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Socioeconomic Impact of Solar Pump on Farmer Livelihood in Southern Punjab, Pakistan: A Case Study of District Vehari

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ABSTRACT

This study enlightens the socio-economic impact of solar energy on farmer livelihood of District Vehari. This is a quantitative study and primary data has been collected through well-structured questionnaire. Structure equation modelling (SEM) is adopted to analyse the impact of observed and unobserved variables on farmer livelihood as well as socio-economic well-being. A comparison of adopter and non-adopter has been done. Socio-economic well-being shows positive and significant on farmer livelihood but strength of impact in case of users of solar pump is more than non-users. In case of total income partial mediation takes place and has direct and indirect (through solar energy) impact is positive and significant on socio-economic well-being. Highest education in family has insignificant impact on solar energy showing that it does not play any role in adoption. The actual reason of non-adoption that has been observed is high cost of solar panel so there is need subsidised the installation of it by the government.

1. Introduction

The role of energy is essential for the survival of human and it is also considered very important for economic development. Sustainable development is one of the core challenges of the world. The shortage of non-renewable energy resources with the depressed economy has led to urgency in search of the sustainable, economical, and environmentally friendly source of energy. In the development process of any country, energy plays an important role. Energy expenditure is one of the best tools to measure the socio-economic development of a country. Renewable energy sector plays positive role for environmental improvement (Chan et al., 2007).

Today the alarming global issue is having not access to sufficient energy resources, particularly in under-developed nations that have access to the limited supply of energy. Energy demand is rising rapidly especially in the developing nations as it is predicted that it will be almost 3 times more than today in 2050 due to high population growth rate, particularly in the continents of Africa and Asia (UN, 2014). Solar energy is one of the best solutions to resolve fossil fuels environmental issues in developing countries. It is very cheap and environment friendly source of energy. Solar energy has an enough potential to fulfil the energy need of world's population. The earth's surface receives much energy from the sun which is enough to provide 7900 times as much energy as the world's population currently uses. As well as it also reduce the dependency of developing nation on conventional source of energy and fossil fuels which have too much cost (IEA, 2016).

The use of solar energy in agriculture sector can also play a vital role for the growth of this sector. Farmers can use it for many purposes like irrigation and light purposes. Better facilities of irrigation can boost up the productivity of crops. As we know Pakistan is an agriculturist country and this sector continues to play a pivotal role in the economy. More than 65% population of Pakistan is directly or indirectly related to agriculture and 25% of total land area is utilized for cultivation of crops. This sector contributes 18.5 percent in GDP and absorbing 38.5 percent labour force of the country (GoP, 2019). In Pakistan, there are some issues linked with this sector that creates obstacle for the growth of agriculture sector. An energy crisis is one of the core issues in these days. The shocking fact is that almost half population of rural areas doesn't have an access of electricity. Due to this crisis, a farmer cannot do the proper farming and agriculture sector has to face downfall. There is need to resolve this alarming issue for the betterment of agriculture sector as well as the economy of Pakistan.

To resolve the issue of energy crisis there is a need to shift on the renewable energy sources. Solar energy is considered as one of the cheapest and best source of renewable energy. Pakistan is among those countries that are blessed with a bountiful amount of solar energy. It is estimated that Pakistan possesses a 2.9-TW solar energy potential (IEA, 2016). In agriculture sector, farmers can use it for the purpose of irrigation, light and many others. Irrigation is considered as the essential determinant of productivity of crops. If we use the modern technology of irrigation like solar PV water pump, it will definitely prove beneficial for the growth of agriculture sector. As far as concern the use of solar energy for light, so the areas where the electricity facility is not available it will help the farmer by solving his problem that he has to face at night. It is also obvious that proper lighting in the rural areas increases community safety as well as the resident's productivity during night time.

The rest of the paper is structured as: Section 2 gives the literature review. Research methodology and model specification are shown in Section 3. Section 4 is about results and discussions while section 5 concludes the study along with policy recommendations.

2. Literature Review

Energy has vital role for the economy and consider as most important tool for socio-economic development. Mekhilef et al. (2012) compared the conventional fuel and solar water pumping (used for the irrigation in agriculture sector) and claimed that the use of solar energy is better than any other sources due to its numerous advantages i.e. no fuel and maintenance cost, no noise and pollution etc. They compared solar water pump, Diesel generator and Electrical grid connection economically. They found that installation cost of solar water pump is higher than any other energy source but the price of solar panel is decreasing every day. As far as concerned the maintenance cost so diesel generator has high operating and maintenance cost due to the increasing prices of fossil fuel and lubricant. The operating cost of solar water pump is too low. Mehmood et al. (2015) stated the economic feasibility of solar water pump in agriculture sector for five major divisions of Pakistan; Multan, Faisalabad, Hyderabad, Rahim-Yar Khan and Dera Ghazi Khan in RETScreen international software. The outcomes predicted that if a farmer install 4.48kW DC solar photovoltaic water pump then he could save 7-8 MWH electric power and could reduce 1.2-1.4t CO_2 greenhouse gas emissions that might be produced due to the burning of fuel for greenhouse electric power. The authors argued that the commercial use solar water pump could resolve the issues of farmers, agriculture, economy and environment. It could improve the farmer's livelihood and drowning condition of agriculture sector of Pakistan.

Although the solar energy consider as better than other conventional energy sources but there are some reason due to that people don't want to replace their conventional water pump with solar pump as Jafar (2000) mentioned that there is high installation cost of solar water pump and lack of information about solar energy. Rao et al. (2018) discussed that there were two main drawbacks of solar power, one is high initial cost and other is low efficiency of photovoltaic cell conversion but now in this modern era, low cost power electronic systems and photovoltaic cells are available in the market.

Shahsavari & Akbari (2018) mentioned some barriers in the development of solar energy. They identified that price of solar technology is higher as well as efficiency of it is lower (as compare to fossil fuel). This is mainly due to inadequate government policy, lack of awareness about it and inadequate research and development in the developing countries.

There is needed to take the initiative by the government for the growth and development of solar power sector. The government should launch web base portal for guideline, build solar park and solar cities. Mekhilef et al. (2012) stated that the government should improve the usage and efficiency of the solar system by investing and depending on alternative energies rather than fossil fuels which are costly and harmful for the environment. Shahsavari & Akbari (2018) suggested that the government of developing nation (like Pakistan) has to make effective policies for the promotion and development of solar energy and to reduce the dependence on fossil fuels.

As in the literature, there is very little work done on impact of solar energy on agriculture sector in Pakistan. The work that has be done in other areas like central Punjab Khyber Pakhtonkha (KPK) etc. In the areas of southern Punjab like division Multan, Bahawalpur where high potential exist the little work has been done till today. This study will be conducted in District Vehari where before today little work has been done on impact of solar energy on farmer livelihood.

3. Research Methodology and Model Specification

Partial least square structural equation modeling (PLS-SEM) approach is used to analyze hypothesized causal relationships among structural parameters in case of small sample size. This method commonly comprises of confirmatory factor analysis and path analysis. It is more elastic than conventional regression model as it can incorporate observed as well as unobserved variables. Unobserved constructs are measured by observed variables and there is causal sequence of integrated channels among all variables in the light of theoretical framework. This paper assessed the socio-economic impact of solar energy on farmer livelihood in agriculture sector. It is a comprehensive model which encompasses the previous studies about the entire hypothesized channel.

In structural regression model, the relationships among variables are explained. In proposed regression model, there are variables which play mediator role in farmer livelihood. Equation (1) shows the possible predictor of farmer livelihood. Mediator variables explain a phenomenon while moderator affects the strength of relationship between variables and this is the beauty of SEM which incorporates unobserved and observed mediator, moderator, dependent and independent variables simultaneously. In this model solar energy plays role of mediator. Equation (2) describes the determinants of solar energy and equation (3) shows the predictor of socio-economic well-being. Socio-economic well-being and livelihood asset are endogenous variables.

$$\text{FLH} = \alpha_1 SEW + \varepsilon_1 \quad (1)$$
$$SE = \beta_1 TI + \beta_2 ADP + \beta_3 HE + \varepsilon_2 \quad (2)$$
$$SEW = \gamma_1 SE + \gamma_2 HE + \gamma_3 TI + \varepsilon_3 \quad (3)$$

Where:

FLH = farmer livelihood

SEW = Socio-economic well-being

SE = Solar energy

TI = Total income

HE = Highest education in family

ADP = Adoption of solar pump

In measurement model we estimate factors loadings of indicators of latent variables**.** Latent variables are described along indicators in following way:

a) Socio-economic well-being

Socio-economic well-being is endogenous latent variable and measured by four indicators farm productivity (FP), saving (SAV), air pollution (AP) and time saving (TS) which are presented in the following equations 4 to 7, respectively:

$$FP = \alpha_1 SEW + \varepsilon_1 \quad (4)$$

$$SAV = \alpha_2 SEW + \varepsilon_2 \quad (5)$$

$$AP = \alpha_3 SEW + \varepsilon_3 \quad (6)$$

$$TS = \alpha_4 SEW + \varepsilon_4 \quad (7)$$

b) Farmer livelihood

Farmer livelihood is also endogenous latent variable and measured by five indicators human capital (HC), financial capital (FC), physical capital (PC), natural capital (NC) and social capital (SC) which are described in the following equations 8 to 11, respectively:

$$HC = \beta_1 FLH + \varepsilon_1 \quad (8)$$

$$PC = \beta_2 FLH + \varepsilon_3 \quad (9)$$

$$NC = \beta_3 FLH + \varepsilon_4 \quad (10)$$

$$SC = \beta_4 FLH + \varepsilon_5 \quad (11)$$

To assess the social impact of solar energy on the livelihood of people, following variables are considered in this study.

Exogenous Variables

Following variables are considered as exogenous variable in this model.

Solar energy

This will be a dummy variable taking value "1" for a farmer who adopts the solar technology and "0" for those who does not adopt the solar technology.

Total income (TI)

This income includes farm income and non-farm income in term of rupees.

Highest education in the family (HE)

This variable shows the higher education of the person in the household. in term of year of schooling.

Adoption
This variable indicates that which factors influences the farmer to adopt the solar technology. The farmer can be influenced by due to economic benefits of SE, by media, suggestion by a friend and govt policies to enhance the use of solar energy. This variable is measured on Likert scale for every factor from "1" to "5".

Non-adoption
This variable indicates those factors which creates hurdles to adopt the solar technology. The factors are: high cost of installation, insecurity and low efficiency. This variable is measured on Likert scale for every factor from "1" to "5".

Socio-economic well-being indicators
Following are the possible indicators of socio-economic well-being.

Saving (SAV)
This variable is calculated through saving on fuel and other expenditure per month in term of rupees.

Farm productivity (FP)
This variable is measured on Likert scale value from "1" to "3". The values show different groups of income from farm yield per acre per year.

Air pollution (AP)
This variable is measured by data about diseases that spread from air pollution which is due to the use of fossil fuel machinery. If the Farmer visited hospital due to this disease, then value will be "1" and otherwise "0".

Time saving (TS)
It is a dummy variable. This variable includes time saved in term of hours from bringing the fuel, irrigation process and maintenance of the conventional machines. The value "1" indicate "yes" and "0" for "no"

Farmer livelihood asset

Following are the assets of farmer livelihood.

Human capital (HC)

This is output variable. It calculated the number of children getting an education under the age 25.

Physical capital (PC)
This is output variable. It includes current values of assets in term of rupees that a household possesses like tractor, machinery and car etc.

Natural capital (NC)
This is an output variable. It is calculated on the basis of per capita area of cultivated land

Social capital (SC)
This is output variable. It is calculated by either people of society cooperated with farmer in different tasks of farming like irrigation or not if yes then the value"1" otherwise value "0".

Following figure is representing the possible linkage of endogenous as well as exogenous variables. Figure 1 also showing the mediation effect of solar energy and socio-economic well-being which transfer the impact of different variables to farmer livelihood.

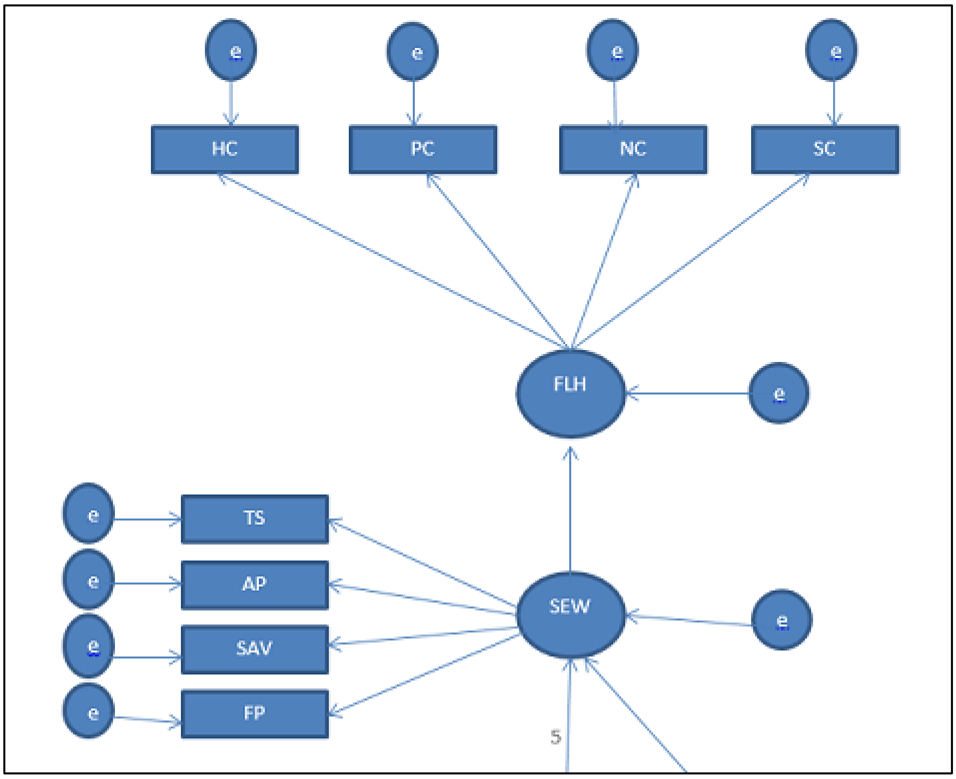

Figure 1
Theoretical Path.

In Figure 1, farmer livelihood (FLH) has four indicators: human capital (HC), physical capital (PC), natural capital (NC) and social capital (SC). Socio economic well-being also has four indicators; time saving (TS), air pollution (AP), savings (SAV) and farm productivity (FP). Farmer livelihood is influenced by socio economic well-being while Socio economic well-being is influenced by total income (TI) and solar energy (SE). In this figure, it is obvious that solar energy is playing a mediating role by doing transfer of impact of total income and adoption of solar pump (ADP).

Table 1

Variables and its Signs

Abbreviation	Variable	Definition	Expected Sign
SAV	Saving	Saving on fuel and other expenditure/Rs./month.	+ or -
FP	Farm productivity	Income from farm yield/ acre/ year.	+
AP	Air pollution	Diseases due to air pollution.	-
TS	Time saving	Maintenance and supply of fuel	+
HC	Human capital	Children getting an education < age 25.	+
FC	Financial capital	Saving expenditure	+
PC	Physical capital	Current values of assets (Rs.)	+
NC	Natural capital	Per capita area of cultivated land	+

SC	Social capital	Output and dummy variable. NGO member or not	+

There is more potential of solar energy in southern Punjab as compare to other areas of Pakistan. From southern Punjab, Multan division is selected due to high potential of solar energy. There are four districts of Multan division, Multan, Khanewal, Vehari and Lodhran. By using simple random sampling we are going to select district Vehari for analysis. Using simple random sampling data has been collected from 116 respondents in which 58 users and non-user of solar energy are also 58.

A household survey is conducted. A survey questioner has been used to evoke a response from the respondent. In social research, the household survey has become a key method to collect data. It may be in the form of structure and semi-structure form to collect data. A survey can be defined as a collection of data by asking different people same questions about, a way of living, character, and qualities (O'leary, 2013). Neuman (2002) stated that survey is useful when you are collecting data from many individual and independent responses are required. The aim of the survey of this study is to know the socio-economic impact of solar energy on the livelihoods of people. A comparative analysis has been conducted between those people who are using solar pump and who are not using. It has examined that how much the solar pump is beneficial for the farmer by saving his expenditure on fossil fuel and other sources of energy. It has been examined that how solar energy is considered as environment friendly. Considering the wide range of information that we have collected from the survey; this study is also helpful for policy implications.

The data have been collected through household survey in the form of structure and semi-structure questionnaires and it has been treated as a quantitative data. The responses from Household survey are codified accordingly. A structure equation model (SEM) will be used to estimate the impact of solar energy on livelihood of farmers of District Vehari.

4. Results and Discussions

In this section, the results are estimated to measure the socio-economic impact of solar energy on farmer livelihood and interpreted according to their nature. The discussion about the results is according to respective order of the equations. The technique which is adopted for the estimation of results is covariance based structural equation modeling (CB-SEM) which measures the impact of exogenous variables on farmer livelihood and socio-economic well-being of farmers in selected area. This technique encircles all the relevant theories and studies for confirmatory factor analysis by taking into account both observed and latent variables. Ringle and Mena (2012) stated that "Covariance-based structural equation modeling (CB-SEM) has been mostly used due to its efficiencies like treatment of latent variables, multiple checks at a same time and most important inclusion of most complex relationships."

4.1 Demographic Analysis

In the demographic analysis, different set of methods and techniques are used to measure the different aspects and dynamics of target population. This study is depends upon 116 respondents in which 58 were those who adopt solar technology and rest 58 were non-adopters. The technique which was used to collect is simple random sampling because it was convenient for that circumstance. As shown in survey that all respondents were 'male' because in our study area female are not directly linked with agriculture (Table 2). As survey accounted that in the case of adopter. 9% respondents are lying in age group of 25 to 35 years, 47% of the respondents are ranging between 36 to 45 years, 29% of the respondents exist in age group of 46 to 55 years and remaining 15% of the respondents fall in the age group of 56 years to above. In the case of non-adopter of solar technology 6% of the participants are ranging between 25 to 35 years, 22% of the respondents are falling in age group of 36 to 45 years, 41% of participants are lying in the age group of 46 to 55 and 31% of the respondents are in the range of 56 years and above. So we can conclude that maximum farmers of the age group 36 to 45 years are adopter of technology while mostly non-adopter lies in the range of 46 to 55 years. It is obvious after the analysis that mostly youngsters adopt this technology (Table 2).

As far as concern of the qualification of farmers, in the case of adopter as depicted in survey 14% of farmers are illiterate, 27% of the respondents have primary education, 24% are secondary passed, 16% of the participants got intermediate education and 19% farmers have graduation or master degree. So majority of respondents have primary or secondary education (Table 2). From the respondents who are non-adopter: 28% of the respondents are illiterate, 31% of the respondents have primary education, 29% have secondary education, 7% of the participants got intermediate education and 5% farmers have graduation or master degree. Mostly non-adopters are having primary education. The income of the respondents who are adopters: 7% of the participants have income between 25,000-50,000, 33% of the respondents have income between 51,000-75,000, 35% of the respondents are earning between 76,000-100,000, of the participants have income between 101,000-125,000 and 13% of the respondents are earning more than 126,000. It is evident that majority of respondents lies in the income slab of 76 to 100 thousands (Table 2).

In the case of non-adopters 7% of the respondents earning income between 25,000-50,000, 35% of the participants have income between 51,000-75,000, 31% of the respondents are earning between 76,000-100,000, 10% of the participants have income between 101,000-125,000 and 17% of the respondents are earning more than 126,000. It is obvious that mostly respondents lie in the income slab of 76,000 to 100,000 (Table 2).

Table 2
Demographic Analysis of Respondents

		Adopter		**Non-Adopter**	
		Frequency	**Percentage**	**Frequency**	**Percentage**
Gender	Male	58	100	58	100
	Female	0	0	0	0
Age	25 to 35	5	9	3	6
	36 to 45	27	47	13	22
	46 to 55	17	29	24	41
	56 to above	9	15	18	31
Qualification	Uneducated	8	14	16	28
	Primary	16	27	18	31
	Secondary	14	24	17	29
	Intermediate	9	16	4	7
	Graduate/ Master	11	19	3	5
Income	25000 to 50000	4	7	4	7
	51000 to 75000	19	33	20	35
	76000 to 100000	20	35	18	31
	101000 to 125000	7	12	6	10
	126000 and above	8	13	10	17

4.2 Estimates of Latent Variables

As the name "SEM" depicts that there is causal analysis in which we can measure unobservable variables with the help of observed indicators. In this analysis unobservable variables are farmer livelihood and socio-economic well-being which can be measured by suitable indicators.

4.2.1 Reliability of reflective measure

The measuring tool of the reliability of reflective measure in the research is Cronbach's alpha. As Nunnally (1978) mentioned that the value of Cronbach's alpha is greater than 0.7 is the sign of reliability of reflective measure and we can used it as a construct. Cronbach's alpha of latent variables and the value of all latent variables is greater than 0.7 which indicate that our constructs are reliable (Table 3). Following formula is used to measure the Cronbach's alpha:

$$\alpha = \frac{N.\bar{C}}{\bar{V} + (N-1).\bar{C}}$$

Where:

- α = Cronbach's alpha
- $\bar{C}$ = average variance between item-indicators.
- N = the number of indicators
- $\bar{C}$ = average variance

Table 3
Reliability of the latent construct

Constructs	Farmer Livelihood	Socio-economic well-being
Cronbach alpha	0.756	0.767

4.2.2 Validity of Constructs

Peter and Churchill (1986) stated that relationships between latent variables are meaningful only when validity of constructs is recognized. To make the model meaningful and interpretable, there is need to assess the validity of constructs which is further divided into two parts which are convergent and discriminant validity. Convergent validity is usually measured by taking into account average variance extracted (AVE). AVE is grand mean of squared loadings of all the indicators of a construct in the model. If a construct has indicator which have less than 50 percent of variance, it is not feasible to keep it in the model. Table 4 gives the value of AVEs of all constructs and the actual estimation of all the indicators associated with specific construct (Table 5).

Another part of validity of construct is discriminant validity which show that whether a construct is overlapped with other constructs or not (Ringle et al. 2012). So it verifies that one construct is totally different from other construct in the model. If a latent variable has share less variance with constructs in a same model and more variance with its factors, then it ensure the discriminant validity. According to this criterion correlation of a construct with others constructs in the model must be less than square root of AVE (Fornell & Larcker, 1981). Table 4 depicts the square root of average variance extracted (AVEs) and Table 5 shows the correlation between these two latent variables. We can observe that values of AVEs are greater than correlation between two constructs which ensure discriminant validity.

Table 4
Validity of the latent construct

	AVEs	Square root of AVEs
Farmer Livelihood	0.723	0.850
Socio-economic well-being	0.756	0.869

Table 5
Correlation between latent variables

	Farmer Livelihood	Socio-economic well-being
Farmer Livelihood	1	
Socio-economic well-being	+0.36	1

In this model, there are two latent variables an each variable is measured by their appropriate indicators. Indicators which has factor loading less than 0.5 or they are insignificant cannot be consider as a factor of latent variable. Farmer livelihood is measured by four indicators: human capital, physical capital, natural capital and social capital. Socio-economic well-being is also measured by five indicators which are savings, farm productivity, time saving and air pollution.

As far as concern the indicator of farmer livelihood so human capital has factor loading 2.039 and is significant at 1% p-value. Physical capital has 2.059 and it is significant at 5% p-value. Natural capital has 1.373 factor loading and significant at 5% p-value. The last indicator is social indicator which has factor loading 1.926 and significant at 5% p-value. All these indicators are significant and have factor loading greater than 0.5 so these all will be retain in the model (Table 6).

Socio-economic well-being has four indicators: savings, farm productivity, time savings and air pollution. Saving is highly significant and factor loading is 1.698. Farm productivity is significant at 1% p-value and factor loading is 1.373. Time savings is significant at 5% p-value and factor loading is 1.431. The last indicator sir pollution has factor loading 0.449 which is less than 0.5 and it is also insignificant so it cannot retain in the model (Table 6).

Table 6
Results of Measurement Model

Indicators / **Latent Variables**	**Human Capital**	**Physical Capital**	**Natural Capital**	**Social Capital**
Farmer Livelihood	2.039** (0.569)	2.059* (0.970)	1.373* (0.641)	1.926* (0.892)
	Savings	**Farm productivity**	**Time savings**	**Air pollution**
Socio-economic well-being	1.698*** (0.204)	1.373** (0.393)	1.431* (0.652)	0.449 (0.578)

Standard errors are in parentheses
* p<0.05, ** p<0.01, *** p<0.001

4.3 Estimates of Structural Model

The proposed relationship between different variables checked by using structural equation modeling (SEM) The best feature of SEM is that it is flexible to include the multiple latent variables as endogenous as well as exogenous constructs. It is a built-in feature in SEM that it can tackle the endogeneity which makes it more attractive. We have estimated the determinants of socio-economic well-being and farmer livelihood by using SEM. According to our limited knowledge, this technique (SEM) is rarely used to measure the impact of solar pump on farmer livelihood. The actual reason of using SEM is to do path analysis which is mentioned in the given section. There are many research papers available in the literature which describes the impact of solar energy on the livelihood of people but to describe the relationship through mediation is rarely discussed. SEM provide us an opportunity by including mediating as well as moderating effect of multiple variables at a same time in a single regression.

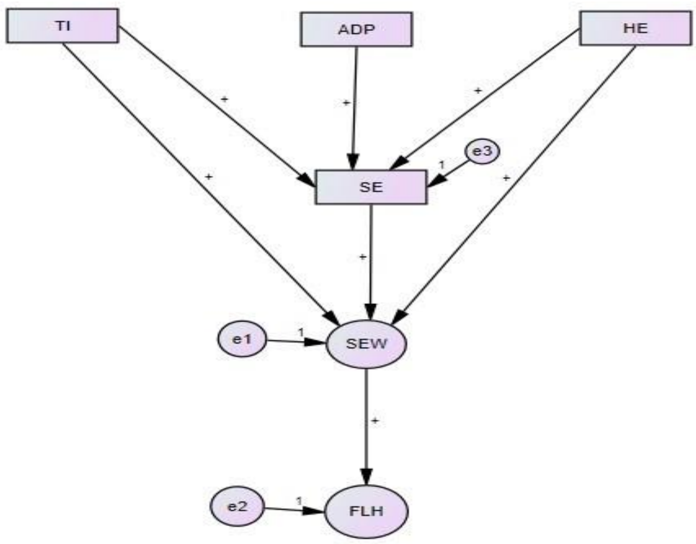

Figure 2
Initial Path Diagram

Table 7
Estimated standardized path coefficients for (adopter) initial SEM model

Variables	**FLH**	**SEW**	**SE**
SEW	.247*		
SE		.217*	
TI		.436**	.379*
HE		.325**	.229
ADP			.424**

Sample size= 116
* p<0.05, ** p<0.01, *** p<0.001

In the initial model as shown in Figure 2, there are three endogenous variables: farmer livelihood (FLH), socio-economic well-being (SEW) and solar energy (SE). Solar energy and socio-economic well-being will be treated as endogenous as well as exogenous variable. Solar energy is determined by total income (TI), highest education in the family (HE) and adoption (ADP). If we compare the impact of these variable on solar energy (SE) so the influence of total income on solar energy (SE) is lower than adoption (ADP) and higher than highest education (HE). Adoption is also significant at 1% p-value and positively related with solar energy. The impact of adoption (ADP) on solar energy is much greater than total income (TI) and highest education (HE) (Table 7). Adoption is a compound variable which is constructed by those reasons that become cause of adopting the solar technology. As far as concern the last determinant of solar energy which is highest education in family so it is insignificant. Therefore, HE cannot retain in the model as a determinant of solar energy.

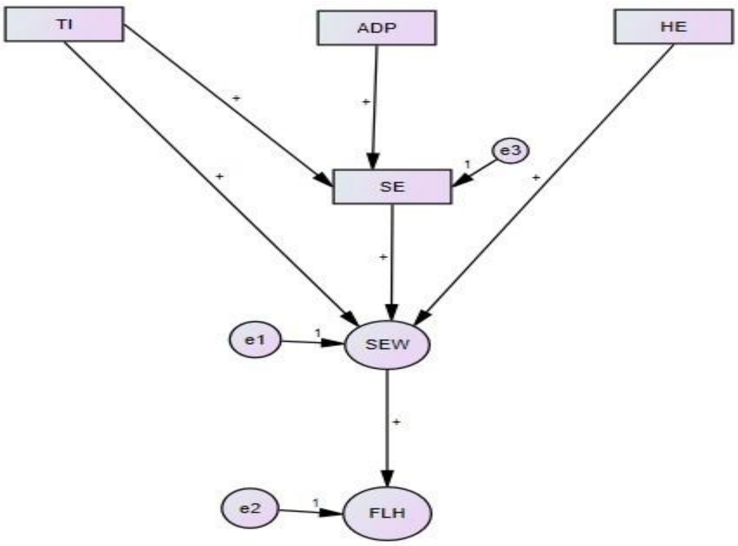

Figure 3
Final Path Diagram

Table 8
Estimated Standardized path coefficients for final SEM model

Variables	FLH	SEW	SE
SEW	.268*		
SE		.219*	
TI		.436**	.381*
HE		.329**	
ADP			.426**

Sample size= 116
* p<0.05, ** p<0.01, *** p<0.001

After deducting the one variable from model we regress a regression once again as shown in Figure 3. At that time all variables are significant that's why it is our final model of those people who adopt the solar energy. There is positive relationship between solar energy and socio-economic well-being but its impact on socio-economic well-being is less than total income (TI) and highest education (HE). Total income is positively associated with socio-economic well-being and significant at 1% p-value. The direct impact of total income on socio-economic well-being is significant and greater than its own mediation (indirect) impact through solar energy (SE). Highest education in family is significant at 1% p-value and positively associated with socio-economic well-being. Its impact is more than solar energy (SE) and less than total income (TI) on socio-economic well-being. As far as concern our last endogenous variable which is farmer livelihood and its determinant is socio-economic well-being. So there is positive association between farmer livelihood and socio-economic well-being and SEW is significant at 5% p-value. Sher et al (2015) also stated that the use of solar energy will improve the agricultural productivity as well as living standard of the people. After this analysis, we observed that those people who adopt the solar technology in agriculture sector have more socio-economic well-being and due to this their livelihood condition also improved (Table 8).

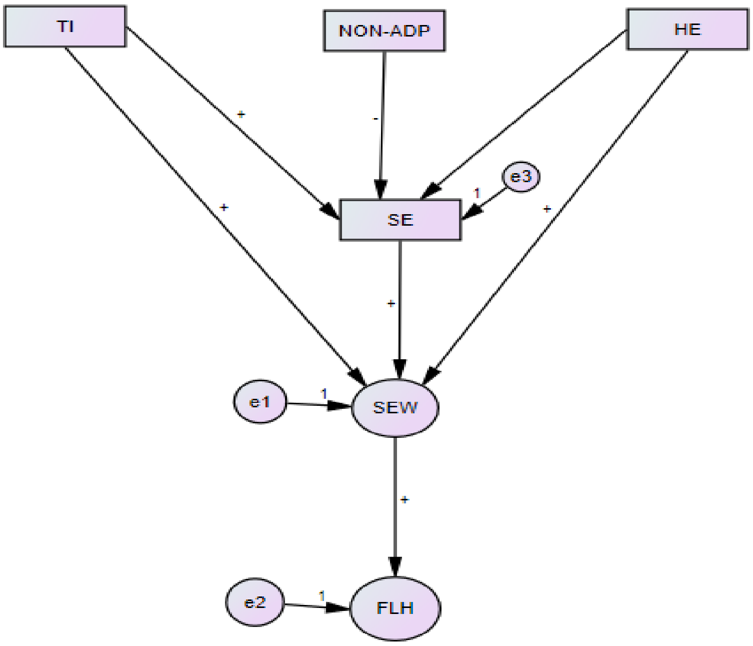

Figure 4
Initial Path Diagram

Table 9
Estimated standardized path coefficients for (non-adopter) initial SEM model

Variables	FLH	SEW	SE
SEW	.215*		
SE		-.194*	
TI		.412*	.124
HE		.321**	.189
NON ADP			.452**

Sample size= 116
* p<0.05, ** p<0.01, *** p<0.001

In a second model which is shown in Figure 4 related to the non-adopter of solar energy there are three determinants of socio-economic well-being which are solar energy (non-adopter), total income and highest education in the family. Total income is positively associated with socio-economic well-being and significant at 5% p-value. The direct impact of total income on socio-economic well-being is greater than its own mediation (indirect) impact through solar energy (SE). Highest education in family is significant at 1% p-value and also positively associated with socio-economic well-being. . Its impact is less than total income (TI) and more than solar energy (SE) on socio-economic well-being. There is negative and significant relationship between solar energy and socio-economic well-being is at 5% and its extent is less than total income and highest education in opposite direction (Table 9).

There are three determinants of SE total income (TI), highest education in family (HE) and non-adoption (NON-ADP). In this model, non-adoption is highly significant at 1% p-value and positively associated with SE. In our model non-adoption is a compound variable which is the combination of different causes that creates hurdle in installing of solar plant. In that reasons, one reason is high initial cost. As Rao et al. (2018) discussed that there were two main drawbacks of solar power, one is high initial cost and other is low efficiency. The association of total income is positive but insignificant with solar energy (non-adopter) so to improve the model this variable will not retain.

Table 10
Estimated Standardized path coefficients for (non-adopter) revised SEM model 2

Variables	FLH	SEW	SE
SEW	.215*		
SE		-.191*	
TI		.423*	
HE		.321**	.189
NON ADP			.452**

Sample size= 116
* p<0.05, ** p<0.01, *** p<0.001

After dropping the TI from model, now there is need to check the association of next variable which is HE. Highest education in family is also positively but insignificantly associated with solar energy (Table 10). So HE will be dropped in order to make model more parsimonious.

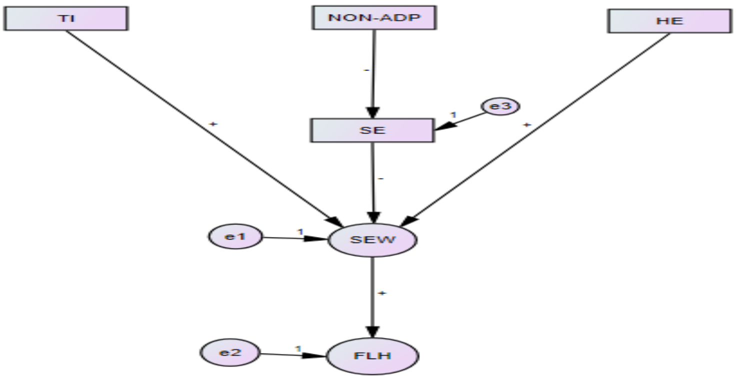

Figure 5
Final Path Diagram

Table 11
Estimated path coefficients for (non-adopter) final SEM model.

Variables	FLH	SEW	SE
SEW	.215*		
SE		-.191*	
TI		.423*	
HE		.321**	
NON ADP			.452**

Sample size= 116
* p<0.05, ** p<0.01, *** p<0.001

After removing all those variables which are insignificant from the model now this is precise and final model which depict the socio-economic condition and its impact on their livelihood of those people who have not install solar pump. In this final model all determinants of endogenous variables are significant. Socio-economic well-being has significant and positive impact on farmer livelihood (Table 11).

4.3.1 Mediation Analysis through Simulation

SEM is famous to explain the mediation effect of variables. Furthermore, mediation can be divided into two types: partial mediation and full mediation. Partial mediation takes place when a variable influences other variable directly and as well as exerts significant indirect effect through mediating variable. In full mediation, only indirect effect becomes significant while direct effect is insignificant. In order to verify the mediation, we must check the significance of indirect effect in this process. For this purpose, bootstrapping is applied which is just like Monte Carlo simulation technique but the main difference between these two implies in the selection of random samples. Monte Carlo simulation draws the random sample after taking the summary of data but bootstrapping used original data set and random samples of original sample size are taken with replacement and then compute sampling distribution of standard errors for path coefficients. So if indirect effects in bootstrapping is significant, then it prove the significance of original outcomes in path analysis while total effect is equal to direct effect plus total indirect effects. Indirect effect is calculated by multiplying

In first model, there are Total income (TI) and highest education which are linked with the socio-economic well-being directly and indirectly in this model. There is need to check that whether the indirect impact of both variable is significant through mediation by applying bootstrapping. After doing analysis it is evident that the indirect impact of Total income (TI) on socio-economic well-being through using mediator as solar energy is significant. So the total impact of Total income (TI) can be calculated by adding direct and indirect impact of it. The indirect impact of HE on socio-economic well-being is insignificant through using SE as mediator. So the direct impact of highest education will be considered as total effect of it (Table 12).

Table 12
Estimated standardized path coefficients of model 1 direct and indirect effects.

	Direct effect	Indirect effect	Total effect
TI→SE→SEW	$.436^{**}$	$.112^{\wedge}$	$.548^{*}$
HE→SE→SEW	$.329^{**}$	.105	$.329^{**}$

Sample size= 116
* p<0.05, ** p<0.01, *** p<0.001

In second model there are also those two variables (Total income and highest education) are influencing socio-economic well-being directly and indirectly through using solar energy (SE) as mediator. The indirect impact of Total income (TI) on socio-economic well-being through using mediator as solar energy is insignificant in second model. So the total impact of Total income (TI) is considered as same of direct impact of it. The indirect impact of HE on socio-economic well-being is insignificant through using SE as mediator. So the direct impact of highest education will be considered as total effect of it (Table 13).

Table 13
Estimated standardized path coefficients of model 2 for direct and indirect effects.

Path	Direct effect	Indirect effect	Total effect
TI→SE→SEW	$.436^{**}$	.108	$.436^{**}$
HE→SE→SEW	$.329^{**}$	.103	$.329^{**}$

Sample size= 116
* p<0.05, ** p<0.01, *** p<0.001

The R^2 for each endogenous variable is for final SEM models (adopter and non-adopter) which is the proportion of explained variation in endogenous variables due to exogenous variables. Although coefficients of determinations for both endogenous variables are not much high due to limited sample size and missing variables but still considerable high in current situation. R^2 for farmer livelihood is 0.59. For socio-economic well-being R^2 is 0.61 and for solar energy R^2 is 0.67. In fact, it provides further avenues to explore phenomenon more deeply by including more plausible variables (Table 14).

Table 14
R^2 For each endogenous variable in the final SEM model

Endogenous variable	FLH	SEW	SE
R^2	0.5978	0.6134	0.6724

Maximum likelihood estimation of final SEM model as depicted in Table 15 shows mostly acceptable range of model fit indices. Comparative fit index (CFI), normed fit index (NFI) and Relative fit index (RFI) have values greater than 0.9 which lies in acceptable range. Root mean square error of approximation (RMSEA) is 0.063 and 0.065 which is less than 0.08 which is consider as good measure. One measure is out of fit and that is goodness fit index (GFI) which is 0.84 which is not greater than 0.9. As the majority of indices fall within acceptable range so we conclude overall model has good fitting.

Table 15
Model fit indices for various models

	CMIN/DF	NFI	CFI	GFI	RFI	RMSEA
Initial SEM model (adopter)	2.569	0.982	0.944	0.862	0.923	0.069
Final SEM model (adopter)	2.578	0.937	0.939	0.844	0.935	0.063
Initial SEM model (non-adopter)	2.487	0.964	0.948	0.859	0.919	0.061
Revised SEM model 1 (non-adopter)	2.474	0.942	0.942	0.851	0.946	0.063
Revised SEM model 2 (non-adopter)	2.414	0.943	0.945	0.827	0.943	0.067
Final SEM model (non-adopter)	2.485	0.940	0.943	0.842	0.935	0.065

Finally, we can conclude the results of estimation as done by PLS-SEM that almost many determinants of endogenous variables are significant and they have positive impact on it but the impact of highest education in family on solar energy is insignificant with positive sign in the case when farmer have solar pump. In another case where farmers are using conventional method for irrigation sector, some determinants of endogenous variables are insignificant (impact of total income on solar energy (non-adopter), highest education in family on solar energy (non-adopter) and impact of solar energy (non-adopter) on socio-economic well-being) with positive sign. As far as concern of our core endogenous variable which is farmer livelihood so socio-economic well-being has positive and significant impact on it in both cases but it explain more the farmer livelihood in the case of adopter of solar energy as compare to other one.

5. Conclusion and Recommendations

This study is conducted to check impact of using solar energy by a farmer on socio-economic indicators and how these indicators influence the farmer livelihood. This is a case study of district Vehari and primary data is used for this survey. The technique which is adopted to evaluate the impact is structural equation modeling (SEM). It can help us to check the direct as well as mediating impact on endogenous variables. As compare to other methodologies SEM is more flexible and usually used to find out the relationships its extent which is latent in nature. It has power to do multiple functions at a same time and can control obvious as well as latent variable more perfectly than other traditional econometric techniques. More important and attractive thing is that it has built-in feature to tackle endogeneity and can explain the causal relationship of multiple variables.

The criteria which have been followed of selecting respondents for this study allowed us to do a comparison of socio-economic condition and livelihood of both: solar energy (adopter and non-adopter). Results of this study depicts that the impact of socio-economic well-being on livelihood of those farmer who installed solar pump is more than those who has not installed. It is obvious after getting these results that socio-economic condition and livelihood of those who are using solar energy is better than of non-user. It is also analyzed that the use of solar pump has positive impact on the farmer's income, savings, and time savings. This positive impact improves the socio-economic condition as well as livelihood of the farmers. The results also indicate that solar energy is environment friendly because the user of solar pump for irrigation are facing less health issue as compare to those who are using conventional source of energy. One variable highest education in family (HE) has insignificant impact on SE so it's mean in our case highest education in family does not play any role for adopting the solar energy. This study figures out some solid reasons of using solar energy that are; zero operating cost, economic benefits, high yields of crops and in some areas non availability of other sources for irrigation. On the other hand this study also reveals some factors of non-adopting solar energy that are; high installation cost, in some areas it has low efficiency and lack of awareness. This study also observed that the impact of socio-economic indicators on farmer livelihood is also positive and significant.

Policy Recommendation

As our results depicted that solar is environment friendly source of energy so there is need to educate and aware the people to enhance the use of solar energy and do less use of fossil fuels in irrigation for the betterment of environment and their health.

This study also identified the reasons of not using the solar energy so the core reason is high cost of solar panel. Government should take following steps:

- Government should provide subsidized installation of solar plant.
- Government should take steps for the domestic manufacturing of solar plant. It will enable us to self-reliance and less our reliance on imports in a long term.
- Government should introduce the scheme of renewable energy credits. A user of solar energy can supply the extra energy to mainstream of grid station and can earn reasonable profit.

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