in these regions. This discrepancy is explained by the greater human capital in non-SSA nations, which allows for more significant GDP growth per capita in contrast to better export growth in SSA. Appiah advocates for legislative changes targeted at raising educational standards to promote economic growth, Appiah's work highlights the vital need to place a higher priority on educational quality than merely raising enrollment numbers. The conclusion reached is that increasing expenditure for education is essential for under-developed nations to experience economic growth, supporting the notion that investing in education is pivotal to improving Per capita GDP.

Similarly, Tombolotutu (2018) worked with statistics of the Central Sulawesi province. Using regression analysis of data Tombolotutu tried to show a linear correlation between literacy rate and development. The link was poor, as indicated by the Pearson correlation coefficient ($R^2 = 0.4$).

Working on similar lines, Boris (2018), in his study of Economic growth in Cameroon, revealed a null result in his investigation of the relationship between literacy rate and Per Capita Income.

Yadav (2020) provided empirical support for his correlation theory, arguing that a high literacy rate encourages more people to enter the labor sector. Increased literacy has led to women entering the workforce and men accepting them in the workplace, especially in a country like India where men previously made up the majority of the labor.

After 2020, scholars have examined whether there is a correlation between the literacy rate and Per Capita Income using data from larger areas, nations, and regions. Égert et al.'s (2020) study investigated the impact of educational policies on human capital and income in OECD and European Union countries. The focus was on the advantages of enhancing pre-primary education, increasing school autonomy, and lowering student-to-teacher ratios. The study advocated the swift adoption of policies of public spending on pre-primary education since it would take up to three decades for their advantages to completely materialize in terms of income and human capital. The research pinpoints specific strategies, notably changes in pre-primary education and university autonomy, that could result in elevated per capita GDP. The study predicted a potential increase in per capita GDP by over 1%, in nations where disadvantaged students were prevalent and pre-primary education enrollment is low.

Nilofer Hussaini (2020) identified a relationship between economic growth and higher education in South Asia, identifying a significant investment gap in higher education compared to more developed countries. Through econometric panel co-integration analysis, Hussaini discovers a positive correlation between higher education enrollment ratios and long-term economic growth in the region. The study cautions against the risks of continued underinvestment in higher education, which threatens to widen the economic divide between South Asia and wealthier nations by impeding the development of a skilled workforce. By pointing to the economic ascension of countries like China, South Korea, Singapore, and Malaysia, which have benefited from substantial investments in human capital, the research advocates for South Asian countries to enhance their education funding to bridge the development gap.

Issoufou (2020) study compares the positive effect of education on national income in France, Turkey and Niger. These three countries are very different in economic history and have high differences in GDP. Indeed, they range from developed, developing and under-developed levels of economic status. Yet all three showed a positive relation between literacy rate and GDP.

Using statistics, Germinal et al. (2021) investigated the relationship between education and economic development in low-income nations. Their research findings indicated a favorable correlation between economic development and literacy rates. No modeling was done in their work.

Weatherly et al. (2022) assessed the impact of education on GDP per capita worldwide, employing 2015 data from the World Bank and the Barro and Lee database. The regression model revealed a strong link between education and economic prosperity, with GDP per capita, rising by 36% for each additional year of education, though this model explained only 56% of the variation in GDP per capita. Incorporating other factors such as unemployment rates, foreign direct investment, savings, and manufacturing sectors into the analysis refined the results, indicating a 34.4% increase in GDP per capita for every extra year of schooling. The research showed the importance of education and savings rates in encouraging economic growth, validating the theory that enhanced education levels and savings rates are crucial for elevating GDP per capita.

Sumera et al. (2022) used data from 70 nations to investigate how different income levels and educational attainment affect real GDP per capita during the COVID-19 pandemic. The results showed that, despite early negative impacts, primary education enrollment had a long-lasting beneficial influence on income levels in 2020, mirroring the relationships between education and income growth in 2010. It was shown that secondary education was very advantageous, considerably increasing real GDP per capita. However, the study did not discover any significant correlation between enrolment in higher education and levels of Per Capita Income. The analysis highlights the vital significance of increasing enrollment in basic and secondary schools while also highlighting the robust impact of education on economic growth during the epidemic.

Ibrahim Abubakarr Bah (2023) reports the effect of education on economic growth across 89 countries of varying income levels, using the human capital index from the Penn World Table and growth data from the World Bank's World Development Indicators. Applying the Generalized Method of Moments to the 2002–2020 data set, Bah's research highlighted education's significant role in stimulating economic growth. He showed that a 0.1 improvement in the education index is associated with a 0.8 percentage point increase in real GDP per capita growth. The study also pointed out that the economic dividends of education are more pronounced in low- and middle-income countries than in high-income ones, reinforcing the argument for focused educational investments as a pivotal growth strategy in developing nations.

Heming Wang (2023) study, which concluded that a higher proportion of people holding bachelor's degrees is correlated with more economic success. The result based on data collected over several United States, uses the proportion of adults 25 years of age and older who have a bachelor's degree as a measure of educational attainment. To improve the model, it adds factors like urbanization and unemployment. According to the research, states with greater percentages of individuals with college degrees often had higher GDPs per capita. Despite exceptions like Alaska and South Dakota, where GDP is boosted by their rich oil and gas industries, the study affirms the pivotal role of higher education in economic growth and advocates for greater investment in tertiary education to elevate both economic status and quality of life.

Robert Solow's growth model, developed in 1956, gives a basic framework to link economic growth and capital accumulation. The model showed that a gradual increase in capital stock through savings contributes significantly to economic growth but ultimately attains a steady state. The Solow model has since evolved, with subsequent researchers, including human capital along with capital stock. That is, present extensions of the model include education, training, and skill development as important drivers of economic growth. In other words, present extensions of the growth model focus on the accumulation of human capital as a key factor for long-term prosperity. For example, Romer (1990) integrated human capital and knowledge accumulation growth models, enriching the understanding of how education drives innovation and economic growth. Barro (1991) studied 98 countries in the period 1960–1985 and found that the growth rate of real per capita GDP positively relates to initial human capital (proxied by 1960 school enrollment rates). Mankiw et al. (1992) also showed a significant positive association between cross-national differences in the initial endowment level of education and subsequent rates of growth. According to Klenow (1997), education augments labor, physical capital, and total factor productivity (TFP), thus showing a correlation between educational attainment and economic growth. Woessmann (2016) too, in a recent work, showed the role of education in economic growth, employment, and earnings in modern knowledge-based economies. Hanushek and Woessmann (2021) conclude that long-run growth in gross domestic product (GDP) is largely determined by the skills of a nation's population, which was gauged by standardized tests of cognitive achievement. These studies significantly enhance our understanding and provide valuable insight into how education interacts with economic growth.

We pictorially represent the information gained from the literature in Fig. 1. Literacy rate leads to an enhancement of Per Capita Income. This increased Per Capita Income leads to an improved life that results in an enhanced sense of self-esteem. This has been confirmed in studies done by Beder (1999), Bingman (2000) and Abadzi (2003) for various countries including African nations, Brazil, India and America. The increased self-esteem is more significant among women, Stromquist (2015). This improved lifestyle and increased self-esteem, especially among women leads to a delay in the average marriage age of women. This in turn reduces infant mortality and death at childbirth, resulting in an increased life expectancy, Jasneet (2023) and reference therein. An offshoot of decreased fertility means a decrease in population growth/growth rate. Amandeep (2020) suggested an increase in life expectancy leads to Technological Advancements in the region/ country. Increased life expectancy and technological advancements give a feedback pathway which Solow's model explains the formation of economic growth with capital formation.

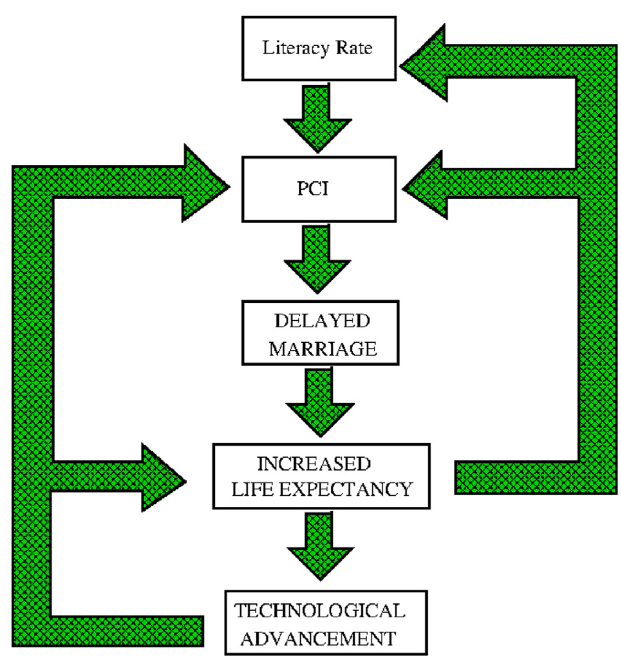

Fig. 1. Pictorial representation of how education leads to economic development and nation-building. (Source: Authors).

In this present work, we aim to offer fresh perspectives by focusing on the role of education on Per Capita Income/economic growth in India in the period 1960–2010.

3. Methodology and model development

It is common knowledge that an educated person would earn more than an uneducated person. Thus, interpolated on society, increasing the literacy rate would lead to an increase in Per Capita Income. However, to develop a mathematical model, one would require exhaustive data on economic indicators like literacy rate, Per Capita Income (PCI), mortality rate, birth rate, etc. Luckily, these social indicators have been collected and recorded yearwise in India by various government agencies and academics (cited as they appear). In the present study, literacy rate and PCI will be first expressed as a function of time. Then, by estimating parametric function, PCI would be written as a function of literacy rate. While mathematically this would be valid, it would fail to give information about underlying issues that link PCI to the literacy rate. In this work, we will investigate a question one of the authors (JKW) focuses on, namely the role of literacy on people's earnings, and attempt to model and develop a structural equation to relate PCI to the literacy rate.

As can be seen in Fig. 2, the nature of the curve is not linear. In fact, one might be tempted to assume that there are two distinguishable regions, namely for 40 $\leq$ literacy rate $\leq$60% and, thereafter, for a literacy rate greater than 60%. Such non-linearity is observed in the I–V characteristics of a diode, where the device allows a flow of small current before the ``knee voltage" and after this voltage allows a large current to flow through it. That is, there is a barrier beyond which currents rise rapidly. Hence, the question would be, "Is there a threshold level in literacy rate after which the Per Capita Income of a nation would rise rapidly" or "Is PCI just fundamentally a non-linear function of literacy rate"?

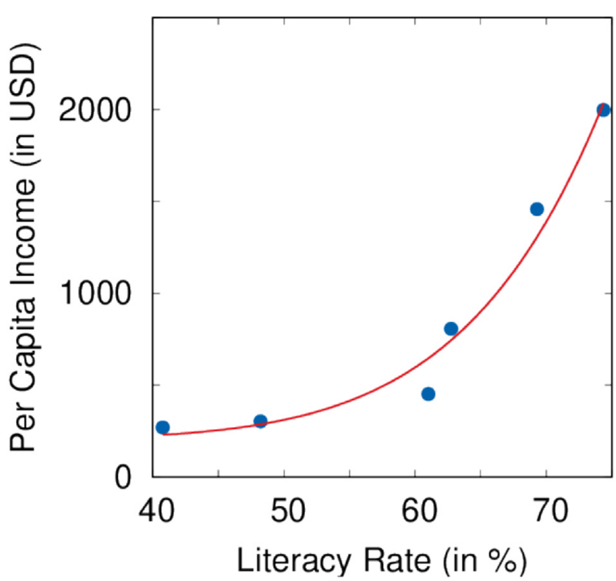

Fig. 2. The variation in Per Capita Income (in USD) with varying Literacy rates (in %) since 1980. Data clearly shows Per Capita Income is strongly related to the Literacy rate. The line in the figure is only for the visual aid of the reader. (Source: Authors).

This "threshold question" is of significance since the take-off of PCI after India attained a literacy rate of 56–60% occurred post-1991. The year 1991 marks a significant turning point for India's economy with the introduction of economic liberalization measures under the leadership of Prime Minister P.V. Narasimha Rao. A series of reforms were implemented to dismantle the country's heavily regulated and protectionist economy. One notable outcome of the 1991 economic liberalization was the opening up of the markets which encouraged foreign direct investment, promoting competition, and facilitating trade liberalization. Factors that could have independently contributed to the significant jump in India's Per Capita Income (PCI) without any role of literacy rate. So, is PCI a function of literacy rate? To investigate this question, the present study investigates (in Section 2) how the literacy rate and Per Capita Income vary over time and tries to determine if only education plays a role or whether other significant players contribute to the PCI.

Developing a model for evaluating a relationship between literacy rate and Per Capita Income for a complex country such as India is difficult, and to make things further involved, consider its population size. Hence, as a first principle approximation, we have restricted our study to time intervals where most of the parameters may be considered a linear function of time. For example, the variation of India's population taken post-1950 shows an S-natural or logistic curve, as described by Sydsaeter and Hammond (1995). However, the increase in the Indian population can be approximated as a linear function of time if the study is restricted to the period 1960 $\leq$ t $\leq$ 2010.

In the following sections, we shall develop equations for literacy rate and Per Capita Income which would not only give us a qualitative understanding of how they vary with time but also highlight the major factors that quantitatively affect their values.

3.1. Expression for literacy rate

Formally, the literacy rate is defined by the percentage of the population of a given age group that can read and write. However, in the context of this study, the percentage of the population that has entered the formal educational system and might have left at any level. For this, we develop an expression of the enrollment rate at various levels of the formal educational system as a function of time. The evolution of India's population is also expressed as a function of time by which the country's literacy rate can be expressed as a function of time.

3.1.1. Student enrollment and drop-out rate

Jandhyala's (2005) work shows that since the 1950s, the number of student enrollments has been steadily increasing every decade at every educational level (graphically shown in Fig. 3). However,

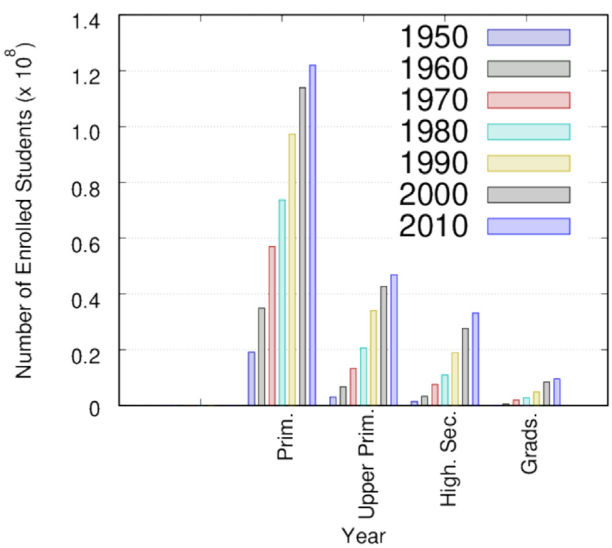

Fig. 3. Clustered histogram shows the number of students enrolled at various levels in the year mentioned. The distribution of the number of students falls exponentially with increasing levels. (Source: Authors).

there is an exponential fall in the enrollment numbers from the primary stage to higher educational levels.

This exponential trend has been evident throughout the decades. The enrollment at an educational level, '*l*', shows Maxwell–Boltzmann's distribution and can be written as

$$E(t,l) = E_o(t)e^{-b(t)l} \quad 1$$

where 'b' is the rate at which the number of students enrolled falls, in a given year as the level increases. $E_o(t)$ is the maximum enrollment at the primary level for the year, 't'. In fact, by fitting Eqn (1) to the data, one can obtain the values of E_o and 'b' for different years. It was found that 'b' decreases linearly with time (see Fig. 4). That is,

$$b(t) = mt + b_o \quad 2$$

Curve-fitting gave b_o = 13.32 per level and m = -6.53×10^{-3} per year per level. Similarly, curve-fitting shows $E_o(t)$ to be a linear function, increasing with years (Fig. 4). This means that enrollment in primary classes has been increasing consistently with the passing years.

With knowledge of the number of enrollments at each educational level, we can determine the total enrollment or total number of students receiving education for a given year using Eqn (1),

$$E_{Total}(t) = \sum_{l=l_i}^{l_f} E_l = \sum_{l=l_i}^{l_f} E_o(t)e^{-b(t)l} \quad 3$$

where l_i and l_F are the starting level and final educational levels, respectively. Interestingly, by sustaining subsidies in education, India has

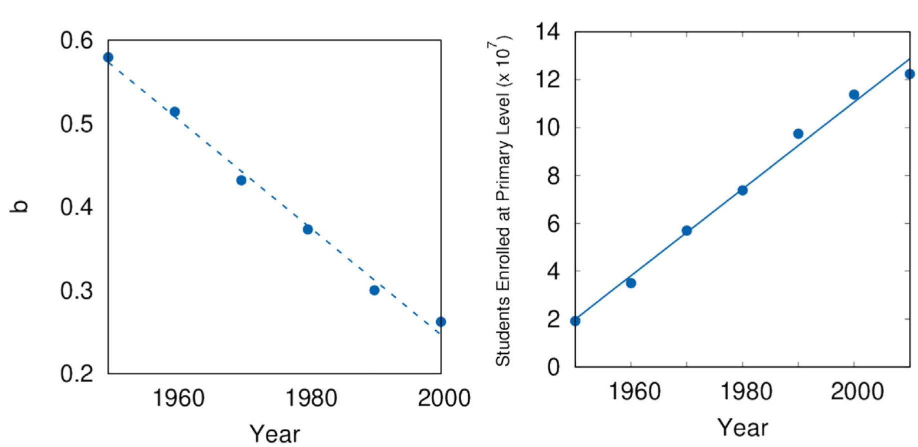

Fig. 4. The rate at which students drop out from various levels (b) shows a linear decrease with time, i.e., India has been fairly successful in retaining students in the formal education system with passing years. A Pearson correlation (r^2) of 0.992 is obtained for the fit b(t) = -6.53 × 10^{-3}t+13.32 (for t ≥ 1950). The second graph shows how E_o has been increasing linearly over the years. A Pearson correlation coefficient of 0.98 is obtained for the fit $E_o(t)$ = 5.98 × 10^6t-11.54 × 10^9 (for t ≥ 1960). (Source: Authors).

increased enrollment at every level for each decade, and hence 'b' has steadily decreased with time (see Fig. 4). Using Eqn (2), Eqn (3) reduces to

$$E_{Total}(t) = \sum_{l=l_i}^{l_f} E_o(t) e^{-(b_o+mt)l}$$

Assuming smooth variation for increasing level, '*l*', the summation sign can be replaced by an integral sign. Thus, the above equation reduces to

$$E_{Total}(t) = \int_{l=l_i}^{l_f} E_o(t) e^{-(b_o+mt)l} dl$$
$$= -\frac{E_o(t)}{(b_o+mt)} \left[e^{-(b_o+mt)l_f} - e^{-(b_o+mt)l_i} \right]$$

3.1.2. Literacy rate from enrollment number and total population

Dividing this by the total population of the country, we obtain the literacy rate (L) of the country for a given year. In other words

$$L(t) = \frac{-100E_o(t)}{(b_o+mt)P(t)} \left[e^{-(b_o+mt)l_f} - e^{-(b_o+mt)l_i} \right] \quad 4$$

Where P(t) is the total population of the country in the year 't' and the obtained expression is the literacy rate in percentage. India's population for the period of interest can be seen increasing linearly with time (see Fig. 5). The best fit for the population

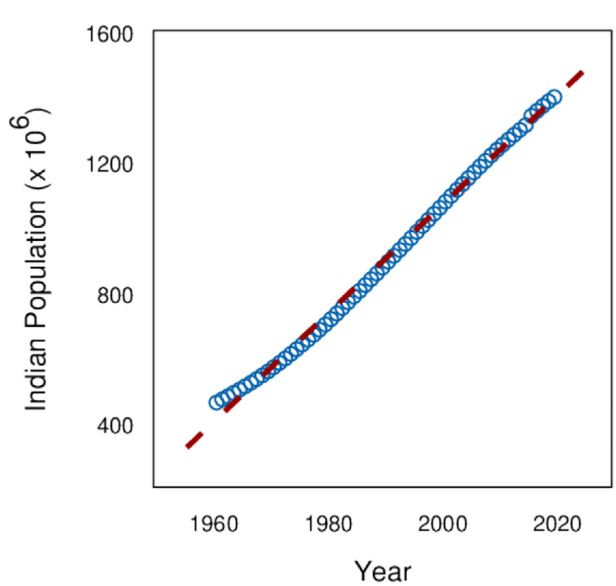

Fig. 5. The variation of India's population with time. Though the variation is not linear, as a first approximation, we are using a linear fit with P(t) = 16.67 × 10^6t - 3.2295 × 10^{10} (for t ≥ 1960) (Source: Authors).

post-1960 is given as P(t) = 16.67 × 10^6t-3.2295 × 10^{10}. For the reasonable assumption that between the period 1960 ≤ t ≤ 2010 where, $e^{-(b_o+mt)l_i} \gg e^{-(b_o+mt)l_f}$, eqn (4) can be written as

$$L(t) = \frac{100E_o(t)}{(b_o+mt)P(t)} \left[e^{-(b_o+mt)l_i} \right] \quad 5$$

3.2. Expression for PCI

From similar arguments, we can calculate the net earning (*En*) on getting some level of education. This can be achieved by calculating the number of people at every level of education and multiplying with the average salary people with that level of education attained, i.e.

$$En(t) = E_o(t) e^{-(b_o+mt)l} \times S(l,t) \quad 6$$

where *En* is the earnings made and S (*l*,t) is the average salary earned by people who had obtained the educational level '*l*' in the year 't'. S (*l*,t) is called the Earnings Function. The Earnings function was given by Mincer (1958) who modelled it as

$$ln(S) = ln(S_o) + \gamma l + \gamma_1 \eta + \gamma_2 \eta^2 \quad 7$$

where S_o(t) is the earnings of an uneducated person for the year 't' and 'η' is the experience gained working in a job. Truncating the above equation (linearizing it by neglecting the term η^2) and rewriting, we have

$$S = S_o(t) e^{\gamma_1 \eta} e^{\gamma l} \quad 8$$

The salary of an uneducated person too would change with time to accommodate the inflationary trend in a country, hence $S_o \rightarrow S_o(t)$. Even the rate at which salaries change with education level would change with time, hence γ(t). Thus, we write the above equation as

$$S = S_o(t) e^{\gamma_1(t)\eta} e^{\gamma(t) l} \quad 9$$

Over the years, more influencing factors have been added in Eqn (7) and tested. For example, Heckman (1979) added factors such as marital status, full-time or part-time jobs, etc. Hence, using Eqn (7) by itself would not have been exhaustive and truncating it to Eqn (9) is expected to show deviation from actual data.

3.2.1. Variation of salary with literacy

There is limited data on Salary based on education level collected over a period of time. In fact, the only data available for India is the data for the period 2000–2010 given by Rathore and Bhattacharya (2018).

To facilitate modeling, we have ignored an increase in salary due to experience gained since available data of Rathore and Bhattacharya (2018) have only documented earnings made after each education level, with no quantification of the experience. Hence, reducing Eqn (9) to

$$S = S_o(t)e^{\gamma(t)l} \qquad 10$$

we determine 'γ', the rate at which salary increases with educational level. The coefficients obtained after regression calculations done on available data from Rathore and Bhattacharya (2018) are listed in Table 1.

There is a recent study by Kapoor et al. (2021) that reports $\gamma = 0.0702$ for the year 2018 (There is no comment on S_o). The average of the three values'γ listed in Table 1 and the recent report is found to be 0.0945. Since the variation of the three γ's from the average value is small, we assume it is invariant with time and approximate it as $\gamma \sim 0.1$ for this study.

3.2.2. Variation of salary with inflation

We now need to know how $S_o(t)$ varies with time. $S_o(t)$ is defined as the starting wages paid to an uneducated person. We believe the increase in $S_o(t)$ in Table 1 is essentially due to inflation.

Hence, using the two data of Table 1 as starting points, we have used an online inflation calculator, to calculate the starting wage for each year corrected for inflation such that, in 2011, S_o = Rs 3000/-. Fig. 6 shows that $S_o(t)$ varies exponentially with years, hence

$$S_o(t) = pe^{qt} \qquad 11$$

where 'q' is the rate at which the salary of the uneducated worker increases with time.

Hence, Eqn (10) for this study can be written as

$$S_o(l,t) = 2.75 \times 10^{-62} e^{0.0745t} e^{0.1l} \qquad 12$$

Significantly, the result obtained now shows that the variables 't' and 'l' are separable.

3.2.3. Net earnings of literate population after accounting for unemployment

The net earnings of the population can be calculated by summing the earnings of people from all levels of education using Eqn (6). Again, assuming

Table 1. The regression results for available data given by Rathore and Bhattacharya (2018).

Year	S_o (in Rs)	γ
1999	1850	0.0904
2011	3000	0.1245

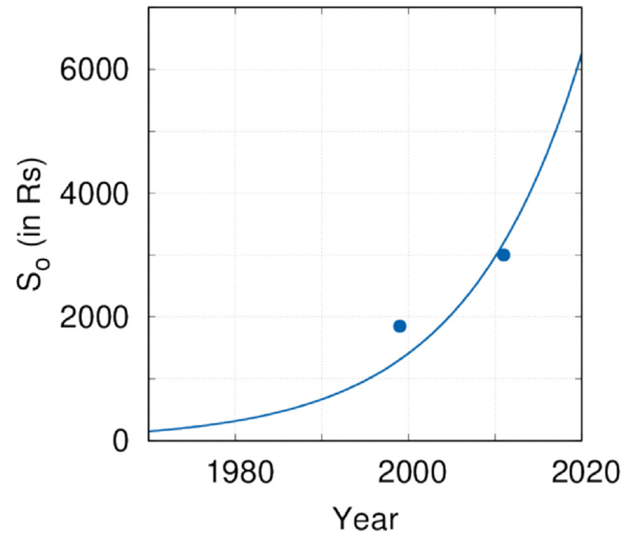

Fig. 6. The wages paid to an uneducated worker over the years corrected due to the inflation trend calculated using an online inflation calculator. Two points in the figure are the values of $S_o(t)$ listed in Table 1, shown to confirm the assumption that change in $S_o(t)$ with time is due to inflationary effects. (Source: Authors).

that the summation can be replaced with an integration, we have

$$En_{Total}(t) = \int_{l=l_i}^{l_f} E_o(t)e^{-(b_o+mt)l} \times S(l,t)dl \qquad 13$$

For completeness, one has to deduct the number of unemployed educated people (from expression Eqn (13)), considering they would not contribute to the net earnings (En). Hence, we write the above equation as

$$En_{Total}(t) = \int_{l=l_i}^{l_f} \left[E_o(t)e^{-(b_o+mt)l} - U(l,t)\right] \times S(l,t)dl$$

Assuming that the number of literate unemployed people would be a fraction of the literate population we can write $U(l,\ t) = \alpha(l,\ t)E_o(t)e^{-(b_o+mt)l}$, where $\alpha \le 0$. Hence, we have

$$En_{Total}(t) = \int_{l=l_i}^{l_f} [1-\alpha(l,t)]E_o(t)e^{-(b_o+mt)l} \times S(l,t)dl$$

The PCI(t) is obtained by dividing the above expression by the total population of the country, or

$$PCI(t) = \frac{1}{P(t)} \int_{l=l_i}^{l_f} [1-\alpha(l,t)]E_o(t)e^{-(b_o+mt)l} \times S(l,t)dl$$

Using Eqn (8) and expression for $S_o(t)$, we can write the above equation as

$$PCI(t) = \frac{1}{P(t)} \int_{l=l_i}^{l_f} [1-\alpha(l,t)]E_o(t)e^{-(b_o+mt)l} \times e^{\gamma l} dl \quad 14$$

We now need to establish the functional form of $\alpha(l, t)$, the fraction of the educated unemployed youth. For this, based on the fact that the variables such as E_o (t,l) and S (t,l) are separable, we make a reasonable assumption that $\alpha(l,t)$ too is separable and can be written as $\alpha(l,t) \rightarrow \alpha(t)\alpha_l(l)$. A recent study by Mehrotra and Parida (2019) presented data on unemployment according to education level for the years 2011–12 and 2017–18. They showed that unemployment increased exponentially with qualification. Thus, we have

$$\alpha(l,t) = \alpha(t)e^{sl} \quad 15$$

's' is the rate of increase in the number of unemployed members at different educational levels. This rapid rise in unemployment with qualification is expected. Basically, an illiterate person is without pretension and is willing to take up any job, whereas a qualified person looks for a job befitting his or her qualifications and would rather sit it out, unemployed for a few years. For calculations, we have taken s = 0.2 (value for the year 2011–12, Table 2).

The lack of data in the literature on $\alpha(t)$ makes it difficult to curve-fit and comment on its functional behavior with respect to time, 't'. Mehrotra and Parida (2019) in their work commented that a major cause of change in $\alpha(t)$ with changing years is due to the carrying forward of the number of unemployed youths from previous years into present year's statistics, along with some unemployed youths being forced to take up jobs below their qualification, etc. The complex coarseness in data is smoothened out due to the large number of unemployed being considered, and this pile-up of educated unemployed people can be assumed to grow as a geometric progression, i.e.

$$\alpha(l,t) = \alpha(t)e^{sl} = \left[a_o r^{t-1}\right]e^{sl} \quad 16$$

where 'a_o' and 'r' inside the square bracket have the usual meaning and represent the Geometric Progression of the tth term, for r > 1. Using trivial mathematics and data from Mehrotra and Parida (2019), we may write (using Eqn (16) and data from Table 2)

$$ln[\alpha(t,l)] = ln(a_o) + (t-1)ln(r)$$

$$ln\left[8.9 \times 10^{-4}\right] = ln(a_o) + 2011\, ln(r)$$

$$ln\left[4.23 \times 10^{-2}\right] = ln(a_o) + 2017\, ln(r)$$

The value of 'r' and a_o obtained by solving the above simultaneous equation is listed in Table 2. Based on the model and constants introduced therein, we have listed the important coefficients required for quantitative modeling and their numeric values for every five years, since 1960 in Table 3.

Table 2. The regression results from fitting $\alpha(t)e^{s.l}$ to available data on the educated unemployed population given by Mehrotra and Parida (2019).

Year	$\alpha(t)$	s	r	ln (a_o)	a_o
2011–12	0.89×10^{-3}	0.2	1.3	-2.32×10^{-2}	1.4×10^{-101}
2017–18	4.23×10^{-3}	0.14	1.3	-2.33×10^{-2}	0.7×10^{-101}

4. Results and discussion

Inspection of Table 3 shows that the numeric value of the coefficient $s+\gamma-b_o-mt$ takes positive values post-1995, while they were negative before the year 1995. Based on this, we have divided the next section into two parts, namely for the period 1960 ≤ t ≤ 1990 and t ≥ 1995 for studying the influence of literacy rate on the Per Capita Income of India. From Tables 3, it is also clear that the unemployment factor $\alpha(t)$ will not play a significant role in the period of study (1960 ≤ t ≤ 2010), considering the maximum value it has is 6.74×10^{-3} in 2010–11, making it negligible in Eqn (14). Inserting Eqn (15) into Eqn (14), we have

$$PCI(t) = \frac{1}{P(t)} \int_{l=l_i}^{l_f} \left[1-\alpha(t)e^{sl}\right]E_o(t)e^{-(b_o+mt)l} \times e^{\gamma l} dl$$

$$PCI(t) = \frac{E_o(t)S_o(t)}{P(t)} \int_{l=l_i}^{l_f} e^{\gamma-b_o-mtl} dl - \frac{\alpha(t)E_o(t)S_o(t)}{P(t)} \int_{l=l_i}^{l_f} e^{s+\gamma-b_o-mtl} dl \quad 17$$

Table 3. The Table lists values of the various coefficients used in the model for every five years from the year 1960.

Year (t)	$b_o + mt$	$\gamma - b_o - mt$	$s+\gamma-b_o-mt$	$\alpha(t)$
1960	0.521	−0.421	−0.221	1.35×10^{-8}
1970	0.456	−0.356	−0.156	1.87×10^{-7}
1980	0.390	−0.290	−0.090	2.57×10^{-6}
1985	0.358	−0.258	−0.058	9.55×10^{-6}
1990	0.325	−0.225	−0.025	3.55×10^{-5}
1995	0.292	−0.192	0.007	1.32×10^{-4}
2000	0.260	−0.160	0.040	4.89×10^{-4}
2005	0.227	−0.127	0.072	1.82×10^{-2}
2010	0.194	−0.094	0.105	6.74×10^{-3}

4.1. For the period between 1960 and 1990

In this period, it is observed that the coefficients obtained by curve-fitting, $\gamma - b_o - mt$ and $s + \gamma - b_o - mt$ are both negative (see Table 3). This is true since γ and γ+s have small numerical values. Considering the fraction of the educated population who were unemployed α is negligible, the second integral of Eqn (17) can be ignored. Also, since $l_f >> l_i$ the terms $e^{(\gamma - b_o - mt)l_f}$ with negative exponents can be neglected. The above equation (Eqn (17)) reduces to

$$PCI(t) = \frac{E_o(t)S_o(t)e^{\gamma l_i}}{(\gamma - b_o - mt)P(t)} e^{-(b_o - mtl_i)}$$

Many of the terms of the above expression are common with those of Literacy rate given by Eqn (5). Substituting the expression for literacy rate here, we have

$$PCI(t) = \frac{-e^{\gamma l_i}}{100}\left[\frac{(b_o + mt)S_o(t)}{(\gamma - b_o - mt)}\right]L(t)$$

The denominator term of the square bracket is a negative number (see Table 3). Thus, we can remove the negative sign in the above expression. Using Eqn (11) and the reasonable assumption that the exponential term of e^{qt} will play a dominant factor over other terms in the square bracket, we write

$$PCI(t) = \frac{pe^{\gamma l_i}}{100} e^{qt} L(t) \quad 18$$

The Literacy rate is expressed as (See Eqn (5))

$$L(t) = \frac{100E_o(t)}{(b_o + mt)P(t)}\left[e^{-(b_o + mt)l_i}\right]$$

which we can re-write as

$$e^{-(ml_i)t} = \frac{(b_o + mt)P(t)e^{b_o l_i}L(t)}{100E_o(t)}$$

or

$$(e^t)^{-ml_i} = \frac{(b_o + mt)P(t)e^{b_o l_i}L(t)}{100E_o(t)}$$

$$e^t = \left[\frac{(b_o + mt)P(t)e^{b_o l_i}L(t)}{100E_o(t)}\right]^{-\frac{1}{ml_i}} \quad 19$$

Using Eqn (19) in Eqn (18) and some mathematical operations, Eqn (18) can be re-written in (terms of literacy rate) as

$$PCI(t) = \frac{pe^{\gamma l_i}}{100} \times \left[\frac{(b_o + mt)P(t)e^{b_o l_i}L(t)}{100E_o(t)}\right]^{-\frac{q}{ml_i}} \times L(t)$$

or on further simplification,

$$PCI(t) \approx A_o\left[(b_o + mt)\frac{P(t)}{E_o(t)}\right]^{-\frac{q}{ml_i}} L(t)^{1-\frac{q}{ml_i}} \quad 20$$

where the constant A_o encompasses all the time independent terms. For the coefficients obtained by curve fitting, for the period 1960 ≤ t ≤ 1990, the terms inside the square bracket are a linear function of time (t) with a positive slope and a negative intercept. Considered along with A_o, the square bracket terms are insignificant with respect to the literacy rate, and hence

$$PCI(t) \propto L(t)^{3.28} \quad 21$$

That is, for the period between 1960 and 1990, the PCI follows a power law relation with literacy rate.

4.2. For the period beyond 1990

Eqn (17) for the period beyond 1990 would be reduced to (the first integral will be reduced to the expression of eqn (20) of the period 1960 ≤ t ≤ 1990)

$$PCI(t) = \left\{A_o\left[(b_o + mt)\frac{P(t)}{E_o(t)}\right]^{-\frac{q}{ml_i}} L(t)^{1-\frac{q}{ml_i}}\right\} - \frac{\alpha_o(t)E_oS_o(t)}{P(t)}\int_{l=l_i}^{l_f} e^{(s+\gamma-b_o-mt)l}dl$$

$$PCI(t) = \left\{A_o\left[(b_o + mt)\frac{P(t)}{E_o(t)}\right]^{-\frac{q}{ml_i}} L(t)^{1-\frac{q}{ml_i}}\right\} - \frac{\alpha_o(t)E_oS_o(t)}{(s+\gamma-b_o-mt)P(t)}e^{(s+\gamma-b_o-mt)l_f} \quad 22$$

As can be seen from Table 3, the values of α during the period 1995 ≤ t ≤ 2010 are negligible and hence we assume that the first integral term is more significant than the second integral of eqn (22) and write

$$PCI(t) = \left\{A_o\left[(b_o + mt)\frac{P(t)}{E_o(t)}\right]^{-\frac{q}{ml_i}} L(t)^{1-\frac{q}{ml_i}}\right\} \propto L(t)^{3.28}$$

The above results suggest that for the total period (1960 ≤ t ≤ 2010), the Per Capita Income's dependence on literacy rate follows a power law relation

($PCI \propto L(t)^{3.28}$). In general, the relation between Per Capita Income and literacy rate may be written as

$$PCI(t) = A(t)L(t)^{n} \quad 23$$

As was noted in the section on the literature review, Desai (2012) discusses a correlation between India's GDP and literacy rate. Like Rocha (2011), Desai (2012) did not try to create a model that connected the PCI to the literacy rate. Boris (2018) and Tombolotuku (2018) attempted to establish a linear model that connected PCI to literacy rate. A weak connection between the two parameters was reported by both.

The inability of the researchers stated above to establish a linear model between the two factors is explained by our model (PCI proportional to L^n). Given that the power "n" is influenced by "q," the pay for illiterate labor, and "m," the annual rate at which the dropout rate falls, some countries with low development indices may see "n" approach unity, leading one to interpret PCI and L(t) as having a linear relationship. To apply this erroneous assumption to the industrialized nations where 'n' would exceed unity would be incorrect. As a result, our approach has shown to be broadly relevant to both rich and developing nations. The model also allows for further interpretations. For example, contrary to our initial assumption and popular notion, there is no "threshold literacy rate" beyond which the PCI would show drastic or rapid growth. The sustained growth in PCI is actually due to a sustained growth in literacy rate resulting from increased enrollment in schools and a decreased drop-out rate from formal education. This model, of course, has limitations since it does not dwell deep into the cause of increased enrollment and decreased drop-out rate. One may give credit to the government's sustained advertising on the advantages of educating children along with the high subsidies provided in education over the years. Other than subsidizing education, Shah (2013) in his work has detailed the various methods that were adopted by various Governments to sustain the literacy rate in the country. Also, the γ-factor that related the salary to educational levels seems to have helped in playing the quintessential "carrot" to the middle class to keep their wards in schools/colleges.

The value of the power (3.28 in eqn (21)) of our model is much less than the value returned by curve-fitting our available data (see Fig. 7). This would mean our model has made an underestimation in our expression of literacy rate. Examination of Fig. 7 shows that three data points deviated from our trend line (of $L^{3.28}$). These data points suggest a surge in literacy rate (between 1991 and 2001) with

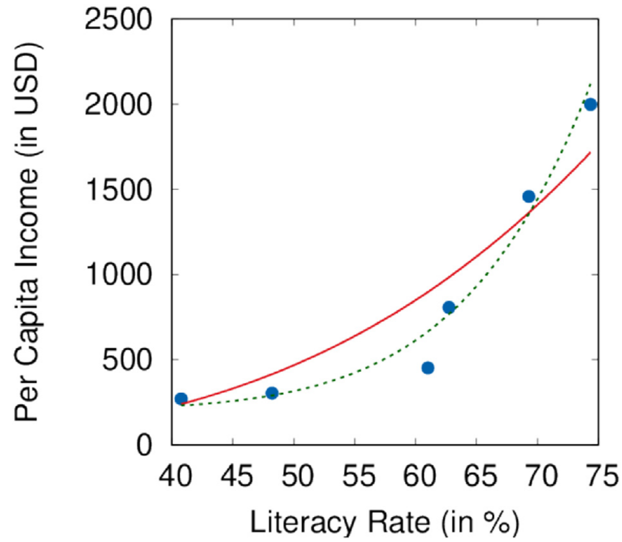

Fig. 7. The solid line is the best fit of our model to data points for the period between 1960 ≤ t ≤ 2010. The agreement is fairly good considering the simplifying assumptions made throughout the development of the model. The dashed line is a best–fit curve, with $PCI \propto L(t)^{7.2}$. (Source: Authors).

no or minimal effect on PCI. A plausible explanation is given by the Government of India in The Economic Survey (2003–2004) for this increase in literacy rate during the decade 1991–2001 (which was the highest with an increase of 12.6%, i.e., from 52.2 to 64.8%) as due to the increased female literacy during this period, resulting in a bridging of gender-gap which was also accompanied by a bridging in the rural-urban literacy rate. Our model does not accommodate such spikes in data. A second possible explanation for the underestimation may be the over-implication of the expression for literacy rate (eqn (5)). This expression does not take into account the population that has become literate in previous years. The inclusion of these numbers should be involved, since one would then have to take into account the numbers removed due to the death rate etc. By not including the already literate population in evaluating the literacy rate, a clear underestimation was inevitable.

Thus, within the limitations discussed, our model has been able to show the existence of a structural equation relating PCI to literacy rate. This equation does not have any threshold value beyond which PCI increases rapidly. It, however, shows a smooth and continuous power relation, showing as the literacy rate increases, the PCI's increases more rapidly. The equation shows that India, with its increased literacy rate, has successfully moved from a labor-based economy to a service-sector-driven economy, In the period 1960 ≤ t ≤ 2010, the unemployment rate, though a social and political issue, was not a serious parameter that affected the PCI. Any subsequent increase in the unemployment fraction (α) is expected to bring PCI growth down (due to the negative sign before the second integral of eqn (17)). However, the lack of data in the decade after 2010 (including the pandemic years) refrains us from making any comment. We leave that for future work after more data is available.

To summarize the implications of our result, visa verse Eqn (22), remember P(t) is the population of the country at time 't', $E_o(t)$ the maximum enrollment at primary school level (l_i) at the time 't'. While 'q' is the salary of uneducated labor, 'b' is the dropout rate or rate at which student enrollment falls with increasing educational level and 'm' is the rate at which 'b' falls with years (under favorable development, i.e. dropout number falls as students move from primary school to junior school, etc., 'm' is a negative number). Considering by and large, the world over, students enter school at the age of 4–5 at the primary level (l_i is invariant across countries), 'n' of eqn (23) is invariant for all countries on account of l_i. It is 'q', the pay of an uneducated laborer that seems to be the controlling factor, considering if the baseline is high then the remunerations of literate workers would be higher. This is evident considering an uneducated worker in an underdeveloped country gets bare minimum wages.

Another aspect that becomes evident from eqn (23), is the rate of change of PCI with change in literacy rate is given as $nA(t)L(t)^{n-1}$. For a developed country, A(t) will take a small value due to a lower population, P(t), and in turn a lower number of enrollments in schools, $E_o(t)$. This, explains Issoufou's (2020) observation that an under-developed country responds faster and shows better economic development with an increased literacy rate as compared to a developed country.

5. Policy implications

Drawing from our research, strategic investments in education are crucial for economic growth and reducing income inequality. India, and indeed any nation stands to benefit significantly by implementing targeted educational policies. The key policy implications are:

1. Improving the quality of education while ensuring it is accessible to all. This includes modernizing curricula, investing in teacher training, and utilizing technology to reach underserved areas.
2. Investment in Early Education: Policies should support the expansion of preschool education to set a strong foundation for lifelong learning, addressing educational disparities from the outset.
3. Vocational Training and Skills Development: Aligning education with a market requirement of vocational training and skill development can equip India's youth for better employment opportunities, supporting economic growth.
4. Enhancing quality in higher education and enhancing infrastructure for research and development.
5. Implementing policies to tackle the educational divide between urban and rural areas, and among different socioeconomic groups that will ensure a more equitable distribution of educational resources.
6. Expanding digital learning platforms to ensure uninterrupted access to education across the country.

By focusing on these strategic areas, countries can enhance their Per Capita Income growth and work towards a more equitable society. Education, as suggested by the collective insights from global research, is not just an individual investment but a critical foundation for national development and progress. Thus, governments will have to ensure quality education and ensure dropouts from the system are minimized.

6. Conclusion

The collective research from various scholars highlights a universal truth: education plays a pivotal role in enhancing economic growth and diminishing income inequality across the globe, touching economies as diverse as those in affluent European countries, developing regions in Sub-Saharan Africa, and leading nations like the United States, China, and India. The findings suggest that investments in education lead not only to improved employment prospects but also contribute significantly to the increase of a nation's Per Capita Income and the reduction of economic disparities among its population.

The insights drawn from these studies advocate for a strategic approach to educational investment. This approach encompasses improving the quality of foundational education, granting more autonomy to educational institutions, ensuring a lower student-to-teacher ratio, and emphasizing the importance of secondary education. Such focused investments are deemed crucial, especially for economically disadvantaged countries, as they pave the way for rapid economic growth and a decrease in poverty levels.

The present work presents a model to explore how changes in literacy rates influence PCI. The analysis conducted on the relationship between literacy rate and Per Capita Income (PCI) in India yields significant findings that contribute substantially to our understanding of this relationship. The study also emphasizes that sustained PCI growth is found to be driven by continuous enhancements in literacy rate, facilitated by increased enrollment and reduced dropout rates, contrary to the notion of a "threshold literacy rate" triggering rapid PCI growth.

The study acknowledges certain limitations, such as not exploring the causes of increased enrollment and reduced dropout rates in-depth and underestimating the expression for literacy rate by not accounting for the already literate population. Additionally, the analysis highlights the negligible impact of unemployment on PCI during the 1960–2010 period. The unemployment rate, though a social and political issue, was not a serious parameter that affected the PCI during that period. It should be noted, however, that any subsequent rise in the fraction of unemployment is anticipated to impede PCI growth. However, the non-availability of data beyond 2010 (including the pandemic years), refrains us from making conclusions about the impact of unemployment in subsequent years.

Despite these limitations, the study demonstrates a structural equation relating PCI to literacy rate, indicating India's transition from a labor-based to a service-sector-driven economy. The study emphasizes the importance of sustained efforts in improving literacy rates and promoting education as key drivers for economic growth and development in India. By prioritizing investments in educational infrastructure, ensuring equitable access to quality education, and implementing policies that effectively reduce dropout rates, policymakers can unlock the true potential of the country and pave the way for sustainable economic growth.

Conflict of interest

The authors declare no conflict of interest.

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