WORKING PAPER 169/2018

Modelling the Characteristics of Residential Energy Consumption: Empirical Evidence of Indian Scenario

Zareena Begum Irfan
Divya Jain
Satarupa Rakshit
Ashwin Ram

MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

April 2018

Modelling the Characteristics of Residential Energy Consumption: Empirical Evidence of Indian Scenario

Zareena Begum Irfan
Associate Professor, Madras School of Economics
(Corresponding Author)
zareena@mse.ac.in

Divya Jain, Satarupa Rakshit and Ashwin Ram
Madras School of Economics

WORKING PAPER 169/2018

April 2018

Price : Rs. 35

MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

Phone: 2230 0304/2230 0307/2235 2157
Fax : 2235 4847/2235 2155
Email : info@mse.ac.in
Website: www.mse.ac.in

Modelling the Characteristics of Residential Energy Consumption: Empirical Evidence of Indian Scenario

Zareena Begum Irfan, Divya Jain, Satarupa Rakshit and Ashwin Ram

Abstract

Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Household sector is one of the largest users of energy in India, counting for about 30 per cent of final energy consumption (excluding energy used for transport) reflecting the importance of that sector in total national energy scenario. The pattern of household energy consumption represents the status of welfare as well as the stage of economic development. Household energy consumption is expected to increase in future along with growth in economy and rise in per capita incomes. This paper analysis the manifold aspects of anthropogenic activities with focus on household characteristics influencing the residential carbon dioxide emissions. Data on expenditure incurred for purchase used for both indoor and outdoor use as well as the socio-economic indicators have been taken into account to estimate their contribution to the level of emissions. The various indicators of household expenditure have been categorized separately under technological innovations, affluence, household demographics, biophysical characteristics and control variables. The theories of Ecological Modernization, Political Economy and Human Ecology have been highlighted to discuss the significance of household energy consumption pattern. Household income in India has increased considerably in line with economic growth over the last decades. In this study, household data has been extracted from India Human Development Survey- II (IHDS – II), 2011-12 which is a cross sectional survey conducted by ICPSR 36151. The expenditures on energy consumption and emission factors are to a great extent influenced by the factors that are beyond the control of humans such as development trends regarding urban forms and infrastructure. In this study we have used household data which makes it an expanding literature to anthropogenic environmental degradation.

Key words*: urbanization, carbon emission, ecological modernization, energy consumption, economic expansion, human ecology, political economy*

JEL Codes: *C01, O31, 032, Q4, Q55, Q18, R21*

Acknowledgement

The authors are grateful to their parent institute which provided them the infrastructural benefit of conducting the research work. The authors are also thankful to the audience and eminent researchers of Nanyang Technological University, Singapore and other research forums for providing their valuable suggestions during the East Asian Association of Environmental and Resource Economics, Annual Congress, 2017.

Zareena Begum Irfan
Divya Jain
Satarupa Rakshit
Ashwin Ram

INTRODUCTION

Earth's global surface temperature is warming at a steady rate. It has been rising for 11 years now between 1995 and 2006 and continues to rise. Global warming is caused largely by the rising concentration of GHGs (principally CO_2, CH_4 and N_2O) in the earth's atmosphere, which helps trap excess heat. The main reason behind this are the human driven increase in the greenhouse gas emissions particularly carbon dioxide which has posed a greatest challenge to climate change problem. In its Fourth Assessment Report, the IPCC characterized climate change as "any change in climate over time, whether due to natural variability or as a result of human activity" **(IPCC, 2007, 2013, 2014)**. Households remain one of the most significant contributors to the climate change issue with some of the member states having thrice or more emission footprint than the other states. Goods and services consumed by humans induce pressures on the food and resources needed to support human life. Moreover, building cities and constructing roads remove a similar amount of bio productive land area. Carbon footprint also explains the environmental impacts of human activities. The definition of carbon footprint is the total CO_2 emitted directly or indirectly by a certain activity or the accumulation of CO_2 during a product life cycle.

There is a big difference in world's per capita energy consumption. The major difference is observed in the patterns of energy consumption between developed and developing countries. The developing nations like India and China are among the poor countries seeking to develop its resources. Rapid economic expansion has lead India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Household sector is one of the largest users of energy in India, accounting for about 30 per cent of final energy consumption

(excluding energy used for transport) reflecting the importance of that sector in total national energy scenario **(Reddy, 2003)**. The pattern of household energy consumption represents the status of welfare as well as the stage of economic development.

As the different economies develop, they consume higher magnitude of energy and there is a rise in cleaner options too. Household energy consumption is expected to increase in future along with growth in economy and rise in per capita incomes. The projected increases in household energy consumption are expected to result from changes in lifestyles.

Household income in India has increased considerably in line with economic growth over the last decades. The ministry of statistics and programme implementation (MOSPI) reports that urban wages have been rising by 17.38 % between 2000 and 2005.In line with wages also household expenditure has been rising especially in the urban areas were richer households are located. We expect a large share of households to pass the critical income level of 2 dollars per day and we expect that carbon emissions from Indian households will account for a significant share of global greenhouse gas emissions (GHG) in the future. The rise in carbon emissions is correlated with increasing direct and indirect energy requirements of households. Energy consumption and carbon footprints vary with what and how households consume. We can account for the differences also on the basis of rural and urban areas. Rural households spend their income on more energy intensive commodities than a person from a metropolitan area on average. The motivation behind this was to characterize household consumption patterns with respect to their environmental implications and hereby search for evidence on the Environmental Kuznets Curve (EKC). The findings support previous research in the EKC energy literature, as energy requirements increase monotonically with household expenditure with no turning point observed **(Stern, 2004)**.

There is still lack of knowledge on how energy consumption relates to the demographic and economic characteristics of the household **(Brounen *et. al.*, 2012),** on the relative importance of these characteristics, and whether changes in household's socio-economic circumstances translate in changes in energy consumption. The literature has analyzed how various individual, household and housing characteristics correlate with environmental impacts, however measured **(Buchs and Schnepf, 2013b; Buchs *et. al.*, 2011; Tukker *et. al.*, 2010).** Many studies have used input output analysis along with household consumption expenditure data in India.

Only few studies use multivariate regressions to analyze the relative importance of the various socio-economic factors, and most of them use cross-section data. This means that they cannot give us any indication of what changes in household circumstances may have an impact on energy consumption.

The objective of this paper was to estimate the impact of anthropogenic activities particularly the household consumption expenditure undertaken for both indoor and outdoor use on their contribution to the overall emissions. The aim was to identify which household characteristics and which changes in these characteristics have the largest impact on energy expenditures. Such knowledge is necessary to be able to design more effective policies to reduce the carbon footprint of a country.

METHODOLOGY

Human dimensions of climate change phenomenon have become the widely researched subject. The main domains which are included here are the anthropogenic drivers of climate change, the effects of climate change on ecosystems, mitigation or efforts to curb the emissions of greenhouse gases and how do we adapt to the impacts of climate change.

Three theoretical perspectives have been considered here include ecological modernization (EM), political economy (PE) and Human Ecology (HE). Ecological perspective is seen as the ecological restructuring of processes of production and consumption in modern societies due to environmental considerations. The reason is modernization will lead to greater concern for environmental problems among experts and this will spur the institutions to take steps to curb environmental problems. The aspect of technological innovation is considered to be an important factor underlying EM perspective **(Spaargaren and Mol, 2009; Foster *et. al.*, 2010)**. It focuses on the EKC phenomenon as discussed above also that first environmental impacts increase in the early stages of development and falls once the nation reaches the aggregate level of affluence.

This perspective stands in contrast with the political economy perspective which says that rising level of affluence will lead to increasing consumption and thus rising environmental impacts. Thus, the rising portion of EKC is in line with the PE and the inverted U shaped curve supports EM.

Human ecology researchers consider humans as part of the ecosystem. Thus, despite their ingenuity and culture, humans are not exempt from ecological constraints **(Catton and Dunlap, 1980; Dunlap, 1980, 1982).** The HE perspective recognizes that population characteristics (size, rate of growth, density, age structure) and affluence are important drivers of anthropogenic environmental impacts. The question addressed here is whether the biophysical characteristics play a role in influencing anthropogenic environmental impacts. We apply the HE perspective to examine the impacts of household-level demographic characteristics and affluence on residential CO_2 emissions.

In this study, household data has been extracted from India Human Development Survey- II (IHDS – II), 2011- 12 which is a cross

sectional survey conducted by ICPSR 36151. Only IHDS survey variables have been selected here which show the household level consumption patterns depicting emission factors. Any other source which includes household characteristics at state level has not been taken for the present study. In order to see the impact of household characteristics on indoor and outdoor household expenditure, we run the following two multiple regressions-

Regression 1-

Here the dependent variable includes the expenditure on consumption of LPG, kerosene, coal, household fuel and household electricity.

$$E_1 = \beta_1 + \beta_2 X_i + \beta_3 I_i + \beta_4 E_i + \beta_5 FE_i + \beta_6 D_{1i} + \beta_7 D_{2i} + \beta_8 D_{3i} + \beta_9 D_{4i} + \beta_{10} D_{5i} + \beta_{11} D_{6i} + \beta_{12} D_{7i} + \beta_{13} D_{8i} + \beta_{14} D_{9i} + \beta_{15} D_{10i} + \beta_{16} D_{11i}$$

E_1 = Indoor Expenditure done by the household

X_I = Total consumption expenditure

I_i = Income

E_i = Education of head of household

FE_i = Female education

D_{1i}= Religion for i = 1,2,3,4, 5

D_{2i}= Hours of access to electricity

For i = 0 if D_{2i}= 0

= 1 If 0 < D_{2i} < 6

= 2 if 5 < D_{2i} < 11

= 3 if 10 < D_{2i} < 16

= 4 if 15 < D_{2i} < 20

= 5 if 20 < D_{2i} < 25

D_{3i}= Hours of burning stove for i =0, 1, 2 …. 8…16

D_{4i}= Years in place for i = 1 …. 49

D_{5i} = 1 for household owns a refrigerator
0 if otherwise
D_{6i}= 1 if household owns a electric fan
0, otherwise
D_{7i} = 1 if household owns a generator set
0, otherwise
D_{8i} = 1 if household owns a air conditioner
0, otherwise
D_{9i} = 1 if household owns microwave oven
0, otherwise
D_{10i} = 1 if the household has window in the cooking area
0 if otherwise
D_{11i} = cooking place in the household if i = 1, 2, 3

Regression 2 –
Dependent Variable- Household Expenditure (Indoor) It has been calculated by adding together the expenditure on the purchase of personal transport equipment, spending on public transportation like bus, auto, plane and Diesel, petrol and CNG maintenance.

$$E_2 = \beta_1 + \beta_2 X_i + \beta_3 I_i + \beta_4 E_i + \beta_5 FE_i + \beta_6 D_{1i} + \beta_7 D_{2i} + \beta_8 D_{3i} + \beta_9 D_{4i} + \beta_{10} D_{5i} + \beta_{11} D_{6i}$$

Here all the variables remain the same except for
E_2 = Household outdoor expenditure
D_{5i} = 1 if household owns a car
0 if otherwise
D_{6i} = 1 if household owns a motorcycle
0 if otherwise

Independent Variables:

Affluence-

In our model, we have considered household income and household consumption expenditure under affluence. Affluence indicates the household's ability to spend which is an important component of its income. The first indicator of affluence is **household income**. Household income is analogous to GDP per capita, often used as a measure of affluence in cross-national analysis of anthropogenic environmental impacts. The EM perspective suggests income may have an inverted U-shaped relationship with CO2 emission at the national level, and suggests we should expect this type of relationship at the individual or household level as well: Expenditure incurred both indoor and outdoor should rise giving rise to CO2 emissions as income goes up until a turning point is reached, after which they should decline with further increases in income.

The second indicator which is **household consumption expenditure** which shows the total value of goods and services consumed. This should have a positive impact on the indoor and outdoor household expenditure adding to the higher anthropogenic impacts of carbon dioxide emissions.

Biophysical Characteristics-

Here the indicators used for biophysical characteristics are whether the household has window in the cooking area and where the cooking is done in the household. Dummies are assigned for both the indicators.

D_1 = 1 for household has window in the cooking area

= 0, otherwise

D_2 = 1 if cooking is done in the kitchen

D_3 = 2 if cooking is done in the living area

Household Demographics-

The human ecology perspective of climate change regards the population and its characteristics as important drivers of anthropogenic impacts. Under household demographics, we consider firstly years in place taken to be continuous variable. This is expected to have a positive impact on the household expenditure resulting in a rise in the amount of carbon dioxide emissions.

The second indicator pertains to the hours of access to electricity. This will certainly increase the household expenditure due to more energy consumption resulting in residential carbon dioxide emissions.

The number of hours used by the household for burning stove (cooking, heating water, and making tea) is expected to be positively related to indoor carbon dioxide emissions. With the increase in the number of hours of burning stove leads to increase in the emissions.

Whether the household owns a car or motorcycle as a part of its personal transport equipment adds to the outdoor emissions due to the anthropogenic activity. Therefore, as taken in every case dummy is assigned to the two variables.

Control Variables-

We control for the effects of the variables which are not expected to directly influence the dependent variable but have an impact on it in some way or the other. Education of head of the household and the female education impact the household emissions both indoor and outdoor. More educated the head of the family or the more literate the female in the household is, it is expected that they will take the necessary measures that will decrease the emissions in terms of using energy efficient technology.

One more variable considered here is religion. The relevance of this variable to affect the household indoor and outdoor expenditure and thus emissions is highly questionable. It is expected that people belonging to different religions behave differently when undertaking their expenditures which is not certainly true.

Technological Innovations-

Electric fan, refrigerator, microwave, air conditioner, generator set are purchased by households or not. Dummies are assigned to the five different categories. They form an important part of ecological perspective which says that innovations will decrease the amount of emissions with the effect being negative. Thus, the owning capacity tells us about their effect on the carbon emissions.

Descriptive statistics for all the variables is analyzed in **Table 1.**

Table 1: Descriptive Statistics of Dependent and Independent Variables

	MEAN	STANDARD DEVIATION	RANGE	
			MIN	MAX
Dependent Variable 1.Household Expenditure(INDOOR)	1434.343	2180.567	90	89558
2.HOUSEHOLD Expenditure(OUTDOOR)	2274.377	16616.32	0	1202400
Technological Innovations: Whether household owns-				
1..Electric Fan				
2. Fridge / Refrigerator	.7543237	.4304927	0	1
3. Generator set	.2750947	.4465674	0	1
4. Microwave Oven	.0181235	.1333997	0	1
5. Air conditioner	.0167818	.1284545	0	1
	.0206521	.1422185	0	1

	MEAN	STANDARD DEVIATION	RANGE	
			MIN	MAX
Affluence:				
1.Household Consumption Expenditure	117484.6	120048.9	180	4080760
2.Household Income	126611.2	216516.4	-1037040	1.14e+07
Household Demographics:				
1.Years in place (1-46)	77.29898	25.77968	0	90
2.Owning of vehicles(Yes=1)	.0480045	.2137783	0	1
a. Car	.2864326	.4520995	0	1
b. Motorcycle	.6403651	.4798992	0	1
3.hours of access to electricity				
Biophysical Characteristics:				
1) Having a window or vent in cooking area?	.7518739	.4319321	0	1
2)Cooking place in the house a. Separate Kitcher	.584798 .2365618	.4927628 4249761	0 0	1 1
b. Living area				
Control Variables:				
1. Education of head of household	.221024	.4149422	0	1
2. Female education				
a.1	.5389963	.4984831	0	1
b.3	.0731365	.2603636	0	1
c.4	.0196707	.1388676	0	1
3. Religion				
a.2	.1208891	.3260024	0	1
b.3	.0232129	.1505809	0	1
c.4	.0236067	.1518223	0	1

Data Interpretation and Discussion

The graphical analysis has been shown below by calculating the average for different states as well for India at aggregate level. States such as Mizoram, Daman and Dui, Dadar and Nagar Haveli, Sikkim, Nagaland,

Manipur, Nagaland, Tripura, Meghalaya, Pondicherry and Manipur have been excluded from the study due to some missing observations for various variables in order to avoid ambiguous results.

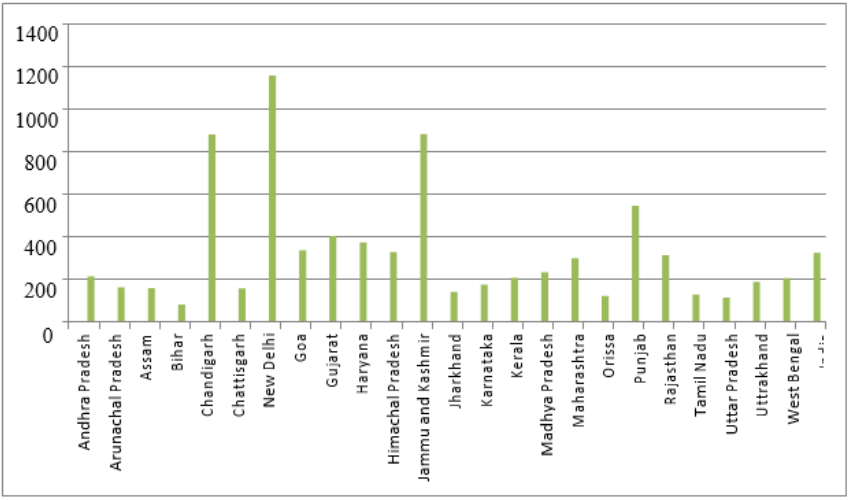

Figure 1: Total Household expenditure on Electricity during past one month

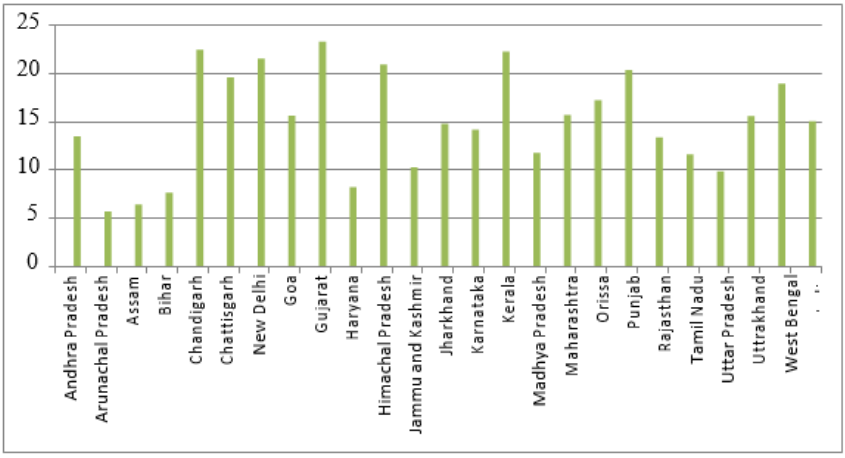

Figure 2: Number of hours household has access to electricity per day

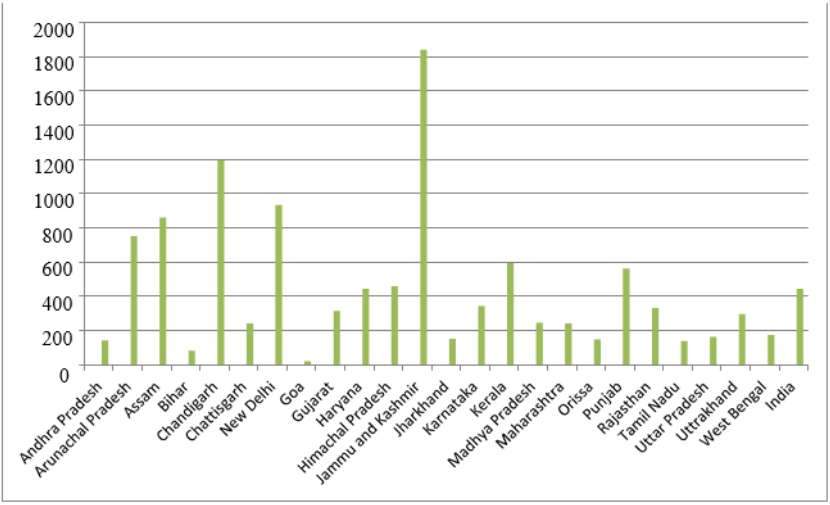

Figure 3: Household Expenditure on purchase of cooking and housing appliances

The above three **Figures 1-3** can be interpreted as follows-

New Delhi spends the highest on household electricity compared to other states. Jammu and Kashmir, Chandigarh, New Delhi and Punjab spend more than the Indian average on electricity. If we compare this with number of hours household has access to electricity we can observe that in spite of incurring significant expenditure on electricity, Jammu and Kashmir has less number of electricity access hours. The main reason for this could be climatic conditions prevailing there which in turn affect their hours available for electricity use.

The same happens when the expenditures on the cooking and household appliances is taken into account. Average household expenditure on electricity for Jammu and Kashmir, New Delhi and Chandigarh is positively related to their expenses on cooking and household appliances which includes electric fan, AC, washing machine, refrigerator etc.

TOTAL EXPENDITURE ON DIESEL, PETROL AND DIESEL MAINTAINENCE DURING PAST ONE MONTH

Figure 4 and **5** show that almost all the states spend more than the Indian average on the purchase of personal transport equipment with Himachal Pradesh and Punjab spending the highest adding the most. Chandigarh, Himachal Pradesh and Punjab spend less on Public transport modes compared to private modes adding to more energy expenditures and thus more emissions. In contrast to the above case, New Delhi spends more on public modes of transport versus private mode. This depicts higher expenditure on public transportation for India as a whole. Thus, less are the outdoor emissions due to household activities.

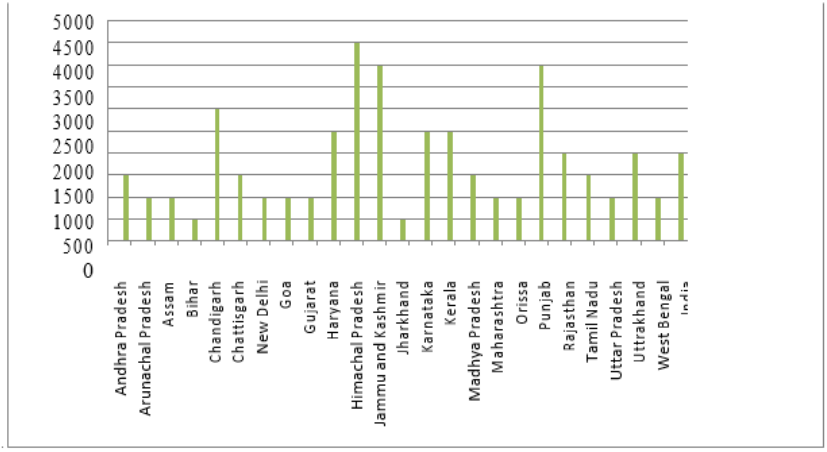

Figure 4: Household consumption expenditure on personal transport equipment during past one year.

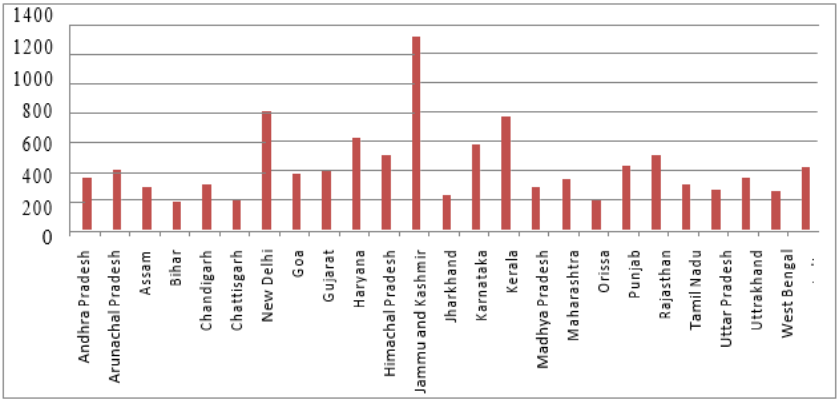

Figure 5- Total Household Expenditure on Public Transportation During Past One Month

In **Figure 6**, we can see that analogous to their expenditure on purchase of personal transport equipment the same states that is Chandigarh, Punjab and Jammu and Kashmir spend the highest on diesel and petrol maintenance.

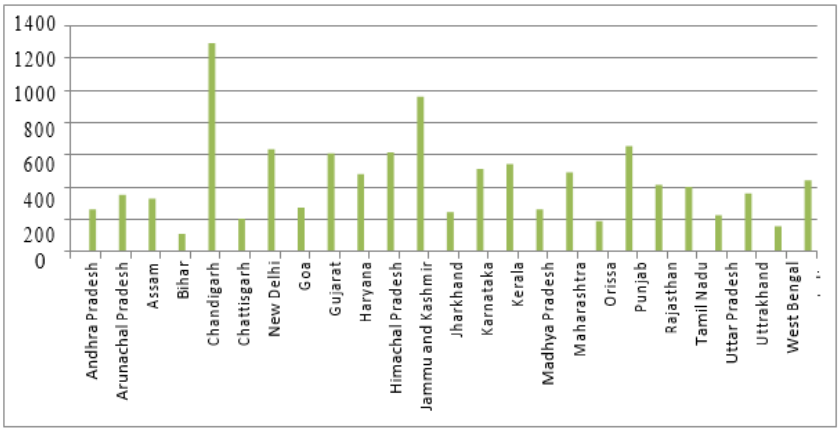

Figure-6 Total expenditure on diesel, petrol and diesel maintenance during past one month

Figure 7 does not explicitly show difference in the expenditures done by households in different regions in India to make possible comparisons.

Apart from a few states, almost all the states spend more than Indian average on the purchase of different types of household fuel.

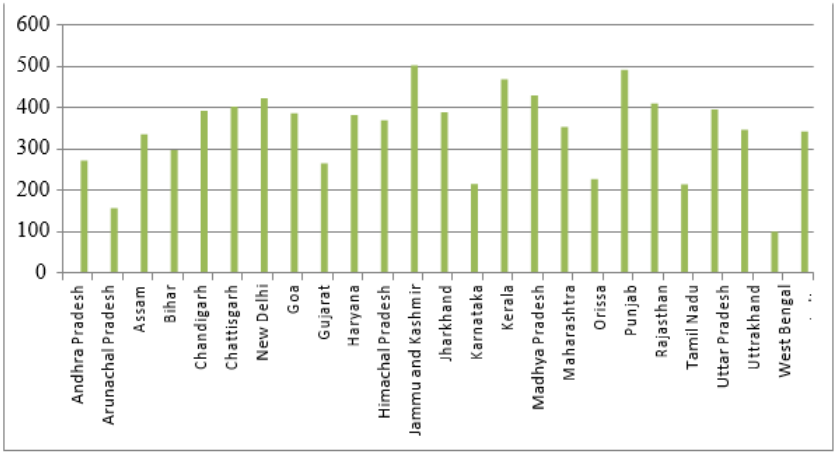

Figure 7-Value of household fuel that the household consumed during past one month

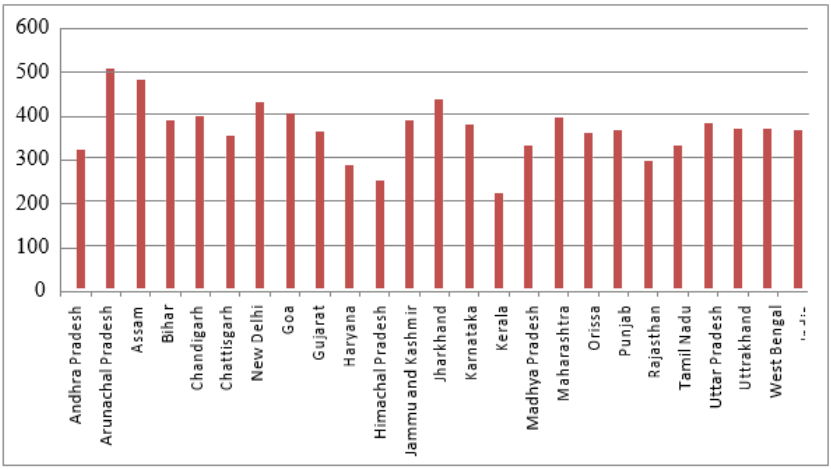

Figure 8- Household expenditure on the purchase of LPG

With most of the state spending more than the Indian average on the purchase of LPG leads to its higher expenditure and thus, more household indoor emissions **(Figure 8).**

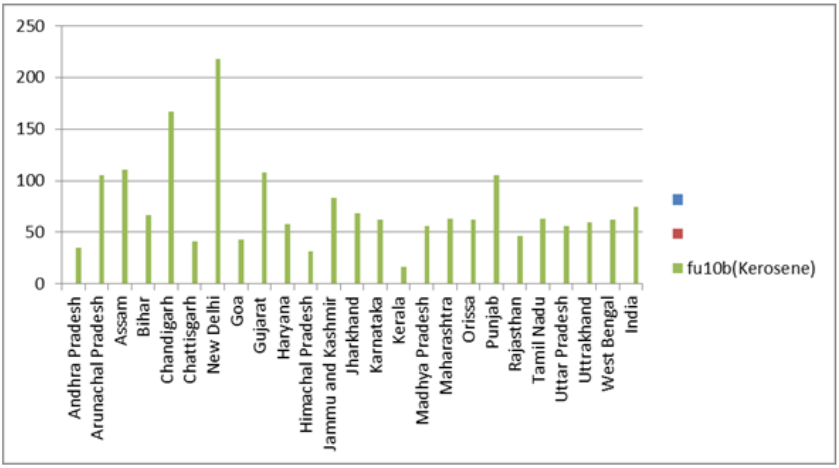

Figure 9- Household expenditure on the purchase of kerosene

Expenditure done on kerosene is highest by New Delhi as per the **Figure 9**. New Delhi, Punjab and Chandigarh spend more than the Indian average which shows higher Indian average expenditure on kerosene adding to the indoor emissions.

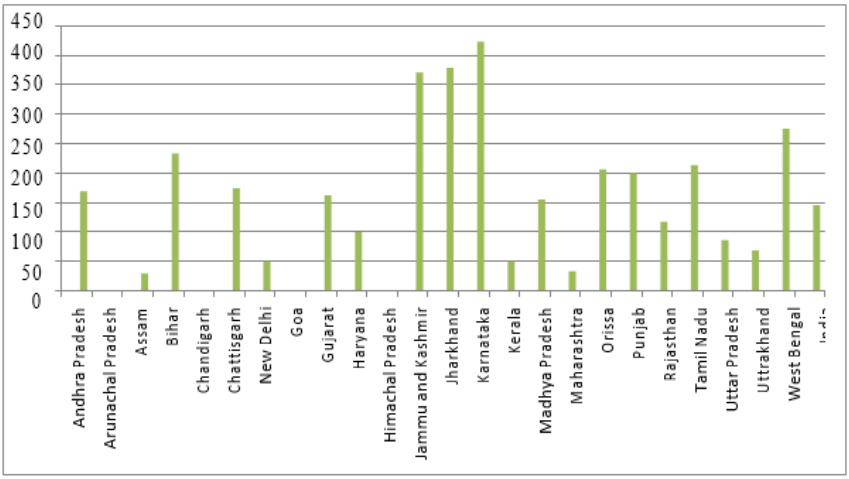

Figure 10- Household expenditure on the purchase of coal

Coal is either collected from the nearby village or some other place or it is purchased. Jammu and Kashmir, Jharkhand and Karnataka incur high amount of expenditures on the purchase of coal **(Figure 10).** We will look at the next four figures to see the time taken by the households in different States to collect fuel.

From the four figures (**Figure 11-14),** we can see that Chhattisgarh spends highest time in collecting fuel. This applies to both boys and girls under 15 years of age and adult women and adult men more than 15 years of age. The reason behind this could be that Chhattisgarh being a backward region tops the list of states in terms of its poverty rate. So, people over there spend more amount of time in collecting fuel rather than purchasing it. The economic condition of the households may not be financially sound for them to purchase fuel.

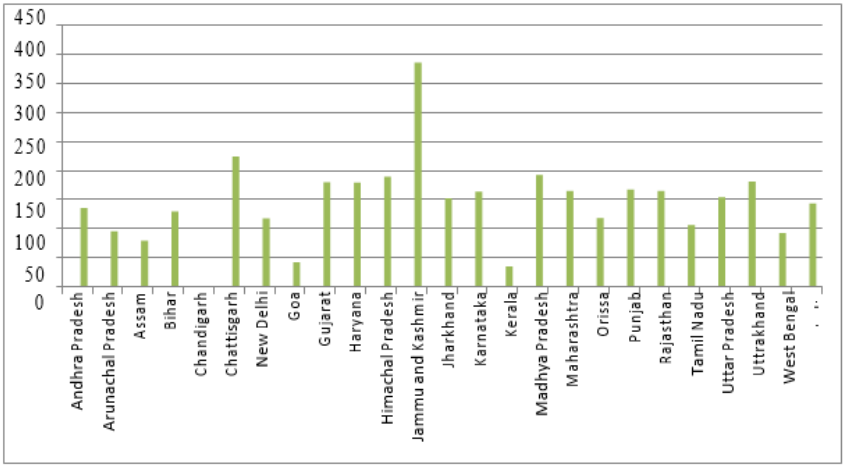

Figure 11-Time taken by adult women older than 15 years of age on collecting fuel

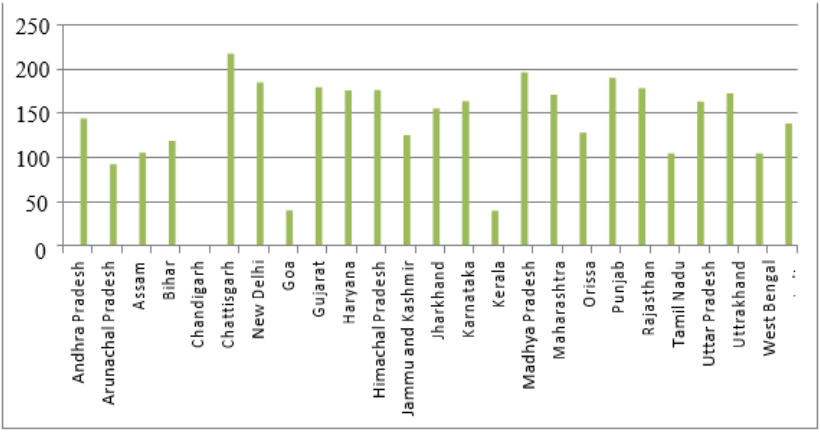

Figure 12-Time taken by adult men more than 15 years of age spend time in collecting fuel

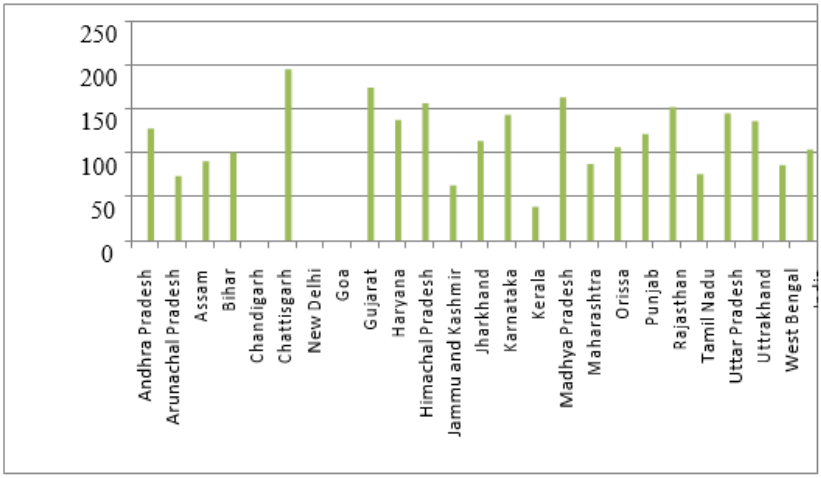

Figure 13-Time taken by girls under 15 years of age in collecting fuel

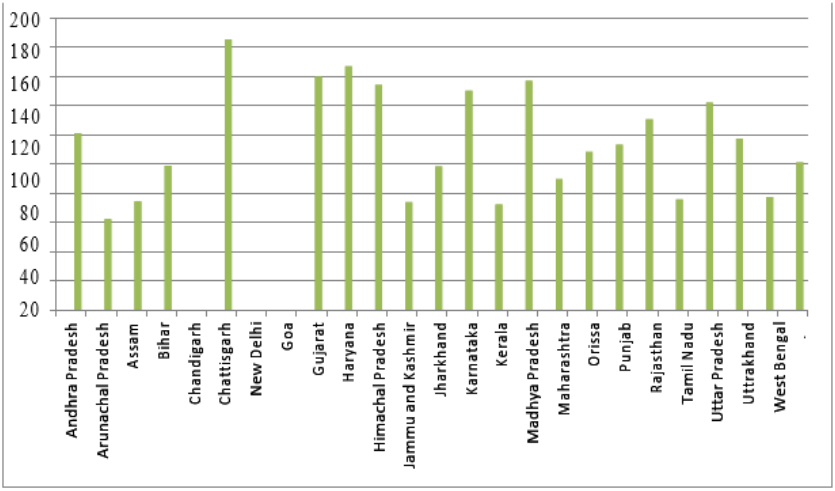

Figure 14-Time taken by boys under 15 years of age in collecting fuel

RESULTS AND DISCUSSION

Regression results from the two regression equations stated previously are discussed here. Similar to the graphical interpretation, here also the various states have not been taken into consideration.

From the first regression, we obtain that the R square value shows that 14.22 % of the variation in the indoor expenditure is explained by the explanatory variables such as income, owning capacity of household, hours of access to electricity and hours of burning stove or chulha. The R square value obtained above is pretty good for a cross sectional surveys like this.

Education of the head of the household given by headedu has insignificant p value for the both the dummies generated for the three categories. Cototal ie total consumption expenditure for all the purposes has p value as 0.000 which is highly significant and seems to be

positively related to the indoor expenditure. When the total household consumption expenditure increases by 1 unit, the increase in the household indoor expenditure is by 0.0047 units.

The variables such as income and years in place have p values greater than 0.1 which depicts their insignificant effects on the indoor expenditure. Biophysical characteristics explained by the cooking place in the house and whether the household has a window or vent in the cooking area have insignificant p values.

Hours of burning stove or chulha has a positive effect on the indoor expenditure contributing to higher indoor emissions. This is supported in the above results as their p values turns out to be significant. With the increase in the number of burning hours of stove from 1-8 hours by 1 unit, the indoor emissions rise due to the rise in the indoor expenditure from 167.07 to 673.27.

Female education and religion do not have a significant effect on the household indoor expenditure as the null hypothesis is accepted at 10% level of significance due to their p values greater than 0.1.

Number of hours the household has access to electricity has p value 0.14 which is slightly greater than 0.1. Hence we can say that the null hypothesis for such a variable can be rejected to show its significant effect on the indoor expenditure and thus emissions. The increase in the number of hours the electricity access by 1 unit leads to increase in the indoor expenditure by 89.92 units. This has a overall effect on rising household indoor emissions.

Owning capacity of households in India for indoor use is shown by whether the household owns a generator set (cg6), refrigerator (cg18), electric fan (cg13), microwave (cg27), air conditioner (cg22). For all the variables, p value is significant except for cg6. cg13 which shows whether the household owns a electric fan or not. The average

expenditure when the household has a electric fan is greater by 244.79 units as compared to the base category. cg18 which holds for refrigerator shows that the average expenditure for the household on refrigerator is higher by 324.544 units when compared with the benchmark category. Similar interpretation holds for cg27 as the average expenditure on microwave oven is more by 478.98 units. The average expenditure incurred by the household when it owns a refrigerator is greater by 891.38 units as compared to when it does not.

On examining the p values shows us the significance for each of the variables. At 10 % level of significance, the p value ie the probability of committing type I error shows that if $p > 0.1$, then we accept the null hypothesis whereas if $p < 0.1$ we reject null hypothesis. We see that almost all the variables are significant over here as their p values are turning out to be less than 0.1.

R square for this regression comes out to be 11% which means that 11% of the variation in the expenditure is explained by the all the independent variable including income, years in place, whether the household owns motor cycle or car.

Years in place represented by id15 are highly significant as represented by its p value and has a positive relationship with outdoor expenditure. If number of years that a household has stayed in a place increases by 1 unit, their expenditure increases by 14.73 units.

P value of Total consumption expenditure (cototal) is given by 0.00 is significant at 10 % level of significance. It is as expected to be positively related with the household expenditure. If the consumption expenditure increases by 1 unit, then the outdoor expenditure increases by 0.04 units. As the income of the household increases, the expenditure decreases by 0.011 units. The p value for the income variable also turns out to be significant.

Education of head of family given by headedu is being divided into three categories. For three categories we generate two dummies for 1 and 2. 3 is taken as the benchmark category. Higher the education of head of the family, the less will be the household outdoor expenditure for the activities contributing to the emissions. P value for the variable turns out to be insignificant.

This is taken as a part of the control variable which may or may not have an effect on the expenditure undertaken.

Cg8 and cg21 explain whether the household owns motorcycle or car for which we get significant p values as 0.00. The average expenditure when the household owns the motorcycle is more by 1666.554 as compared to when the household does not own a motorcycle. Similarly, the average outdoor expenditure when the household owns a car is more by 5885.127 as compared to the base category. For the Female education also, the p value is rejected at 10 % level of significance as it is less than 10% level of significance. More the females are educated in the household, the less will be expenditure incurred by them on the activities contributing to emissions. There appears to be a negative relationship between female education and expenditure incurred for outdoor purposes. If the female education increases by 1 unit, expenditure falls by 527.944.

Religion explained by three dummies. The base category belongs to the people who are Hindu. P value for the people who are Muslim is significant and expenditure for them is lower by 663.04 as compared to the outdoor expenditure by Hindus. P values for the other two dummies are not significant as we accept the null hypothesis.

The characteristic such as whether the household has window in the cooking area or where cooking is done in the household have their p

values as significant. The average expenditure done by the household for outdoor purposes if it has window in the cooking area is less than the base category by 592.73 units. The differences between the states with almost all displaying significant p values at 10% level of significance. We see the behavior of variables for India as a whole rather than for different states separately.

Summary of the Findings:

We summarize our findings in the form of a table in relation to the theories evaluated- EM, PE, HE.

Table 2 provides the information on the relationship between each of the independent variables and dependent variables of household expenditure. It also provides information on the theory (theories) supported by clarifying remarks for each of them. When we analyse EM perspective for Indian households we find that the aspect of technological innovations is not in line with the theory as it has a positive effect on expenditure and thus increasing emissions.

They support PE perspective due to the plus sign which prevails. Household income has a negative effect on the outdoor expenditure and thus follows the point stated by EM theorists regarding the EKC curve.

Household demographics play a key role in driving anthropogenic environmental impacts and both biophysical characteristics combined do not give a clear indication of their impact on the dependent variable. Thus, HE perspective shows that household demographic characteristics are important drivers to anthropogenic carbon emissions.

Table 4: Relationship between each of the independent variables and dependent variables of household expenditure

VARIABLE	DIRECTION OF EFFECT		THEORY SUPPORTED			REMARKS/ COMMENTS
	HOUSEHOLD EXPENDITURE (INDOOR)	HOUSEHOLD EXOENDITURE (OUTDOOR)	EM	PE	HE	
TECHNOLOGICAL INNOVATIONS						
Whether household owns-						
1..Electric Fan	+	N		#		(+)PE supported
2. Fridge / Refrigerator	+	S		#		(+)PE supported
		N		#		
3. Generator set	NS	S				(+)PE supported
4. Microwave Oven	+			#		(+)PE supported
5. Air conditioner	+	N		#		(+)PE supported
AFFLUENCE						(-)EM supported
1.Household Consumption Expenditure	+	+		##	##	(+) PE, HE supported
						(-)EM supported
2.Household	NS	-	#			(+) PE, HE supported
HOUSEHOLD DEMOGRAPHICS						
1.Years in place	NS	+			#	(+) HE supported
2.Owning of vehicles(Yes=1)						
a. Car						(+) HE supported
b. Motorcycle	N	+			#	
3.hours of access to electricity	S	+			#	
4. Hours Burning stove	N	N			#	(-) HE supported
	S	S				
	+				##	
BIOPHYSICAL CHARACTERSTICS						
1) Having a window or vent in cooking area?	NS	-			#	(-) HE supported
2)Cooking place in the house	NS	+			#	(+)HE supported

NOTE: EM (Ecological Modernization), HE (Human Ecology), PE (Political Economy) NS= Not significant,
(-) Negative Significant Relationship, (+) Positive Significant Relationship,
= Theory or Theories supported by each statistically significant finding,

For dummy- coded variables with multiple categories (home insulation and type of glass in windows) we present a summary for
the variable as a whole rather than for each dummy-coded category, where a significant effect in at least one category is noted.

EM does not necessarily predict a monotonically negative relationship, but it suggests that the relationship should become negative at higher levels of affluence.

CONCLUSIONS

The issue of climate change caused by the residential anthropogenic drivers such as household demographics, biophysical characteristics, affluence and technological innovations has been discussed in the present paper. The diagrammatic representation for the expenditure patterns reveals three main points from the survey for the year 2011-12.

- Households in Jammu and Kashmir spend the highest on electricity and on the purchase of cooking and household appliances contributing to the highest energy expenditures which poses higher indoor emission burden on India.

- In comparing the expenditure on the private means of transportation with public modes, we observe that New Delhi spends more on the use of public modes and households in Chandigarh spend more on private mode. Thus, New Delhi adds less and Chandigarh adds to more outdoor emissions as a part of India's GHG emissions trajectory.

- Time taken by females and males in collection of fuel is highest by Chhattisgarh due to the suitable reasons such as backwardness of the region which stands in contrast with other places in India.

The regression results show somewhat the significance of the various variables as well as their impact on the two dependent variables from the two regressions by looking at their respective p values and the

relationship shown by the sign respectively. Main results come out to be as follows-

- Technological innovations such as owning of electric fan, refrigerator, microwave oven, air conditioner which have been considered here have significant positive effects on indoor expenditure except for generator set which has insignificant effect. This stands in line with the PE theory but contradicts EM perspective which regards technological innovation as a holy grail of human efforts to mitigate the adverse environmental consequences of modern economic growth.

- Affluent indicators such as household consumption expenditure shows positive effect on both the expenditures which confirms to the PE theorists who say that green technologies produce environmental benefits but they are counteracted by affluence based increased consumption. Household income has a negative effect on the expenditure indicating that as India is on the path to development the environmental degradation has started to decline with the rise in income. Since, the analysis is done only for one period over here we cannot make definite conclusions.

- Household demographics and biophysical characteristics also play an important part in explaining issue of anthropogenic environmental degradation. Most of the household demographic factors positively affect the expenses in a positive way. On the other hand, biophysical characteristics do not give a clear indication of their effects on the carbon dioxide emissions .Hence; HE theory shows that affluence and household demographics drive anthropogenic carbon dioxide emissions.

It is crucial to recognize the expenditures on energy consumption and emission factors are to a great extent influenced by the factors that are beyond the control of humans such as development trends regarding urban forms, housing density, type and infrastructure. The policies which affect urbanization and urban development play important roles in

determining household energy use as well as some of political economic factors. These issues which are extremely essential have not been taken into account while carrying out the study. Moreover, we could not account for the difference between the rural and urban areas within India which could have made our analysis much simpler. This was not possible due to less information available for all the states and different sources did not permit us to combine them into one dataset as the analysis was done for 2011-2012. It can be seen that many studies which have been conducted earlier have considered set of predictors which was not enough. But in our study we have used household data this makes it an expanding literature to anthropogenic environmental degradation.

REFERENCES

Catton, Jr. W and Dunlap, R.E. (1980), **"**A New Ecological Paradigm for Post-Exuberant Sociology*", American Behavioral Scientist,* 24,15-47.

Dunlap, R.E. (1980), "Paradigmatic Change in Social Science: from Human Exemptionalism to an Ecological Paradigm", *American Behavioral Scientist,* 24, 5-14.

Foster, J.B., B. Clark and R. York (2010), "The Ecological Rift: Capitalism's War on the Earth", *Monthly Review Press*, New York.

IPCC (Intergovernmental Panel on Climate Change) (2007), "An Assessment of the Intergovernmental Panel on Climate Change", *Climate Change 2007: Synthesis Report*

IPCC (2013), "Climate Change 2013: the Physical Science Basis" *Summary for Policymakers.*

IPCC (2014), "Climate Change Synthesis Report", *IPCC Fifth Assessment Synthesis Report.*

Reddy, S.B. (2003), "Overcoming the Energy Efficiency Gap in India's Residential Sector", *Energy Policy*, 31(11).

Spaargaren,G and Mol,A.P.J. (2009), "Sociology, Environment, and Modernity: Ecological Modernization as a Theory of Social Change", A.P.J. Mol, D.A. Sonnenfeld,G. Spaargaren(Eds.), *The Ecological Modernization Reader: Environmental Reform in Theory and Practice,* Routledge, London and New York (2009), 56-79.

Stern, I.D. (2004), "The Rise and Fall of the Environmental Kuznets Curve", *World Development*, 32, 1419-1439.

MSE Monographs

* Monograph 30/2014
Counting The Poor: Measurement And Other Issues
C. Rangarajan and S. Mahendra Dev

* Monograph 31/2015
Technology and Economy for National Development: Technology Leads to Nonlinear Growth
Dr. A. P. J. Abdul Kalam, Former President of India

* Monograph 32/2015
India and the International Financial System
Raghuram Rajan

* Monograph 33/2015
Fourteenth Finance Commission: Continuity, Change and Way Forward
Y.V. Reddy

* Monograph 34/2015
Farm Production Diversity, Household Dietary Diversity and Women's BMI: A Study of Rural Indian Farm Households
Brinda Viswanathan

* Monograph 35/2016
Valuation of Coastal and Marine Ecosystem Services in India: Macro Assessment
K. S. Kavi Kumar, Lavanya Ravikanth Anneboina, Ramachandra Bhatta, P. Naren, Megha Nath, Abhijit Sharan, Pranab Mukhopadhyay, Santadas Ghosh, Vanessa da Costa and Sulochana Pednekar

* Monograph 36/2017
Underlying Drivers of India's Potential Growth
C.Rangarajan and D.K. Srivastava

* Monograph 37/2018
India: The Need for Good Macro Policies *(4th Dr. Raja J. Chelliah Memorial Lecture)*
Ashok K. Lahiri

* Monograph 38/2018
Finances of Tamil Nadu Government
K R Shanmugam

* Monograph 39/2018
Growth Dynamics of Tamil Nadu Economy
K R Shanmugam

MSE Working Papers
Recent Issues

* Working Paper 160/2017
  An Alternative Argument of Green Solow Model in Developing Economy Context
  Santosh K. Sahu and Arjun Shatrunjay

* Working Paper 161/2017
  Technical Efficiency of Agricultural Production in India: Evidence from REDS Survey
  Santosh K. Sahu and Arjun Shatrunjay

* Working Paper 162/2017
  Does Weather Sensitivity of Rice Yield Vary Across Regions? Evidence from Eastern and Southern India
  Anubhab Pattanayak and K. S. Kavi Kumar

* Working Paper 163/2017
  Cost of Land Degradation in India
  P. Dayakar

* Working Paper 164/2017
  Microfinance and Women Empowerment- Empirical Evidence from the Indian States
  Saravanan and Devi Prasad DASH

* Working Paper 165/2017
  Financial Inclusion, Information and Communication Technology Diffusion and Economic Growth: A Panel Data Analysis
  Amrita Chatterjee and Nitigya Anand

* Working Paper 166/2017
  Task Force on Improving Employment Data - A Critique
  T.N. Srinivasan

* Working Paper 167/2017
  Predictors of Age-Specific Childhood Mortality in India
  G. Naline, Brinda Viswanathan

* Working Paper 168/2017
  Calendar Anomaly and the Degree of Market Inefficiency of Bitcoin
  S. Raja Sethu Durai, Sunil Paul

---

* Working papers are downloadable from MSE website http://www.mse.ac.in
$ Restricted circulation