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Estimation and Forecasting of Per Capita State Domestic Product for different Regions of India using Growth Curves

Pooja R Pagad and Megeri MN

Abstract
State Domestic Product (SDP) is an important measure of economy of the State. With help of PCSDP different policy making is done with respect different sectors of economic development. In the present study an attempt is made study the growth pattens, estimation and forecasting of PCSDP using two growth curves: Modified exponential curves and Gompertz curve. Estimation of parameters of the two curves by method of partial sums. The data collected for the study is from Economic Survey of India and also, five regions of India divided according Mitra, Mukaherji, and Bose (1980). Analysis of the study shows average per capital PCSDP of Western region is above the national average whereas others regions are below it, growth of Per Capita Gross Domestic Products (PCGDP) of India is highly correlated with all the regions except Western region since its growth in this is inconsistent. Gompertz Curve is best fitted for Per Capita State Domestic Product (PCSDP) as compare to Modified exponential curve for all the regions of India but Modified exponential curve is best fitted for PCGDP of India. Forecasting results shows Per capita of PCGDP of India increased nearly double for ten years from 2020 to 2030 by Modified exponential curve. The PCSDP of Northern, Eastern regions increased by three times and that of Southern, Western and Central increased by four time from 2020 to 2030.

Keywords: Per capita GDP, per capita SDP, modified exponential curve, gompertz curve, mape and malpe.

1. Introduction
The economy refers to the system of production, distribution, and consumption of goods and services within a country, region, or the world. It includes all activities related to trade, business, employment, and resource management that contribute to wealth creation and overall well-being. Gross Domestic Product (GDP) is the total monetary value of all goods and services produced within a country's borders in a specific time period (usually a year or a quarter). It is the most commonly used indicator to measure a country's economic performance, According to International Monetary Fund World Economic Outlook (October-2021) Gross Domestic Product is the monetary market value of all final goods and services made within a country during a specific period. From 1981 to 2011 the world economy grew more than five times to reach $71 trillion. According to 2022 the GDP of the total world is $91.98 trillion and United States, China and Japan are the three largest economies in the world as measured by nominal GDP 20,936,600, 14,722,731 and 5,064,873 in millions of dollars respectively. Where United States has been the World's largest economy since 1871. Asian regions share of global GDP in the world was 24% in 2001 and in 2011 it has increased up to 34% and this share is the largest share of global GDP in the world as compared to all other regions. Due to the share of industry and service sectors the GDP has increased in majority of the Asian countries. By both GDP nominal and PPP in the world Asia stands the largest continental economy. The global economy of Asia, North America and Europe together shares about 92% on the nominal GDP and PPP shares of about 89%. And similarly, continents economy as measured by the nominal GDP in 2022 in millions of dollars are Europe and Central Asian (21,960,945), Latin America and Caribbean (4,838,098), Middle East and North Africa (3,098,531), North America (22,587300), South Asia (3,351,520), and Sub-Saharan

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Africa (1,685,632). David Castells Quintana and Vicente Royuele (2012) has studied the effects of income inequality and agglomeration at country level on economic growth and observed that increasing agglomeration whether through rising urbanization or greater urban concentration-promotes growth in low-income countries.

State Domestic Product (SDP) is an essential measure of economic activity at the state level. It plays a vital role in formulating regional policies, resource allocation, and development planning. The growth of SDP varies significantly across Indian states due to differences in industrialization, infrastructure, investment, and government policies and the SDP (State Domestic Product) measures the economic performance of a specific state or region within a country. It helps in understanding the contribution of different sectors to the state's economy and serves as a crucial tool for policymakers, businesses, and researchers.

According to Mitra, Mukaherji, and Bose (1980) [6], India is divided into five regions-Northern, Southern, Eastern, Western and Central regions. Northern region includes-Chandigarh, Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan. Southern regions are Andhra Pradesh, Karnataka, Kerala, Laccadive and Minicoy Islands, Pondicherry and Tamil Nadu. Whereas Eastern regions include Assam, Arunachal Pradesh, Bihar, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura and West Bengal. The Western regions are Gujarat, Goa, Maharashtra and Nagar Haveli and Central regions are Madhya Pradesh and Uttar Pradesh. In this paper, the study discusses about the Growth and distribution of Per Capita State Domestic Product (PCSDP) in India with respect to different regions as stated above. PCSDP of different regions is estimated and forecasted by using two growth curve models namely modified exponential curve and Gompertz curve and compared the goodness of fit of the two model and with help of test of accuracy and bias, the study concludes about the goodness of fit and model overestimates or underestimates and forecasting of PCSDP is done these growth curves.

The estimation and forecasting of urban population for male and female in different regions of India shows the modified exponential model is better fit as compare to Gompertz model (Megeri MN and Pooja R. Pagad, 2023) [7]. The fitting of urban population of India and Chaina gives Gompertz Growth model is best fitted for India and Chaina as compare to Logistic Growth model (Megeri M. N. and Kengnal R. P., 2014) [8]. In the present paper consists of five sections first section gives Introduction, the method and materials is explained in second section, third section consists of results and discussion and last sect concludes the study.

2. Methods and Materials
The data required for Per Capital State Domestic Product (PCSDP) for five regions of India is collected from Economic Survey of India for the year 1960 to 2019. The descriptive and comparative tools is used to study the concentration and comparison of different regions of India. To study the trend and pattern of PCSDP growth curves are used namely Modified Exponential Curve and Gompertz Curve, the parameters of these two models are estimated with the help of method of Partial sums. To test accuracy and bias of the models the MAPE and MALPE is used.

2.1 Modified Exponential Growth Curve
By assuming that the rate of growth is proportional to the size of urban population increase, the Exponential growth model

can be modified. The rate of growth is proportional to the urban populations at that time in Exponential growth model, whereas in Modified Exponential, the rate of growth does not depend only upon the urban population, but there are several other factors that affect the growth rate. Thus, the following equation is the Modified Exponential growth model.

Thus, the following equation is the Modified Exponential growth model.

$$P_t = \propto + \beta \rho^t$$

Where,

$\propto > 0, \beta > 0$ and $0 < \rho < 1$

2.2 Gompertz Curve
The Gompertz Curve was originally derived to estimate human mortality by Benjamin Gompertz (1825) [2]. This Gompertz Curve has been used by various authors as a growth curve, for both the biological and economic phenomenon. The Gompertz Curve was used in actuaries.
For this model

$$P_t = \alpha \beta^{\rho^t}$$

Where,

$\propto > 0, \beta > 0$ and $0 < \rho < 1$

Taking logarithms on both sides we get,

$$\text{Log } (P_t) = \log (\alpha) + \log (\beta) \rho^t$$

Which is the form of the Modified Exponential Growth Curve

Where,

$P_t = \log (P_t)$, $\alpha = \log(\alpha)$ and $\beta = \log (\beta)$.

The Gompertz Curve is related in a similar fashion to the Modified Exponential curve as the Simple Exponential is to the straight line. As ρ^t tends to zero for large t, P_t tends to the constant asymptotic value; modification of the curve is possible which will allow for a sloping asymptotic.

2.3 Mean Absolute Percentage Error (MAPE)
MAPE is the average percentage error when the direction of the error is ignored. In the fitted time series value in statistics, it is the measure of accuracy, specifically in growth curves. MAPE is most used to evaluate cross-sectional forecast (Hyndman and Koehler, 2006) [3]. It usually expresses accuracy in percentage as is defined as

$$\text{MAPE} = \frac{1}{n} \left(\sum_{t=1}^{n} \left| \frac{A_t - E_t}{A_t} \right| \right) * 100$$

Where,

A_t-The Observed urban population at time t.
E_t-The Estimated urban population at time t

2.4 Mean Algebraic Percentage Error (MALPE)
MALPE is the average percentage error when the direction of error is accounted for Smith, 1987. It is the measure of bias in fitted time series data in statistics. Negative error indicates a

tendency that the projection is an underestimate, and a positive error indicates that the projection is an overestimate and is given by MALPE= $\frac{1}{n}\sum_{t=1}^{n}\left(\frac{E_t-A_t}{A_t}\right)*100$

Where,

A_t-The Observed urban population at time t, E_t-The Estimated urban population at time t.

3. Results and Analysis

The systematic study of PCGDP and PCSDP is very important indicators to know the economy of the country and states respectively with in the countries. The study of growth pattern of these indicators is playing vital role for policy making regarding infrastructural development of the nation. In the present study PCGDP of India and combined PCSDP of different is studied through two growth curves for time series data. The exponential growth rate for six decade is calculated and is presented in following Table 1.

Table 1: Exponential growth rate of state domestic product in different regions of India

Years	India	Northern	Southern	Eastern	Western	Central
1960-1970	13.111	86.879	64.564	66.848	62.818	63.599
1970-1980	1.891	76.487	89.517	99.187	91.272	64.294
1980-1990	29.271	108.768	92.721	139.132	100.533	114.865
1990-2000	29.227	113.720	141.391	117.150	138.565	151.910
2000-2010	37.242	51.705	99.102	53.429	107.816	91.635
2010-2019	45.637	98.697	112.208	107.197	104.938	105.608

Table 1. shows Exponential growth rate of PCSDP for six different block periods in different regions of India, the exponential growth rates of India show increasing trend from 1960-2019 except for the period 1970-1980 and also slight decline in the growth rate between 1990-2000 and similar observation is made for all the regions of Northern and Eastern regions show least PCSDP in 2000-2010 (See Table 3.1. and Fig. 3.1), these fluctuations are due to the changes in the policy decisions: During 1970s to 1980s the per capita shows slow but steady growth driven by agricultural improvements and early industrial expansion. The growth rate of per capita PCGDP in India began to increase after the 1970s due to a combination of policy reforms, structural changes, and global economic trends. The investment-to-PCGDP ratio has been rising steadily at an accelerated pace

since the 1970s. This higher level of investment, supported by greater efficiency, has boosted confidence in achieving sustained economic growth. During 1970-1973 The government formed joint ventures with the private sector. It aimed to start industries in areas where the private sector had yet to venture due to a lack of technical knowledge or finances. In the late 1980s and early 1990s, India faced significant economic challenges, including high debt, inflation, sluggish PCGDP growth, and a Balance of Payments (BOP) crisis. To address these issues, the government introduced the New Industrial Policy of 1991, commonly known as the LPG reforms.

Liberalization: Industrial licensing requirements were abolished for most industries, enabling entrepreneurs to start or close businesses without government approval.

Privatization: Sectors previously reserved for government control were opened to private enterprises, leading to better management, efficient resource use, and enhanced competitiveness.

Globalization: Trade barriers on the export and import of goods and services were removed, granting Indian firms access to global markets while allowing foreign corporations to compete in previously protected domestic markets. Both pre-liberalization and post liberalization policies played important role in economic development of India. The policy of import-substitution and reliance on heavy industry create strong industrial base for India. However, India achieved a very slow rate of growth during this period which Raj Krishna called 'Hindu-Rate of Growth' during 1970.

To study the average size of PCGDP of India and PCSDP in different regions are studied through descriptive statistics. The data shows average per capita PCGDP for India is 35710, the for Western region's economy is above the National average and remaining regions are below it and it is also observed that the least per capita PCSDP is from Central region. Further consistency and variability of growth of economy for 60 years from 1960 to 2019 is studied by coefficient of variation, study finds that growth of PCGDP is most consistent as compared to all other regions of India and most variable per capita PCSDP is seen in Western region.
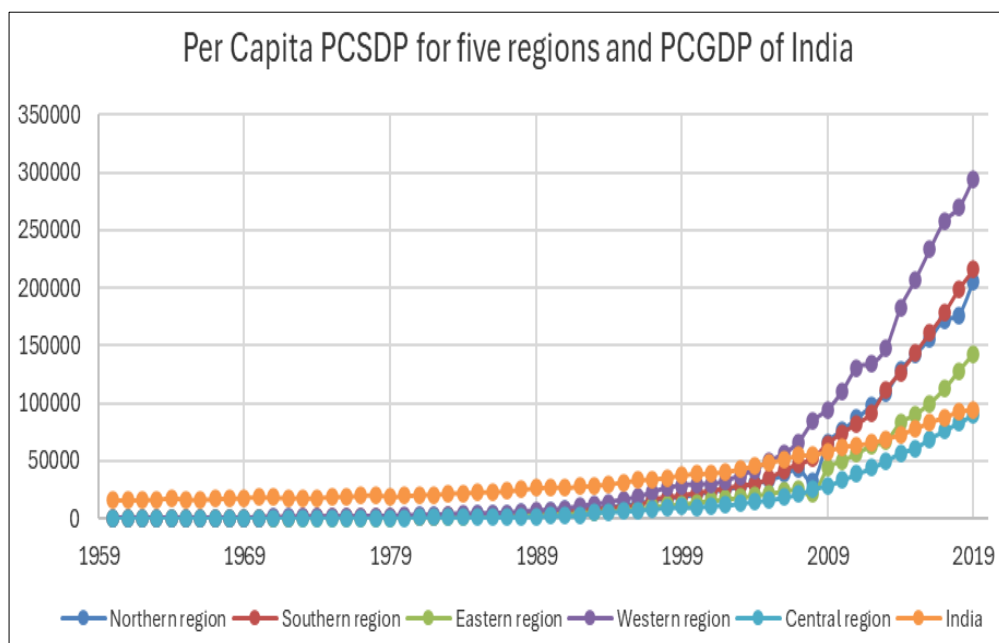
Fig 1: Per capita PCGDP of India and Per capita PCSDP of different regions of India.

Table 2: Descriptive Statistics and Correlation coefficients

Mean	35710	31241	31710	20430	55117	14320
SD	21940	51403	53682	34504	129162	22948
CV	61.44	164.54	169.29	168.89	234.34	160.25
Correlations						
	India	**Northern**	**Southern**	**Eastern**	**Western**	**Central**
India	1	.958**	.957**	.953**	.773**	.967**
Northern		1	.997**	.998**	.850**	.997**
Southern			1	.998**	.853**	.998**
Eastern				1	.862**	.996**
Western					1	.841**
Central						1

To study the National per capita PCGDP with PCSDP of different regions of India the correlation coefficient is used, the results reveals that there is a high positive correlation between PCGDP of India and PCSDP of all the regions of India, but the highest correlation is observed in Central region and lowest is in Western region and also all the regions show 1% level of significance (See Table 2). Hence from analysis, study identifies that the growth of Western per capita PCSDP is not far with National economy.

3.1 Growth and Distribution of Per capita PCGDP in India

Table 3 shows the Per capita PCGDP of India from 1961-2019 period of 60 years where, in 1960 the per capita of India was 16004 and it has increased to 94566 in 2019 which is nearly 6 times increase of Per capita PCGDP for 60 years from 1960 to 2019. The exponential growth rate of per capita PCGDP of India shows 52 years PCSDP positive which is nearly 87% of the data and remaining 8 (13%) years of PCSDP data gives negative growth *viz* periods 1964-65, 1965-66,1970-71, 1971-72, 1973-74, 1975-76, 1978-79 and 1990-91.

Table 3: Per Capita gross domestic product and its estimation by modified exponential and gompertz curves of India.

Year	Per Capita PCGDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve	Year	Per Capita PCGDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve
1960	16004		16305	15957	1990	27319	3.04	26566	26511
1961	16207	1.26	16414	16111	1991	26915	-1.49	27390	27267
1962	16289	0.50	16531	16272	1992	27880	3.52	28272	28074
1963	16910	3.74	16656	16441	1993	28608	2.58	29215	28935
1964	17780	5.02	16789	16618	1994	29934	4.53	30224	29855
1965	16836	-5.46	16933	16803	1995	31620	5.48	31303	30839
1966	16423	-2.48	17085	16997	1996	33436	5.58	32458	31894
1967	17325	5.35	17249	17200	1997	34107	1.99	33693	33026
1968	17488	0.94	17424	17414	1998	35497	3.99	35014	34241
1969	18246	4.24	17611	17638	1999	37968	6.73	36427	35547
1970	18702	2.47	17812	17873	2000	38515	1.43	37939	36954
1971	18535	-0.90	18026	18120	2001	39547	2.64	39556	38471
1972	17962	-3.14	18255	18380	2002	40419	2.18	41285	40109
1973	18140	0.99	18500	18653	2003	42995	6.18	43135	41880
1974	17913	-1.26	18763	18940	2004	45611	5.91	45114	43799
1975	19177	6.82	19043	19243	2005	48387	5.91	47231	45881

1976	19031	-0.76	19343	19562	2006	51431	6.10	49496	48143
1977	20021	5.07	19664	19897	2007	54649	6.07	51918	50605
1978	20738	3.52	20008	20252	2008	55101	0.82	54510	53290
1979	19059	-8.44	20375	20625	2009	58442	5.89	57281	56223
1980	19925	4.44	20768	21020	2010	62170	6.18	60246	59434
1981	20718	3.90	21188	21437	2011	63462	2.06	63418	62956
1982	20858	0.67	21637	21878	2012	65538	3.22	66811	66826
1983	21962	5.16	22118	22345	2013	68572	4.53	70440	71089
1984	22228	1.20	22633	22839	2014	72805	5.99	74322	75795
1985	22890	2.93	23183	23363	2015	77659	6.45	78474	81002
1986	23460	2.46	23772	23919	2016	83003	6.65	82916	86776
1987	23766	1.30	24401	24509	2017	87586	5.37	87668	93195
1988	25540	7.20	25075	25135	2018	92241	5.18	92750	100351
1989	26501	3.69	25795	25802	2019	94566	2.49	98187	108348
MAPE (Mean Absolute Percentage Error)								8.58	7.06
MALPE (Mean Algebraic Percentage Error)								1.23	0.36

Note: PCGDP: Per Capita Gross Domestic Products

The greater number of years negative growth rate is observed in-between the period 1960-1990. In this period around 27% of the year shows negative growth rate which is in the per-liberalization period. In this period there will be lack of competitiveness and also India's economy was not integrated with the word economy.

In the post liberalization period there will be 100% positive growth from 1991-2019 which is true because in the post-liberalization period there is more privatization and globalization and also India's economy was integrated with the word economy. The Least percentage of growth observed in 1978-79 and highest growth rate is seen in the period 1987-88 (See Table 3). The two growth curves namely Modified Exponential curve and Gompertz curves are fitted by using partial sums method.

The estimated value for Modified exponential curve is closer to observed per capita PCSDP as compared to Gompertz curve at beginning of the study period and at the end of the period this is reversed (See Table 3.).

The goodness of fit is calculated and the Mean Absolute Percentage Error (MAPE) results shows the that Gompertz growth curve value is smaller as compared to Modified Exponential growth curve this concludes that Gompertz curve shows good fit as compare to modified Exponential curve for India and the MALPE shows that both the curves are over estimated, but the magnitude of estimated per capita PCSDP is more for Modified Exponential growth curve as compare to Gompertz curve.

3.2 Growth and distribution of Per capita PCSDP in different regions of India
The India is divided into five regions namely Northern, Southern, Eastern, Western and Central regions. The Per

capita PCSDP (Constant price) income is studied for all the five regions of India for 60 years from 1960 to 2019, the two growth curves are fitted to Per capita PCSDP: Modified Exponential and Gompertz curves and the region wise study of economy are given below.

3.2.1 Northern Region
The Northern region economy is predominantly agrarian but is changing fast with rapid economic growth. In this region Delhi has the highest share of service sector about 90% and also one of the leading cities in well-developed infrastructure, the state has several industries and their manufacturing units even though its economy is mainly driven by the service sector. In Northern region of India, the per capita PCSDP is observed from 1960-2019 and shows that in 1960 the per capita PCSDP was 319 and in 2019 it has increased to 172505 which is almost 580 times increased for the period of 60 years. In 2004, Northern region the state with highest PCGDP per capita was Punjab followed by Haryana. Chandigarh has the highest per capita PCSDP of any India Union Territory.

The National Capital region of Delhi has emerged as an economic powerhouse with rapid industrial growth along with adjoining areas of Uttar Pradesh, Haryana and Rajasthan. The Haryana state has vast resources in the agro-based sectors supporting its huge potential in this sector. Himachal Pradesh is a mountainous state where due to the highly dependency of economy on agriculture, tourism, manufacturing, agro-processing, industrial, service sector and hydroelectric power the state is regarded as one of the high growing economies in the country. Jammu and Kashmir popularly known for the tourist destination. In this state the major contribution of PCGDP is from floriculture, horticulture, agro based industry, tourism, handicraft and service sector where service sector is the key growth driver in this state.

Table 4: Per Capita state domestic product and its estimation by modified exponential and gompertz curves for Northern Region of India.

Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve	Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of Modified exponential curve	Expected PCGDP of Gompertz curve
1960	319		365	297	1990	6633	12.54	6784	6715
1961	359	11.74	388	327	1991	7840	16.72	7626	7512
1962	361	0.65	414	360	1992	8608	9.35	8575	8407
1963	370	2.37	443	397	1993	9335	8.11	9645	9414
1964	405	9.21	476	438	1994	10792	14.50	10852	10547
1965	432	6.24	513	484	1995	11799	8.92	12213	11824
1966	529	20.37	555	534	1996	13635	14.46	13748	13262
1967	683	25.48	602	590	1997	16220	17.36	15478	14884
1968	683	0.05	655	653	1998	18246	11.77	17429	16713
1969	761	10.77	715	722	1999	19579	7.05	19630	18778
1970	833	9.07	783	798	2000	21513	9.42	22111	21110
1971	875	4.90	859	884	2001	24185	11.71	24908	23746
1972	936	6.83	945	979	2002	25744	6.25	28062	26726

Year	Per Capita PCSDP	Exp. growth	Modified exp	Gompertz	Year	Per Capita PCSDP	Exp. growth	Modified exp	Gompertz
1973	1128	18.62	1042	1085	2003	28213	9.16	31619	30097
1974	1257	10.84	1151	1202	2004	30805	8.79	35630	33913
1975	1350	7.10	1275	1334	2005	33823	9.35	40152	38235
1976	1462	8.01	1414	1480	2006	38642	13.32	45252	43134
1977	1623	10.44	1570	1643	2007	43654	12.20	51002	48689
1978	1709	5.14	1747	1825	2008	51585	16.70	57485	54992
1979	1789	4.60	1946	2029	2009	65692	24.17	64796	62147
1980	2051	13.63	2171	2256	2010	76487	15.22	73040	70276
1981	2594	23.51	2424	2510	2011	87166	13.07	82335	79516
1982	2850	9.39	2710	2794	2012	97673	11.38	92817	90026
1983	3088	8.05	3032	3112	2013	109149	11.11	104636	101986
1984	3298	6.58	3396	3468	2014	128966	16.68	117963	115606
1985	3771	13.40	3805	3867	2015	142396	9.91	132990	131126
1986	4047	7.05	4267	4313	2016	155846	9.03	149934	148820
1987	4437	9.22	4788	4814	2017	172505	10.16	169041	169007
1988	5309	17.94	5375	5376	2018	189579	9.44	190585	192051
1989	5852	9.73	6037	6007	2019	205611	8.12	214878	218375
MAPE (Mean Absolute Percentage Error)								11.26	10.15
MALPE (Mean Algebraic Percentage Error)								5.54	1.07

In Punjab the contribution of manufacturing and service sector have gradually increased over the years, where Punjab was originally known to be the agrarian economy. Rajasthan is popular destination for tourism where this state is rich in industrial base supported by its vast resource base, expanding infrastructure and government support. And Chandigarh was the first planned city in India. The Exponential growth rate of per capita PCSDP is negative in the period 1960-61 and 2007-2008. The highest growth rate is observed in the period 2008-2009 (See Table 4). The observed Per Capital PCSDP is closed to estimated value for Gompertz curve whereas in case of modified exponential curve after 30 from the starting period estimated value is very high (See Table 4). The MAPE of this region shows that Gompertz curve shows best fit than Modified Exponential growth curve and in MALPE both the curve shows overestimate, but the Modified Exponential growth curve shows over estimated value than compared to Gompertz growth curve.

3.2.2 Southern Region

After Independence, the economy of Southern region of India conformed to a socialist framework, with strict government control over private sector participation, foreign trade, and foreign direct investment. Over 48% of South India's population is engaged in agriculture. In Southern region of India, the per capita income has increased from 233 in 1960 to 215709 in 2019, this shows the increase in the per capita PCSDP from 1960 to 2019 is 926 times. From 1960 to 1990, the south India economies experienced mixed economic growth. In the year 1960's Kerala achieved above average growth while Andhra Pradesh economy declined. Kerala experienced an economic decline in 1970's while the economies of Karnataka, Tamil Nadu, and Andhra Pradesh consistently exceeded national average growth rate, due to reform-oriented economic policies. As of March 2015, there are 109 operational Special Economic Zones in South. In 2000-2001 the importance of service sector in the state economy was highest in Kerala followed by Tamil Nadu and Karnataka. The predominance of the service sector in Kerala is further speed up with emphasis on tourism, technical education and health care services in the state. The net state domestic product of Tamil Nadu is the second largest economy in India after Maharashtra with gross state domestic product of US$ 280 billion and also it is the second most industrialized state in India. The state which is predominantly service based is Kerala, there are few major industries in this state but still its per capita PCGDP is higher than the national average. The net state domestic product of Karnataka is $47 billion, and it is only the state which exports sandalwood in the country and at Shivan Samudra the first power station in Asia was set up to produce hydroelectric power. In Andhra Pradesh agriculture is one of the chief sectors contributing to the economy of the state. Pondicherry is a Union Territory and is largely based on engineering, food processing, chemicals, metals, tourism, textiles and information technology. The Exponential growth rate is negative in the period 1974-95 and highest growth rate is observed in the period 1996-1997. The accuracy of bias is obtained for this region and the results shows that Gompertz curve is the best fit as compared to Modified Exponential curve as Gompertz curve has small values compared to Modified Exponential, also both the curves in this region are overestimated. Hence Gompertz curve is the good fit for this region (See Table 5).

Table 5: Per capita State Domestic Product and its Estimation by Modified Exponential and Gompertz curves of Southern region of India.

Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve	Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve
1960	233		287	216	1990	4999	11.58	5642	5410
1961	245	5.03	303	238	1991	5870	16.06	6394	6099
1962	250	2.02	321	262	1992	6420	8.96	7248	6882
1963	274	9.10	342	289	1993	7472	15.17	8220	7773
1964	308	11.84	365	319	1994	8814	16.52	9326	8786
1965	324	4.94	391	352	1995	9874	11.36	10583	9941
1966	369	13.07	421	389	1996	10901	9.89	12014	11257
1967	402	8.72	456	431	1997	15964	38.15	13640	12759
1968	416	3.23	495	477	1998	18308	13.70	15490	14475
1969	444	6.61	539	528	1999	19369	5.63	17595	16436
1970	643	37.06	589	585	2000	22003	12.75	19988	18681
1971	696	7.89	646	649	2001	23605	7.03	22710	21252
1972	738	5.86	711	721	2002	25740	8.66	25806	24200
1973	946	24.79	786	801	2003	28139	8.91	29328	27583

1974	1041	9.61	870	890	2004	29704	5.41	33333	31468
1975	1033	-0.73	966	990	2005	34513	15.01	37889	35935
1976	1092	5.53	1075	1103	2006	41802	19.16	43070	41077
1977	1222	11.20	1199	1229	2007	46806	11.31	48963	46999
1978	1351	10.08	1340	1371	2008	52180	10.87	55665	53829
1979	1574	15.29	1500	1530	2009	64780	21.63	63289	61712
1980	1728	9.30	1682	1709	2010	74319	13.74	71959	70819
1981	1952	12.19	1890	1911	2011	81676	9.44	81821	81353
1982	2101	7.38	2126	2138	2012	91345	11.19	93037	93547
1983	2399	13.25	2394	2394	2013	111684	20.10	105795	107680
1984	2648	9.87	2699	2683	2014	126951	12.81	120305	124074
1985	2849	7.33	3046	3009	2015	143482	12.24	136808	143112
1986	3125	9.24	3441	3378	2016	160759	11.37	155578	165244
1987	3478	10.70	3890	3795	2017	178150	10.27	176926	190998
1988	3979	13.46	4401	4268	2018	198956	11.05	201208	220999
1989	4452	11.24	4982	4803	2019	215709	8.08	228825	255984
MAPE (Mean Absolute Percentage Error)								8.85	6.20
MALPE (Mean Algebraic Percentage Error)								3.82	0.35

3.2.3 Eastern Region

The Eastern region is well endowed with natural resources like oil and gas, agro-horticultural resources, mineral deposits, immense hydroelectric potential and significant forest resources. In the Eastern region of India, the per capita PCSDP was 118 in 1960, but in 1961 it decreased to 99 later it goes on increasing from 1963 (107) to 2019 (142949) which is 1211 times of 1960 per capita PCSDP. In this region the West Bengal state has the highest contribution of PCGDP among all other eastern states of India, and it is also one of the fastest growing state in India. West Bengal is the hub of industry and economic activities in Eastern India. In Jharkhand the major urban areas are mainly dominated by industrial cities. Patna is the administrative, industrial and educational centre of the state. The largest city of Odisha, Bhubaneswar today is a centre of economic and religious importance in this region. The Eastern India, particularly Odisha and Jharkhand, have rice mineral resources which resulted in economic boom in the state. The negative growth rate is observed in the period 1960-61, 1965-66 and 2007-2008. The highest growth rate is observed in the period 2008-09.

The MAPE result shows that the Gompertz curve is the good fit as compared to Modified Exponential curve and the MALPE shows that Modified Exponential curve is underestimated and Gompertz curve is overestimated, therefore Gompertz curve is the best fit in this region (see Table 6 and Figure 2d).

Table 6: Per capita state domestic product and its estimation by modified exponential and gompertz curves for eastern Region of India.

Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve	Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve
1960	118		19	76	1990	4013	10.46	4230	4272
1961	126	6.42	4	87	1991	4594	13.52	4786	4840
1962	134	6.09	26	101	1992	4929	7.05	5412	5481
1963	145	7.77	45	116	1993	5882	17.68	6119	6203
1964	156	7.02	67	134	1994	6533	10.49	6915	7015
1965	169	8.12	91	154	1995	7897	18.97	7814	7930
1966	199	16.35	119	178	1996	8039	1.78	8827	8958
1967	218	9.35	150	204	1997	10863	30.12	9969	10115
1968	229	4.69	185	235	1998	11662	7.10	11256	11414
1969	231	1.04	225	270	1999	12788	9.22	12709	12872
1970	306	28.02	269	310	2000	14215	10.58	14346	14509
1971	329	7.32	320	355	2001	15938	11.44	16192	16345
1972	362	9.48	377	407	2002	16989	6.38	18274	18402
1973	423	15.66	441	466	2003	18549	8.78	20621	20707
1974	505	17.66	513	534	2004	20423	9.62	23268	23288
1975	513	1.72	594	611	2005	21826	6.64	26253	26177
1976	536	4.28	686	698	2006	24298	10.73	29618	29407
1977	600	11.26	789	798	2007	28050	14.36	33413	33018
1978	721	18.48	906	911	2008	31936	12.97	37692	37052
1979	824	13.33	1037	1040	2009	43839	31.68	42517	41557
1980	1012	20.49	1186	1186	2010	50380	13.91	47958	46584
1981	1566	43.71	1353	1352	2011	56582	11.61	54092	52191
1982	1705	8.49	1542	1540	2012	63653	11.78	61009	58442
1983	1948	13.31	1754	1753	2013	72523	13.05	68809	65407
1984	2178	11.20	1994	1995	2014	83348	13.91	77604	73164
1985	2425	10.71	2264	2268	2015	90313	8.03	87521	81797
1986	2672	9.71	2569	2577	2016	100076	10.26	98704	91402
1987	3015	12.08	2913	2927	2017	112350	11.57	111313	102080
1988	3314	9.44	3300	3322	2018	128061	13.09	125530	113948
1989	3614	8.68	3737	3768	2019	142949	11.00	141562	127129
MAPE (Mean Absolute Percentage Error)								15.95	11.50
MALPE (Mean Algebraic Percentage Error)								-5.59	1.02

3.2.4 Western Region

The Western region per capita income in 1960 was 257 and it increased to 890342 in 2019 i.e., from 1960 to 2019, 3464

times increase is observed. Western Region is highly industrialised, with a large urban population.

Table 7: Per capita state domestic product and its estimation by modified exponential and gompertz curve for western region of India.

Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve	Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of Modified exponential curve	Expected PCGDP of Gompertz curve
1960	168		83	134	1990	2546	10.80	3290	2835
1961	173	4.81	96	146	1991	2742	12.92	3695	3175
1962	173	2.80	110	161	1992	2960	21.17	4149	3559
1963	196	7.75	126	176	1993	5616	15.68	4659	3993
1964	235	12.63	144	193	1994	6119	14.04	5231	4484
1965	224	1.17	165	213	1995	6709	15.34	5872	5039
1966	255	12.89	187	234	1996	7546	12.64	6593	5668
1967	317	12.33	213	257	1997	8828	20.85	7401	6380
1968	291	-1.75	241	283	1998	9735	15.13	8308	7188
1969	317	10.19	273	312	1999	10380	8.18	9326	8105
1970	323	55.89	309	344	2000	9959	2.56	10468	9147
1971	344	4.03	349	380	2001	11575	-0.49	11750	10331
1972	393	0.61	395	420	2002	11732	10.33	13189	11680
1973	467	27.56	445	464	2003	13542	12.60	14803	13215
1974	531	11.17	502	513	2004	15075	14.07	16615	14966
1975	502	8.31	566	567	2005	16299	15.64	18648	16963
1976	533	10.39	638	628	2006	18779	12.11	20930	19245
1977	619	9.82	719	696	2007	21165	16.57	23491	21852
1978	609	5.79	809	772	2008	25951	24.41	26364	24836
1979	615	13.59	911	857	2009	28896	11.11	29589	28252
1980	818	12.33	1024	952	2010	33439	15.47	33208	32168
1981	925	16.73	1152	1058	2011	38805	17.23	37269	36660
1982	1045	9.96	1295	1177	2012	43863	2.26	41827	41819
1983	1164	12.08	1456	1310	2013	49986	9.91	46942	47748
1984	1202	10.04	1637	1459	2014	57091	21.32	52681	54570
1985	1361	0.90	1839	1627	2015	61089	12.23	59122	62425
1986	1420	11.54	2067	1815	2016	69179	12.02	66351	71479
1987	1670	7.54	2322	2026	2017	76070	10.01	74463	81925
1988	1940	19.41	2608	2265	2018	83079	4.48	83566	93989
1989	2131	14.37	2930	2533	2019	89488	119.53	93782	107935
MAPE (Mean Absolute Percentage Error)								16.84	9.23
MALPE (Mean Algebraic Percentage Error)								10.57	1.05

The region generates 24% of the national PCGDP of the country, with an annual growth rate of 14.5% as of 2006. Maharashtra has the highest PCSDP among all the Indian states. Goa state of this region is the India's richest state with the highest PCGDP per capita where tourism is the Goa's primary industry. Gujarat is also one of the most industrialized states with significance presence in pharmacy, chemicals, refining, and petrochemicals, ceramics, textiles, automobiles etc. sectors. Similarly, Maharashtra is the second most industrialized state in India. And business and economy of Dadra and Nagar Haveli are mainly based on agriculture

and manufacturing industries, there are five major activities of this state agriculture, industries, forestry, animal husbandry and tourism. The negative growth rate is observed in the period 1967-68 and 2000-2001. The highest growth rate is observed in the period 1969-1970.

The MAPE result for both the curve shows that Gompertz curve is the good fit as compared to Modified Exponential curve as Gompertz curve values are smaller than the Modified Exponential curve and for the MALPE for both the curve shows overestimate. Hence Gompertz curve is the best fit for this region (see table 7 and Fig. 2e).

Table 8: Per capita state domestic product and its estimation by modified exponential and gompertz curves for central region of India.

Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of modified exponential curve	Expected PCGDP of Gompertz curve	Year	Per Capita PCSDP	Exponential growth rate	Expected PCGDP of Modified Exponential curve	Expected PCGDP of Gompertz curve
1960	168		83	134	1990	2546	17.81	3290	2835
1961	173	2.93	96	146	1991	2742	7.40	3695	3175
1962	173	-0.19	110	161	1992	2960	7.64	4149	3559
1963	196	12.68	126	176	1993	5616	64.06	4659	3993
1964	235	18.29	144	193	1994	6119	8.57	5231	4484
1965	224	-5.08	165	213	1995	6709	9.21	5872	5039
1966	255	13.11	187	234	1996	7546	11.76	6593	5668
1967	317	21.66	213	257	1997	8828	15.70	7401	6380
1968	291	-8.45	241	283	1998	9735	9.78	8308	7188
1969	317	8.66	273	312	1999	10380	6.42	9326	8105
1970	323	1.87	309	344	2000	9959	-4.14	10468	9147
1971	344	6.10	349	380	2001	11575	15.03	11750	10331
1972	393	13.33	395	420	2002	11732	1.35	13189	11680
1973	467	17.41	445	464	2003	13542	14.35	14803	13215
1974	531	12.71	502	513	2004	15075	10.72	16615	14966
1975	502	-5.62	566	567	2005	16299	7.81	18648	16963
1976	533	6.00	638	628	2006	18779	14.16	20930	19245
1977	619	15.07	719	696	2007	21165	11.96	23491	21852
1978	609	-1.68	809	772	2008	25951	20.38	26364	24836

1979	615	0.98	911	857	2009	28896	10.75	29589	28252
1980	818	28.48	1024	952	2010	33439	14.60	33208	32168
1981	925	12.33	1152	1058	2011	38805	14.88	37269	36660
1982	1045	12.17	1295	1177	2012	43863	12.25	41827	41819
1983	1164	10.82	1456	1310	2013	49986	13.07	46942	47748
1984	1202	3.21	1637	1459	2014	57091	13.29	52681	54570
1985	1361	12.45	1839	1627	2015	61089	6.77	59122	62425
1986	1420	4.22	2067	1815	2016	69179	12.44	66351	71479
1987	1670	16.20	2322	2026	2017	76070	9.50	74463	81925
1988	1940	14.99	2608	2265	2018	83079	8.81	83566	93989
1989	2131	9.41	2930	2533	2019	89488	7.43	93782	107935
MAPE (Mean Absolute Percentage Error)								18.57	12.72
MALPE (Mean Algebraic Percentage Error)								3.02	1.24

3.2.5 Central Region

The economy of Madhya Pradesh is significantly agrarian which is reflecting rapid strides towards industrial and service sectors as well. The Indore, Bhopal and Jabalpur districts are the top 3 districts in the state largest economy.
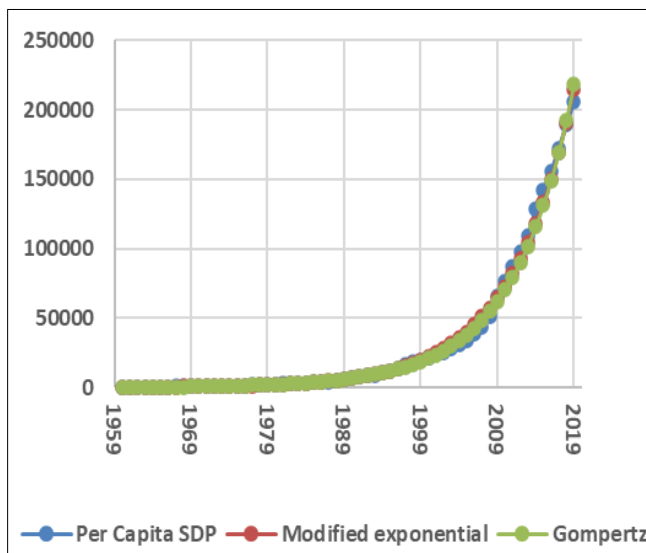
In the Central region the per capita income PCSDP was 168 in 1960, and it increased to 89488 in 2019, this shows 533 times increase from 1960 to 2019. The economy of Madhya Pradesh is the largest in India. The economy of Uttar Pradesh is the third largest of all the states of India. Uttar Pradesh is an agrarian state and the highest producer of wheat. Uttar Pradesh has witnessed rapid urbanization in the past, particularly after the launch of policies of economic liberalisation in the country. The service industry plays a large role in the economy of Uttar Pradesh.

The economy of Chhattisgarh is founded primarily on mining, agriculture, energy production and manufacture. It is among the richest Indian states in terms of mineral wealth with 28 varieties of major minerals including diamonds. Chhattisgarh ranked third in terms of value of mineral production of India. The negative Exponential growth rate is observed in the period 1961-62, 1964-65, 1967-68, 1974-75, 1977-78, and 1999-2000. The highest growth rate is observed in the period 1992-93 (See Table 8). The accuracy and bias for this region shows that the MAPE value is good fit for the Gompertz curve as this curve values are smaller than the Modified exponential curve and for the MALPE, the result shows that both the values are overestimated values. Hence Gompertz curve is the good fit for this region (See Fig 2f.).

From the above table 9 the coefficient of Modified Exponential and Gompertz curve shows that all the α and β values should be greater than one and the ρ values should lie between zero and one. The highest value of α indicates the carrying capacity of the curve is high, in the present analysis Northern region this value is highest for both the curves, indicating carrying capacity for the Northern region is highest in all the five regions of India and India. And the least carrying capacity is observed for Modified Exponential curve is Central region indicates lowest carrying capacity in this region but the lowest value of α for Gompertz curve is in Southern region. The value of β indicates the maximum value of the curve approaches as t increases. In the present analysis the maximum value for Modified Exponential among all the regions including India is Western region and minimum value is India. The most important interpretation of the parameter is sloping parameter (ρ) the other parameters, the value of sloping parameter increases with a increase in t values the per capita PCSDP is increasing and with the decrease in the value decreases that per capita PCSDP, here in the Modified Exponential curve the value of ρ is highest in Western region and least in India indicating the per capita PCGDP is increasing in Western region and its increase is slower in India. For the Gompertz curve the value of ρ is highest is in India and lowest is in Eastern region indicates faster increase in India's PCGDP and smaller increase is observed in Eastern region.

Table 9: the estimated parameters of modified exponential and gompertz curves for per capita PCSDP of different regions of India.

Regions	Parameters	Modified Exponential	Gompertz
Northern region	α	762.19	19.53
	β	109.54	21.93
	ρ	1.13	1.00
Southern region	α	172.32	3.41
	β	115.05	5.74
	ρ	1.14	1.01
Eastern region	α	142.26	12.20
	β	122.90	10.37
	ρ	1.13	0.99
Western region	α	200.13	16.10
	β	135.55	18.45
	ρ	1.15	1.00
Central region	α	20.77	3.48
	β	104.14	5.60
	ρ	1.12	1.01
India	α	147.38	4.09
	β	15.35	0.11
	ρ	1.07	1.04
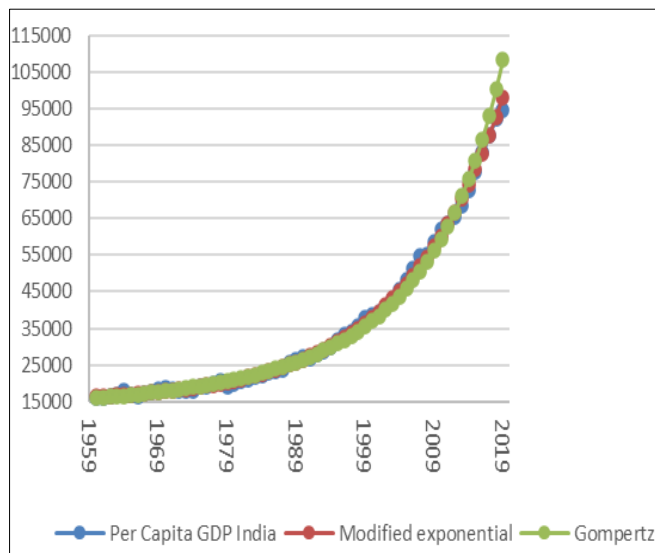
Fig 2a: Fitting of Per capita PCGDP of India

Fig 2b: Fitting of Per capita PCSDP of Northern region
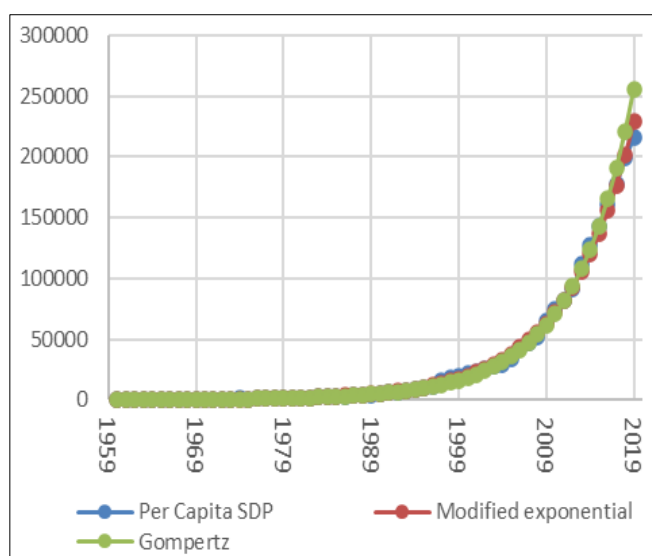
Fig 2c: Fitting of Per capita PCSDP of Southern region
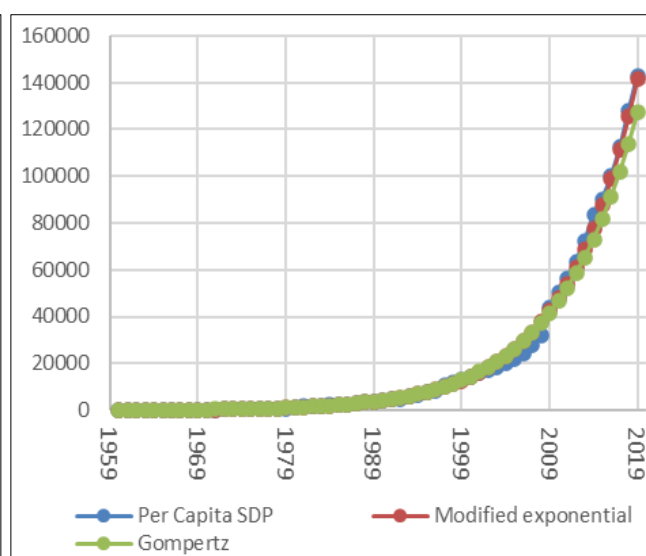
Fig 2d: fitting of Per capita PCSDP of Eastern region
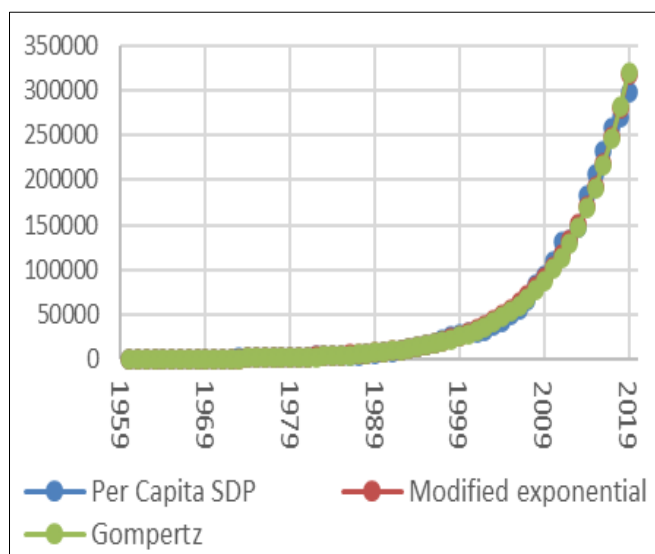
Fig 2e: Fitting of Per capita PCSDP of Western region
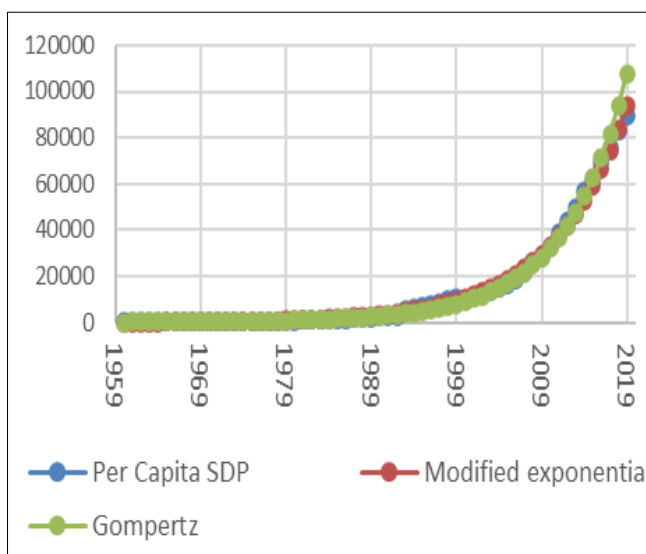
Fig 2f: fitting of Per capita PCSDP of Central region

Fig 2(a-f): Fitting of per capita State Domestic Product by Modified Exponential and Gompertz curves of India and all five Regions of India.

Table 10: Forecasting values of best fitted models for eleven years.

Year	India	Northern	Southern	Eastern	Western	Central

2020	104003	227363	296826	132429	364757	124072
2021	110224	256628	344556	146860	415417	142763
2022	116879	289735	400397	162757	473213	164434
2023	123997	327196	465796	180257	539165	189585
2024	131612	369596	542476	199509	614439	218804
2025	139757	417598	632481	220675	700371	252784
2026	148470	471956	738245	243930	798491	292341
2027	157790	533528	862667	269465	910552	338438
2028	167759	603288	1009204	297484	1038562	392211
2029	178424	682347	1181983	328211	1184822	455005
2030	189831	771967	1385939	361886	1351969	528411

Table 10 shows the forecasting values of per capita PCGDP of India also the per capita PCSDP for different regions of India. The above Modified exponential and Gompertz models used to estimate the per capita values and observed that for India the Modified Exponential curve shows good fit and for all the regions of India Gompertz curve shows good fit. Hence to forecast the values from 2020 to 2030 the Modified Exponential is used for India and for all other regions Gompertz curve is used. And the results shows that the per capita PCGDP in India is increasing from 2020 to 2030 i.e., nearly two times increase is observed. The per capita PCSDPs for the Northern region show nearly three times increase, in Southern region four times increase is observed, in Eastern region nearly three times, in Western region nearly four times increase and in Central region four time increase in the per capita PCSDP is observed. When the result is compared between the five regions of India the results shows that Western, Southern and Central region shows highest increase in per capita PCSDP from 2020 to 2030 remaining Northern and Eastern region shows least time increase in per capita PCSDP from 2020 to 2030.

4. Conclusion
In the present study the estimation of Per capita PCSDP for all the five regions of India including India as a whole using two growth models namely Modified Exponential curve and Gompertz curve is used and the results shows that average per capita PCSDP of Western region is above the national average and remaining regions are below it and least PCSDP is in Central region. Growth of per capita PCSDP is most inconsistent in Western region and consistent in Central region as compared to other regions including India. The growth of per capita PCGDP of India is highly correlated with all other regions of India except Western region. The accuracy and bias of the models are observed by using MAPE and MALPE tests and the result concludes that the growth of per capita PCGDP for India is best fitted with Gompertz curve as compared to Modified Exponential curve and similar observation is made for all the regions of India. Also, all the regions of India show both the curves overestimated except for Eastern region where the Modified exponential curve underestimates the per capita PCSDP. Carrying capacity for Northern region is highest for both the curves and the sloping parameter value is within the range of the parameter for Gompertz curve. Hence from the above fact Gompertz curve is best fitted for per capita PCSDP in all the regions of India, and for per capita PCGDP of India Modified Exponential curve is the best fit. And by using the best fitted curves we have forecasted the values for ten years.

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