Identification of latent structures in qualitative variables – Examples from Renewable Energy users of Nepal

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IASM Workshop - Harnessing the power of latent structure models and modern Big Data learning (23w5009)
10 - 15 December, 2023

Outline

1 Introduction

2 Material and Methods - Data

3 Materials and Methods - Methods

4 Result and Discussion

5 Conclusion

6 References

Table of Contents

1. Introduction
2. Material and Methods - Data
3. Materials and Methods - Methods
4. Result and Discussion
5. Conclusion
6. References

Nepal

Kathmandu University

Introduction - Some Facts about Nepal

- Nepal is a Himalayan country with agriculture based economy.
- Nepal's Energy needs are met by following sources
  - 80% needs are met by biomass
  - where 87.1% comes from fuel wood
- 7% comes from grid electricity
- Nepal Electricity Authority (NEA) provides grid electricity
- Alternative energy promotion center (AEPC) provides off grid electricity

Introduction - Some Facts about Nepal

- The per capita electricity consumption per year
  - 134 Kilo Watt Hour – Nepal
  - 23,000 Kilo Watt Hour – Norway
  - 733 Kilo Watt Hour – India
  - 4000 Kilo Watt Hour - China
- 5000 Giga Watt Hour of Electrical Energy is generated per year in Nepal
  - 33% is produced by Nepal Electricity Authority (NEA)
  - 33% is by Independent Power Producers Cooperation (IPCC)
  - 33% is imported from India

Introduction - Some Facts about Nepal (Hydro Power)

- Being a Himalayan country, Nepal has the capacity to generate 45000MW electricity through its water resources. It ranks 5 th in the world.
- NEA generates 480 MW of electricity mainly by 23 hydro powers owned mainly by NEA.
- There are 30,000 water mills currently operating in Nepal
- 50 hydro powers are built in private sector

Introduction - Some Facts about Nepal (Biogas)

- Government of Nepal promoted the construction of Biogas plants since 1974/75
- There are 3, 05, 147 Biogas plants in Nepal
- Cow dung in Nepal generates 15% of total energy.
- If it was not used in agriculture as a manure, it can produce 40% of total energy needed by the population

Motivation of this Study

- Direct benefits of the use of renewable energy are obvious.
- But there are several inherent benefits that are not directly visible to the eye.
- These inherent benefits are a result of interplay of several latent variables.
- These latent variables and their interrelationships play a significant role in the energy consumption dynamics.

Need of such data based studies in Nepal

- To do evidence based study of overall benefits of clean energy process
- To focus more on indirect cause, effect and benefits than direct attributable advantages, as they are obvious
- To conduct quantitative analysis of Categorical Data generated
- Countries in the developing world don't have a strong backbone of good quality official records
- Remote geographical locations, lack of awareness and lack of incentives have resulted in inefficient registration of vital events
- Such studies supplement official records

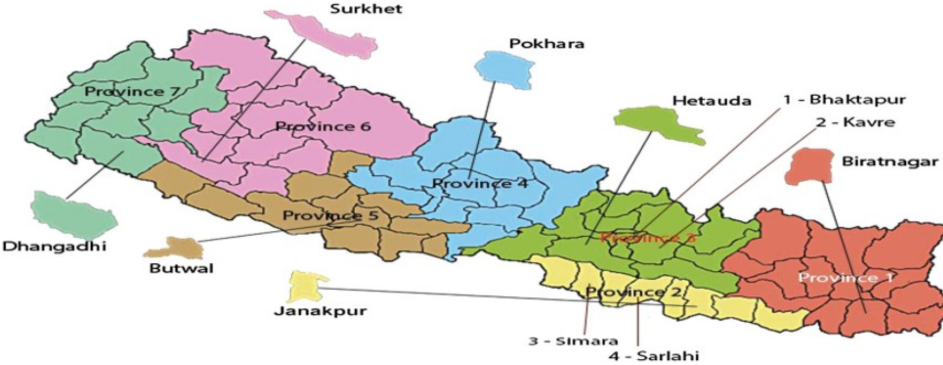
Table of Contents

1. Introduction
2. Material and Methods - Data
3. Materials and Methods - Methods
4. Result and Discussion
5. Conclusion
6. References

Data - Sample Surveys from Three Different Rural Settings

- Survey of 400 household of Biogas users
- Survey of 300 households of National Grid Electricity users

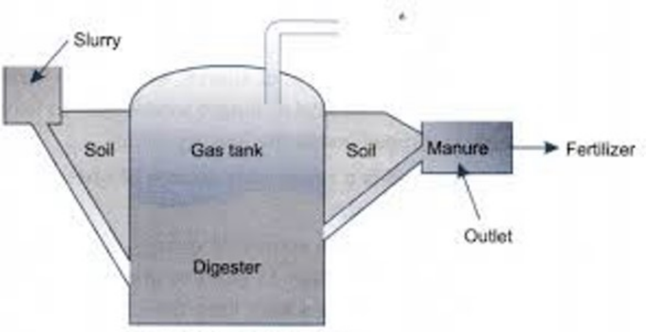
Survey Areas



Karamdanda Micro Hydro

Karamdanda Micro Hydro Water Kanal

Working of a Biogas



Fixed dome type biogas plant

Biogas constructed by Kathmandu University

Biogas constructed by Kathmandu University

Table of Contents

1. Introduction
2. Material and Methods - Data
3. Materials and Methods - Methods
4. Result and Discussion
5. Conclusion
6. References

Materials and Methods - Polytomous Models

It is when the response variable is not dichotomous, that is it has more than two options. This can be explained by Multinomial Probability Mass Function.
The IXJ contingency table

J I	1	2	3	...	j	Total
1	$n_{1,1}$	$n_{1,2}$	$n_{1,3}$	...	$n_{1,J}$	$n_{1.}$
2	$n_{2,1}$	$n_{2,2}$	$n_{2,3}$	...	$n_{2,J}$	$n_{2.}$
3	$n_{3,1}$	$n_{3,2}$	$n_{3,3}$	...	$n_{3,J}$	$n_{3.}$
⋮	...	...				
I	$n_{I,1}$	$n_{I,2}$	$n_{I,3}$	...	$n_{I,J}$	n$_{I.}$
Total	$n_{.1}$	$n_{.2}$	$n_{.3}$	...	$n_{.J}$	$n_{..}$

Here J is the independent variable and I is the dependent variable

Materials and Methods - Polytomous Models

From the contigency table, this probability table is obtained

$$\pi_{ij} = \frac{n_{ij}}{n_{..}}$$

J I	1	2	3	...	j
1	π_{11}	π_{12}	π_{13}	...	π_{1J}
2	π_{21}	π_{22}	π_{23}	...	π_{2J}
3	π_{31}	π_{32}	π_{33}	...	π_{3J}
$\vdots$	...	...			
I	π_{I1}	π_{I2}	π_{I3}	...	π_{IJ}

Materials and Methods - Methods

$$\ln \dot{\Pi}_j = \frac{1}{I}\sum_i ln\pi_{i|j}...(1)$$

where $i = 1, \ldots, I$ and $j = 1, \ldots, J$

$$\dot{\Pi}_j = (\prod_{i=1}^{I} \pi_{i|j})^{\frac{1}{I}}...(2)$$

Here, $\pi_{i|j} = \frac{n_{ij}}{n_{.j}}$ is the conditional probability when $I = i$ given $J = j$
$\dot{\Pi}_j$ is the geometric mean of $\pi_{i|j}$over all values of I

Materials and Methods - Methods

Further,

$$ln(\frac{\pi_{i|j}}{\dot{\Pi}_j}) = \mu_i + \alpha_{ij}...(3)$$

where $i = 1, \ldots, I$ and $j = 1, \ldots, J$
This set of IXJ linear equations to describe how the Multinomial probability is changing in different categories of the explanatory variable.
Some constraints on Equation (3) are the following.
$\sum_i \mu_i = 0$, $\forall j$ and $\sum_j \alpha_{ij} = 0\ \forall i$
The estimates may be obtained by solving I sets of J equations. From equation (3) we get,

$$ln(\pi_{\hat{i}|j}) - \frac{1}{I} * \sum_i ln(\pi_{\hat{i}|j}) = ln(n_{ij}) - \frac{1}{I} \sum_i ln(n_{ij}) = \mu_i + \alpha_{ij}$$

Materials and Methods - Odds Ratio

Odds ratio is defined as probability of some thing happening over it is not happening. So, when the response is dichotomous, that is in a 2X 2 contingency table odds ratio =

$$\frac{\pi_{1|j}}{\pi_{2|j}} = \frac{\pi_{1|j}}{1 - \pi_{1|j}} = \frac{\pi_{1j}}{\pi_{2j}}$$

$$\dot{\Pi}_j = (\pi_{1|j} * \pi_{2|j})^{\frac{1}{2}}$$

So, Equation (3) reduces to

$$ln(\frac{\pi_{1|j}}{1 - \pi_{1|j}}) = \mu + \alpha_j$$

Odds Ratio is

$$\frac{\pi_{1|j}}{1 - \pi_{1|j}} = e^{(\mu + \alpha_j)}$$

Table of Contents

1. Introduction
2. Material and Methods - Data
3. Materials and Methods - Methods
4. Result and Discussion
5. Conclusion
6. References

Result and Discussion - Hypotheses

- Main Hypothesis: There is dependence between the location and socio-economic status of the house on energy consumption dynamics.
- Hypothesis 1 : For household living within 15 minutes to the school the dependence on firewood is less (normal users)
- Hypothesis 2 : For household living within 15 minutes to the employer the dependence on firewood is less (normal users)
- Hypothesis 3 : Low socioeconomic status (indicated by the type of house) implies more time spent on the collection of firewood (normal users)
- Hypothesis 4 : Low socioeconomic status (indicated by the type of house) implies more kilograms of firewood consumed (normal users)
- Hypothesis 5 : Low socioeconomic status (indicated by the type of house) implies less liters of kerosene consumed (normal users)

Result and Discussion - Hypotheses

- Hypothesis 6 : Low socioeconomic status of Biogas owners (indicated by the type of house) implies more time spent on the collection of firewood before the installation of plant
- Hypothesis 7 : Low socioeconomic status of Biogas owners (indicated by the type of house) implies more time spent on the collection of firewood after the installation of plant
- Hypothesis 8 : Low socioeconomic status (indicated by type of house) implies more time saved after construction of Biogas plant
- Hypothesis 9 : Low socioeconomic status (indicated by type of house) implies more firewood saved after a switch over to Biogas plant for cooking
- Hypothesis 10 : More time spent on collection of firewood before the construction of Biogas plant implies "relatively" more time spent in after the construction of Biogas plant

Table 1: Details of categorical data

User/Sample size	Variable name	Values on ordinal scale	Frequency
Biogas	Time spent in the collection of firewood before		
(400 household)	No time spent	0	33
	<15 minutes	1	15
	15-30 minutes	2	21
	30-45 minutes	3	18
	45-60 minutes	4	53
	1 hour-2 hours	5	260
	Time spent in the collection of firewood after		
	No time spent	0	153
	<15 minutes	1	137
	15-30 minutes	2	67
	30-45 minutes	3	24
	45-60 minutes	4	7
	1 hour-2 hours	5	12
	Type of house		
	Concrete	1	166
	Tile/asbestos	2	17
	Modern light roof	3	77
	Mud house	4	140
	Amount of firewood saved after biogas		
	Up to 30 Kg	1	39
	30-50 Kg	2	115
	Above 50 Kg	3	246
	Time saved		
	No change	0	13
	Less than 60 minutes	1	132
	1 hour to 3 hours	2	195
	3-5 hours	3	23
	More than 5 hours	4	37
Normal	Time for the collection of firewood		
(300 household)	Not applicable	0	13
	<15 minutes	1	29
	15-30 minutes	2	176
	30-45 minutes	3	78
	45 min-1 hour	4	04
	Type of house		
	Concrete house	1	4
	Tiled/asbestos	2	89
	Modern light roof	3	185
	Mud house	4	22
	Employer within 15 minutes		
	Yes	1	17
	No	2	283
	School within 15 minutes		
	Yes	1	86
	No	2	214

User/Sample size	Adjective	Variable	Time taken (minutes)				
			No time	<15	15-30	30-45	45-60
Normal (300 households)	Time taken to collect firewood versus school within 15 min of home	School					
		μ_i (average)	-1.1492	-0.2133	2.0535	1.0074	-1.6985
		α_{i1} (yes)	-0.57495	0.4123	0.4121	-0.0924	0.6675
		α_{i2} (no)	0.57495	-0.4123	-0.4121	0.0924	-0.6675
	Time taken to collect firewood versus employer within 15 min of employer	Employer					
		μ_i (average)	-0.2925	0.001395	1.7588	0.1788	-1.6466
		α_{i1} (yes)	0.6918	0.00755	-0.0602	-0.8781	0.2541
		α_{i2} (no)	-0.6918	-0.00755	0.0602	0.8781	-0.2541
	Time taken to collect firewood versus type of house	Type of house					
		μi (average)	-0.3960	0.4999	1.3215	0.0785	-1.5037
		$\alpha i1$ (concrete house)	0.5922	0.7949	-1.8184	-0.5754	1.0068
		$\alpha i2$ (tiled/asbestos)	-0.5002	0.1474	0.657	0.8741	-1.1812
		$\alpha i3$(modern light roof)	-0.4367	-1.4867	0.5912	1.2204	0.1114
		$\alpha i4$ (mud house)	0.3417	0.5445	0.5701	-1.5191	0.06301
			Firewood used (kg/month)				
			0	100	200	300	
	Type of house versus amount of firewood used	Type of house					
		μi (average)	-1.5663	-1.0466	2.2235	0.389	
		$\alpha i1$ (concrete house)	0.8733	1.0466	-1.53	-0.389	
		$\alpha i2$ (tiled/asbestos)	-0.3207	-.14744	0.179	0.239	
		$\alpha i3$(modern light roof)	-0.6897	-1.2096	1.356	0.533	
		$\alpha i4$ (mud house)	0.1373	0.31045	-0.0156	-0.432	
			Kerosene used (liters/month)				
			0	1	2	3	
	Type of house versus amount of kerosene used	Type of house					
		μi (average)	2.03	-0.386	-0.28	1.364	
		$\alpha i1$ (concrete house)	0.471	-0.1341	-0.24	0.844	
		$\alpha i2$ (tiled/asbestos)	0.43	0.1374	0.619	-1.187	
		$\alpha i3$(modern light roof)	0.077	-0.506	+0.237	-0.819	
		$\alpha i4$ (mud house)	-0.036	0.51	-0.616	1.61	

User/Sample size	Adjective	Variable	Time taken (minutes)				
			No time	<15	15-30	30-45	45-60
			Time taken (minutes)				
			No time	<15	15-30	30-45	45-60
Biogas (400 households)	Type of house versus time spent in the collection of firewood before biogas installation	Type of house					
		μi (average)	-0.1115	-0.8868	-0.7948	-0.4581	0.6576
		αi1 (concrete house)	0.4212	0.3978	-0.09942	-0.63101	-0.51035
		αi2 (tiled/asbestos)	0.1896	0.2718	-0.51333	0.5237	1.030026
		αi3(modern light roof)	-0.169	0.0954	-0.40203	0.39731	-0.35033
		αi4 (mud house)	-0.4417	-0.765	1.01477	-0.29001	-0.16935
	Type of house versus time spent in the collection of firewood after biogas installation	Type of house					
		μi (average)	1.619992	1.239025	0.4277	-0.6344	-1.4128
		αi1 (concrete house)	-0.31207	-0.0346	-0.0118	0.5395	-0.697
		αi2 (tiled/asbestos)	0.680932	-0.4044	-0.6919	-0.3228	0.4556
		αi3(modern light roof)	-0.1788	0.3076	0.3567	-0.1216	0.2513
		αi4 (mud house)	-0.1899	0.1315	0.3468	-0.0952	-0.0099
			Time saved				
			30 min	1-3 h	3-5 h	>5 h	no time
	Type of house versus time saved after biogas installation	Type of house					
		μi (average)	0.821712	1.74324	-0.68261	-0.73179	-1.15056
		αi1 (concrete house)	-0.15683	-0.56319	0.083797	0.70352	-0.06729
		αi2 (tiled/asbestos)	-1.08606	0.700459	0.418257	-0.22571	0.19306
		αi3(modern light roof)	0.842625	0.315002	-0.3272	-0.97117	0.140748
		αi4 (mud house)	0.400269	-0.45227	-0.17485	0.493365	-0.26652
			Amount of firewood saved in (kg/month)				
			<=30 kg	30-50 kg	>50 kg		
	Type of house versus amount of firewood	Type of house					
		μi (average)	-1.0805	0.39897	0.68160		
		αi1 (concrete house)	-0.0997	-0.2355	0.3352		
		αi2 (tiled/asbestos)	-0.627	1.225	-0.598		
		αi3(modern light roof)	0.479	-0.541	0.0610		
		αi4 (mud house)	0.248	-0.449	0.202		

Table 3: Details of polytomous models (*continue*)

User/Sample size	Adjective	Variable	Time taken (minutes)					
			No time	<15	15-30	30-45	45-60	>60
Biogas (400 households)	Time spent after versus time spent in the collection of firewood before biogas installation	Time spent after biogas installation						
		μi (average)	-0.58287	-0.94764	-0.51339	-0.46169	0.286038	2.21955
		αi1 (no time)	1.378904	-0.93047	0.021568	-0.72327	0.753621	-0.50035
		αi2 (<15 min)	-0.74252	1.494059	0.892749	-0.45823	-1.61142	0.425357
		αi3 (15-30 min)	-1.36678	-1.00201	-0.04997	1.507774	0.536899	0.374093
		αi4 (30-45 min)	-0.4461	-0.08132	-0.51558	0.125876	0.476757	0.440365
		αi5 (45-60 min)	-0.06233	0.302441	-0.13181	-0.18351	0.860521	-0.78531
		αi6 (>60 min)	1.238825	0.217304	-0.21695	-0.26864	-1.01638	0.045844

Hypo.	User	Factors	Odds ratio	Conclusion
1	Normal grid energy (300 households)	Distance of the households from the School Versus Time taken to collect Firewood	12 times more in favor of households with schools far way for <15 min of firewood collection per day than 45-60 min per day.	Odds in favor tilted towards households far away from school for spending less time in firewood collection
2		Distance of the households from the Employer Versus Time taken to collect Firewood	3 time more in favor of households with employers close to the household for no times spent in the collection of firewood than 30-45 min spent per day.	Odds in favor tilted towards households close to the employer for spending less time in firewood collection
3		Socioeconomic status (indicated by type of house) Versus Time spent in the collection of firewood	14 time more in favor of households with mud houses than households with concrete houses for spending 15-30 minutes in collection of firewood than no time spent	Odds in favor tilted towards households living in mud houses -Indicator of energy poverty
4		Socioeconomic status (indicated by type of house) Versus Kilograms of firewood consumed per month	1.69 time more in favor of people with mud houses than households with concrete houses for spending 200 kg of firewood per month than 300 kg of firewood	Odds in favor tilted towards households living in mud houses-Indicator of energy poverty
5		Socioeconomic status (indicated by type of house) Versus liters of Kerosene consumed per month	2.59 time more in favor of people with mud houses than households with concrete houses for spending 0 liters of Kerosene per month than 2 liters of Kerosene	Odds in favor tilted towards households living in mud houses-Indicator of energy poverty
6		Socioeconomic status (indicated by type of house) Versus time taken to collect the firewood per day before biogas plant	3 times more in favor of people with mud houses than households with concrete houses for spending more than 60 minutes in the collection of firewood than no time in the collection of firewood	Odds in favor tilted towards households living in mud houses- this is indicator of energy poverty
7		Socioeconomic status (indicated by type of house) Versus time taken to collect the firewood per day after biogas plant	More than 2 times for people with mud houses than people with concrete houses for spending more than 60 minutes in the collection of firewood than no time in the collection of firewood	Odds in favor tilted towards households living in mud houses- this is indicator of reduction in energy poverty
8		Time saved from firewood collection Versus	1.55 times more for people in concrete houses than people in mud houses	Odds in favor tilted towards people in concrete houses. This indicated the

8. Time saved from firewood collection Versus Socioeconomic status (indicated by type of house) after the construction of biogas plant	1.55 times more for people in concrete houses than people in mud houses	Odds in favor tilted towards people in concrete houses. This indicated the benefit of biogas in terms of time saved per day is substantial not only in low socioeconomic groups but also in high socioeconomic groups.
9. Amount of firewood saved from biogas plant Versus Socioeconomic status (indicated by type of house) after the construction of biogas plant	1.67 times more for people in concrete houses than people in mud houses.	Odds in favor tilted towards people in concrete houses. This indicated the benefit of biogas in terms of firewood saved per day is substantial not only in low socioeconomic groups but also in high socioeconomic groups.
10. Time spent in the collection of firewood before Versus time taken to collect the firewood after biogas construction	More than 1.28 times for households with no time in the collection of firewood after than less than 15 minutes after to spend more than 60 minutes before the plant than no time before the plant.	Odds in favor tilted towards households spending no time in the collection of firewood after the plant-this is indicator of immensity of positive impact in terms of time saved after biogas construction.

Table of Contents

1. Introduction
2. Material and Methods - Data
3. Materials and Methods - Methods
4. Result and Discussion
5. Conclusion
6. References

Conclusion

- Benefits of use of energy are not only direct but permeate in an intangible manner to several sectors.
- Ten different hypotheses related to energy consumption pattern of normal users and Biogas users are tested with the help of this data.
- In eight of these ten hypotheses the null hypothesis of no dependence is rejected.
- It is found that location of school, location of employer and socioeconomic status plays a critical role in the energy consumption dynamics for both types of users.
- Energy poverty is assessed with the help of socioeconomic poverty in these hypotheses.
- The use of odds ratio has been used in quantifying the impact.

Conclusion

- There is no dependence between socioeconomic status and liters of Kerosene consumed per month.(National Grid Electricity)
- There is no dependence between socioeconomic status and time take to collect firewood after the plant construction

Table of Contents

1 Introduction

2 Material and Methods - Data

3 Materials and Methods - Methods

4 Result and Discussion

5 Conclusion

6 References

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Thank you!

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