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

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CERTIFICATE

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DEDICATION

My this effort is dedicated to my parents, who provided me with an opportunity to study in this prestigious institution with devoted teachers & supporting class fellows, without their support my this effort would have never been worth viewing.

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Hamza Zaka

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List of Abbreviations

ADP Adoption

AP Air Pollution

FP Farm Productivity

GDP Gross Domestic Product

GHG Greenhouse Gases

HC Human Capital

HE Highest Education

NC Natural Capital

NGOs Non-governmental organizations

NON-ADP Non Adoption

PC Physical Capital

SE Solar Energy

SAV Savings

SC Social Capital

SEM Structured Equation Model

SEW Socio-Economic Well-being

TI Total Income

TS Time Saving

Abstract

The global warming and emission of greenhouse gasses pushed the world economy towards renewable sources of energy. Solar energy is one of the essential types of an alternative energy source. Pakistan economy is agriculture based and development in this sector will enhance the overall growth of the country. In past, there was very limited use of solar energy due to the lack of awareness in Pakistan. 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 of both showing 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.

CHAPTER I

Introduction

1.1 Introduction

The role of energy is essential for the survival of human and it is also consider 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 expend iture 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.

1.2 Objective of the Study

The overall objective of the study is to check the impact of socio-economic indicator on livelihood with respect to farmer who is using solar energy in agriculture sector.

Specifically the study has the following objective:

(i) To analyse that how the adoption of solar energy impact on farmer's livelihood (human, financial. Natural and social) assets.

(ii) To find out the impact of irrigation that is done by solar pump on the production of crops.

(iii) To discover that how many people are aware of the solar technology in agriculture sector.

Furthermore, this study seeks to examine the impact of socio-economic indicator on livelihood asset through farm productivity, saving, air pollution, and time saving.

1.3 Research Question

Following are the key questions that are addressed in this study:

(i) Weather socio-economic indicator has a significant impact of using solar pump on farmer livelihood?

(ii) Do farm productivity, saving, air pollution and time saving play a role in the socio-economic indicator and livelihood asset (human, financial, physical, social, and natural)?

1.3 Hypothesis

Following are the hypothesis of the study:

(i) Adoption of solar pump has positive impact on the productivity of crops in agriculture sector.

(ii) Uses of solar pump boost the income of farmers.

(iii) Solar pump generates positive impact on environment.

1.4 The Significance of Research

Today the energy has become a vital necessity of modern life. The renewable energy source like solar energy becomes the cause of social economic development with no adverse effect on environment and health is becoming more significant. These resources are very important to improve the social and economic condition of the people. The adoption of such renewable resources required social acceptability, support from society, economic viability, technical feasibility and support from government. The renewable energy sources are considered environmentally friendly in this present world. Solar energy is one of these energy, through which affordable energy can be supplied to the rural areas and agriculture sector.

CHAPTER II

Literature Review

2.1 Literature Review

Before reviewing the literature about the solar energy, there is need to define the term ‘‘Technology’’. Many authors elaborate technology in different ways. Technology is the methods of producing goods and services, including means of organization as well as physical technique (Loevinsohn et al., 2013). Technology is the knowledge/information that allows some tasks to achieve it more easily (Lavison, 2013). Technology itself is improving a way of production or changing the status to a more desirable level. It assists the adopter to do work efficiently than the non-adopter. It also assists to save time and labour (Bonabana-Wabbi, 2002).

2.2 Technologies Related to Agriculture Sector

Hailu et al., (2014) found that the decision of agriculture technology adoption determined by farmer’s income, access of credit, use of irrigation and distance to market. They also found that there is positive and significant effect of technology adoption on crops yield farmer income. Mwangi1 & Kariuki (2015) mentioned that adoption of agriculture technologies is considered as important tool to eliminate the poverty from developing countries but the bitter fact is that the adoption rate of these technologies in agriculture sector is very low in developing countries. Jain et al. (2009) stated that all types of agricultural technologies, modern techniques and practices affect the growth of agricultural output as well as economy. Technology adoption by the farm households improves their well-being and we can alleviate poverty by enhancing the role of adopting new technology in agriculture sector (Mendala, 2006).

The use of pesticide in agriculture sector surely affects the rate of return per unit of investment and socio-economic factors **(**Yasin, 2003). The study tells that the use of biogas technology by the farmer is not only economically beneficial but it also environment friendly technology. It produce the energy at cheapest cost and help to save cooking time, firewood collection time and the labour of making dung cakes from animal dung (Abbas et al., 2017). There is a causal relationship was considered between the adoption behaviour towards the use of nuclear technology in agriculture sector and variables such as innovation characteristic, attitudes social norms, personal and professional characteristics, knowledge, improvement of social, cultural, health, political, and economic conditions (Sarcheshmeh et.al., 2018).

2.3. Merits of adopting agricultural technologies:

To attain all these advantages of adopting technologies that are mentioned in above paragraph there is need to educate the farmers about the know-how of these modern techniques. Farmers will take decision for the use of these advanced technologies after analysing the merits and demerits of them. As Challa (2013) mentioned that there are two merits of using new technologies which leads to remarkable gain in farmer's income, one is that it raises the productivity and other is that it reduces the average total cost of production.

Some other benefits of adopting technologies are that it leads to higher earning, lower poverty, improved nutritional status, lower staple food prices, and increase employment opportunities (Mwangi1 and Kariuki, 2015). Sarcheshmeh et.al (2018) also discussed some merits by stating that to attain the more productivity, profitability and sustainability in agriculture sector, there is need to develop and utilization of modern technologies that can derive through innovation and research in this sector.

2.4. Issues of Agriculture Sector:

Agriculture sector is considered as core sector of economy. In Pakistan, it is the back bone of the economy but this sector is facing many challenges. There is a huge gap between potential and actual productivity of crops in the developing countries such like Pakistan. Due to this gap the growth of agriculture sector is stagnant in these countries (Elahi et.al 2018). As Rehman et al. (2016) also claimed that in Pakistan there is huge gap between the potential and actual output due to lack of awareness about technology, unavailability of water and inadequate education. They argued that for the development of agriculture sector in Pakistan, govt should introduce new funding programme for the farmers. Mwangi1 & Kariuki (2015) discussed the main source of growth and development of agriculture sector is that to facilitate the smallholder farmers for the implementation of the new technologies.

As Khan et al. (2013) reported that there are some major issues in the largest contributing sector in economy of Pakistan that we have to resolve for the better performance of agriculture sector. These issues are water deficiency and drought conditions, lack of cooperation between agricultural research, lack of modern post-harvest technologies and many others. Abbas et al. (2017) asserted that in this modern era, there is a lot of innovation occurs and many technologies are available in agriculture sector of Pakistan but there is problem of lack of awareness. They suggested that there is need to develop a policy framework for the promotion of these energy saving technologies by using policy makes, researcher, local government and agricultural departments. There is need to introduce modern farming technologies by extension service to improve the socio-economic status of the farmers and to address the growth of population (Saqib and Tachibana, 2014)

Although, issues of Pakistan's agriculture sector was discussed but now there is a need to move towards the positive side and successful modern techniques of production that are using in this sector. The best example of green revolution was experienced by the Asian countries by adopting modern seed varieties, fertilizer, and mechanization techniques of agriculture production including solar energy (Mwangi1 and Kariuki, 2015).

2.5 Energy Crisis

Energy has vital role for the economy and consider as most important tool for socio-economic development. Realizing the important of energy during the period of Millennium Development Goals (MDGs) Koppinger et al. (2007) stated that to achieve MDGs, there was a need to facilitate the people of developing nation with the modern and efficient energy services. Basir et al. (2013) mentioned that energy supply is considered as essential to accelerate the economic development of the country by improving the agriculture, infrastructure and industry sectors. As far as concern of Pakistan, there is sever deficiency of energy due to high population growth rate, expensive energy imports, huge increase in energy demand and poor management.

It is assume that energy is the biggest problem of the world in next century. So there is need to find out the alternative sources of energy (Abbas et al., 2017) The shortage of energy is core issue for the economic development and environment sustainability in different parts of the world. Although living standard of the people is improving but 2.7 billion people is still using wood and other conventional solid fuels for cooking and heating. The statistics shows that 1.9 billion people of the sub-continent Asia rely on traditional biomass energy and kerosene for lighting (IEA, 2016)

Vergragt (2006) argued that the main source of sustainable development is energy. The current situation is that our energy system is based on fossil fuels. The use of fossil fuel in energy sector is unsustainable due to some threats like fast depletion of fossil fuels, of man-made climate change by greenhouse gas emissions, rapid increase in energy prices and instability in oil-dominant countries.

There is an energy crisis in Pakistan. There are many reasons of it as Khalil & Zaidi (2013) stated that one reason is old infrastructure of distribution companies. There is an energy loss due to heavy load on transmission lines and transformers. The report of energy bank of Pakistan mentioned that in 2010, 20% of the total electricity consumed by distribution loss so to eradicate these types of losses we should move towards the renewable energy likes solar energy.

2.6 Solar Energy

Yasar et al. (2017) discussed the source to solve the energy problem (which is considered as a main hurdle in sustainable development) is to install of solar plant. The findings show that many economical social and health benefits can be obtained by using the technology of solar energy because it reduces the cost of fuel and fertilizer a long with time saving and lessen cases of disease. The result shows that 53.3% energy expenditure was saved by using solar energy. Vergragt (2006) also suggested the solution of these arising problems is that we must be use renewable energy efficiently (based on sun, biomass and wind) and improvements in energy storage technologies like flywheels and batteries.

If we compare the two main sources of energy solar and conventional then different types of argument presented in the literature. These arguments are in favour of solar energy and against the usage of conventional source of energy like fossil fuels. Jabeen et al. (2014) found that the use of solar technology is economical and best option in this era where fossil fuel sources are running out and available at high cost. They found that solar energy utilization reduces environment pollution and improve the quality of life. A study stated that it is the most promising substitute for fossil fuel. In the beginning, when the first solar cell was made the price of it is very high but now it has been declined by 80% and it's efficiency has increased (Devabhaktuni et al., 2013). Due to continuous decreasing of the cost of solar cell people will be more interested in the application of photovoltaic system because it will improve their standard of living (Rao.et al., 2018). Mandelli et al., (2016) stated that solar off-grid system is proved very effective to improve the man's life in rural areas by providing the facilities of light and electricity to their homes, educational institutions and basic health units.

2.6.1 Potential of solar energy in Pakistan

Pakistan is luckiest country which has a lot of power potential blessed by nature. The estimated solar power potential is $3.0 * 10^6$ MV of an economic year. It is also figured out that in the area of southern Punjab, Sindh and Bolochistan we can produced 45-83 MW power per month by using solar irradiance (Adnan et al., 2012).

Tahir & Asim (2018) claimed that geographical location and climatic conditions of Pakistan supported for the high potential of solar energy. This potential indicates that there is urgent need to take initiative for the solar projects. Mirza et al. (2003) mentioned that Pakistan should adopt the solar technology not only in remote areas but in many sectors in the country like agriculture and industry because it is proved as environment friendly energy source, will improve people's living standard and reduce the usage of fossil fuels (that will decrease the oil import bill). Basir et al. (2013) found that District Multan and Dera ghazi khan are the best location for installing the solar photovoltaic power plant.

2.6.2 Impact of solar energy on environment

If we talk about the demerits of usage of fossil fuels so Shahsavari &Akbari, (2018) mentioned that rapid growth of population in developing countries leads to serious problems like poverty, pollution and health issues. It also stimulates the demand for energy from fossil fuel which became cause of air pollution and greenhouse gas (GHG) emission. They suggested that to eradicate these issues there is need to enhance the use of solar energy which have not any negative impact on environment and health. The statistics shows that 80% carbon dioxide and two-third (GHG) emission is due to the production and usage of conventional energy in the world (EIA, 2015). Sims et al. (2007) stated that the use of fossil fuels increases carbon-dioxide emission which is a threat for the climate. This shows that, increase in installed capacity of fossil fuel based power plants also increases the pollution level.

2.6.3 Solar energy in agriculture sector

Mekhilef et al. (2012) stated that agricultural technologies that are based on solar energy are more reliable, feasible and environmental clean technologies. Sher et al. (2015) stated that the use of solar PV plants in the rural area will improve the agricultural productivity as well as living standard of the people of these areas.

Shahsavari & Akbari (2018) explored that solar energy have a great potential for overcoming the energy shortage for the rapid growing population and improve the living standard because solar energy is beneficial for environment zero air pollution as compare to conventional energy sources. Every 1GW of extra renewable energy has potential to reduce carbon dioxide emissions, on average, by 3.3 million tons each year (IEA, 2015)

Bhutto et al. (2012) found that in the remote areas, solar is proved as a successful source of energy because other sources carried many problems like grid power have problem of frequent disruption and there is also high transmission and distribution losses in it. As MINES (2008) mentioned that most parts of remote areas in India are now electrified with renewable energy technologies like solar which improve the quality of life of the people.

2.6.4 Use of solar energy for irrigation purposes

Irrigation is compulsory for the agriculture sectors. Farmers use different tools for the irrigation. Hassanien et al. (2016) mentioned that from last decade to till now there is massive increase in the prices of gasoline and fossil fuel which is 250% while rapid decrease in the prices of photovoltaic solar based water pump which is 80%. So the farmers are moving towards the use of solar water pump due to no operating cost and high efficiency. Moreover solar technologies are proved as environment friendly and increase the land productivity.

The use of solar energy in agriculture sector is also considered as very beneficial especially for the irrigation system. Solar energy which is use for the irrigation in agriculture has potential to improve crop production and efficiently water usage Mekhilef et al., (2012). Kelley et al., (2010); Glasnovic & Margeta (2011) analysed that feasibility of solar irrigation system is affected by some factors like as type of crop, type of soil, irrigation area, climate condition, depth and the rate of recharging water. Some studies postulate that solar irrigation system is applicable where low power needed. It means that these pumps are installed for the low flow rate from deep wells.

2.6.5 Solar water pump

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 lowMehmood 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.

2.6.6 Demerits of solar energy

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.

2.6.7 Recommendations for the development of solar energy

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.

2.7 Research Gap

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.

CHAPTER III

Research Methodology

To establish the link of variables affecting livelihood, a number of variables are selected. The purpose is to compute the significance of solar energy on the livelihood of the people in District Vehari. It is well established that social and economic impact of solar energy on the livelihood of people will be the key focus of this study. To prove this linkage of livelihoods and solar energy structure equation model (SEM) was used as an estimation technique in the study.

3.1 Model and Estimation Techniques

To establish the link of variables affecting livelihood, a number of variables were selected (Discussed in section 3.2). The purpose is to compute the significance of solar energy on the livelihood of the people in District Vehari. It is well established that social and economic impact of solar energy on the livelihood of people will be the key focus of this study.

3.2 Econometric Methodology

Structure equation model (SEM) is used to analyse the relationship among the variables, having complex and diverse orientation. For example, the use of solar energy saves money and this saving causes an increase in education expenses and improvement in health simultaneously. "SEM is a set of equation that can be applied to experimental and non-experimental data. This equation can be applied in all fields of psychology, marketing and social science etc. it is a set of simultaneous equation which is useful for observed and unobserved variables" (Kline, 2011). Structural equation modeling is statistical modeling technique and mainly used to deal with latent variables, SEM is widely used to investigate hidden patterns of cause and effect among different variables.

Wright (1921) introduced SEM or path analysis to investigate cause and effects phenomenon based on theoretical assumptions and statistical data. SEM is not a single equation econometric technique; it connects all possible channels among variables whether observed or unobserved. Its ability to take into account latent variables (also modeling various forms of measurement error) and to check validity of multiple theories makes it useful for a plethora of research problems. Pearl (2009) concluded that SEM provides valid results and satisfies cause and effect questions under theoretical framework. Economic phenomenon's are elusive in nature and often cannot be fully captured in a single equation model. That` why SEM is preferred over single equation model to get better and valid results

There are two types of SEM: covariance- and variance-based SEM. This study used variance-based SEM method. McDonald (1996) explains that Partial least squares (PLS) come under variance-based SEM methods which is regarded as "most fully developed and general system. PLS-SEM first creates proxies as linear combinations of observed variables, and then estimates the model parameters using these proxies.

Structural equation modeling is divided in to two parts: one of them is confirmatory factor analysis, in which we usually intended to compute factors loadings of observed indicators which form latent variables. In econometrics, it is commonly called measurement model. Another, part is structural regression model in which we specify relationships between latent variables and causal dependencies (direct and indirect). Model fitness is assessed by using comparative fit index (CFI), Chi square value and root mean square error of approximation (RMSEA).

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.

3.2.1 Structural regression model

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.

$$\mathbf{FLH} = \alpha_1 SEW + \varepsilon_1 \quad (1)$$

$$SE = \beta_1 TI + \beta_2 ADP + \beta_3 HE + \varepsilon_2 \quad (2)$$

$$SEW = \gamma_1 SE + \gamma_2 HE + \gamma_3 TI + \varepsilon_3 \quad (3)$$

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

3.2.2 Measurement model

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:

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

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

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

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

3.2.3 Specification of variables

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

3.2.4 Exogenous variable

Following variables are considered as exogenous variable in this model.

(i) 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.

(ii) Total income (TI)

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

(iii) Highest education in the family (HE)

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

(iv) 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".

(v) 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".

3.2.5 Socio-economic well-being indicators

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

(i) Saving (SAV)

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

(ii) 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.

(iii) 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".

(iv) 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"

3.2.6 Farmer livelihood asset

Following are the assets of farmer livelihood.

(i) Human capital (HC)

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

(ii) 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.

(iii) Natural capital (NC)

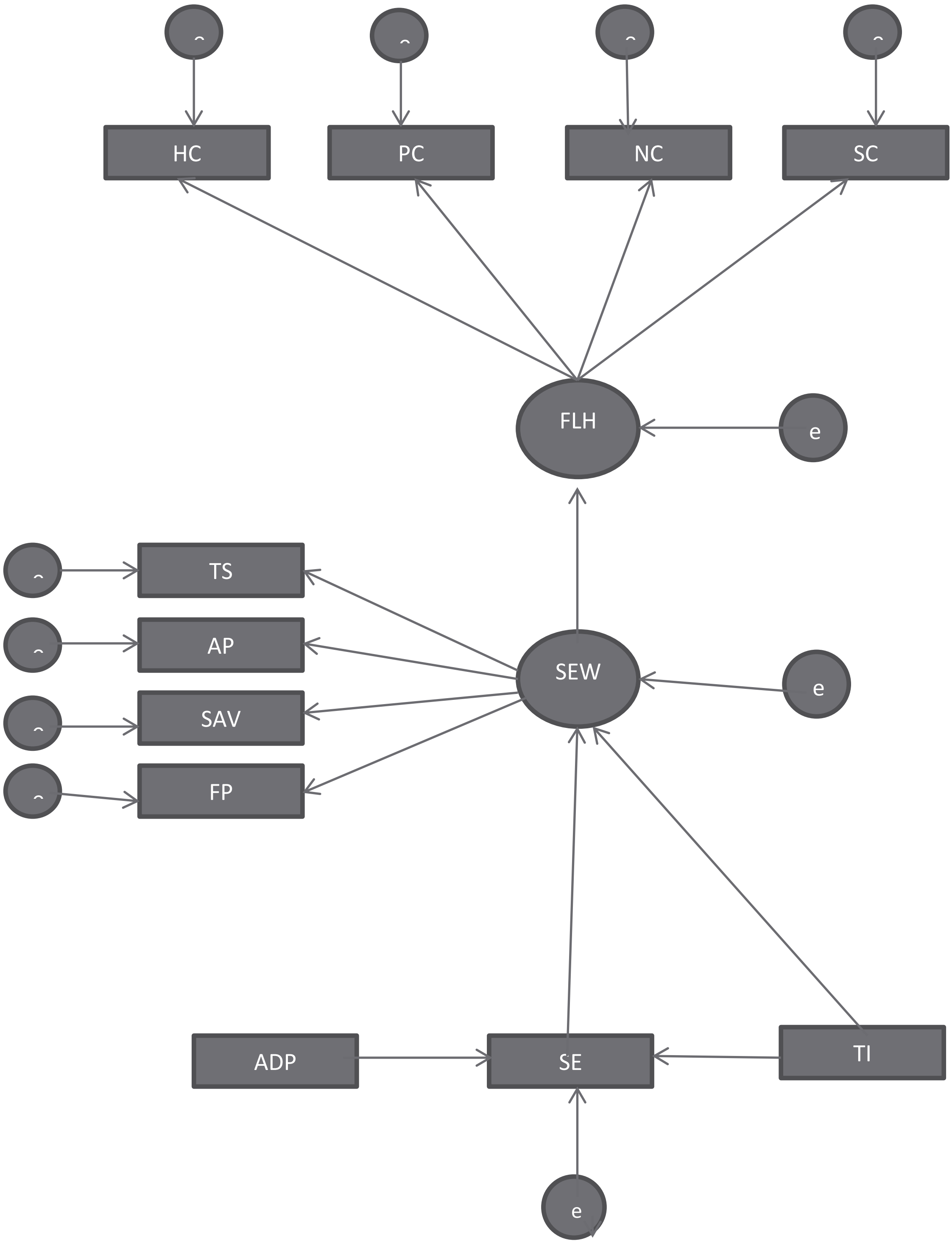
This is a output variable. It is calculated on the basis of per capita area of cultivated land

(iv) 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 3.1: Theoretical path is shown in diagram.



In above diagram, 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 diagram 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 3.1: Definition, Expected sign and Abbreviation of Variables/Indicators.

Sr. No.	Abbreviat-Ion	Variable	Definition	Expected Sign	Reference
1.	SAV	Saving	Saving on fuel and other expenditure/ Rs./month.	+ or -	Challa (2013), Rao et al. (2018), and Mekhilef et al. (2012) stated + tive impact, while Jafar (2000) and Rao et al. (2018) showed - tive impact and high installation cost.
2.	FP	Farm product-ivity	Income from farm yield/ acre/ year.	+	Sarcheshmeh et.al (2018) and Sher et al. (2015)
3.	AP	Air pollution	Diseases due to air pollution.	-	Jabeen et al. (2014), Yasar et al. (2017), Shahsavari & Akbari, (2018) and Mekhilef et al. (2012)
4.	TS	Time saving	Maintenance and supply of fuel	+	Yasar et al. (2017)
5.	HC	Human capital	Children getting an education < age 25.	+	Mandelli et al., (2016), Sher et al. (2015), Shahsavari & Akbari (2018), MINES (2008) and Mehmood et al. (2015) .
6.	FC	Financial capital	Saving expenditure	+	Rao.et al. (2018), Challa (2013) and Mehmood et al. (2015) ,
7.	PC	Physical capital	Current values of assets (Rs.)	+	Mehmood et al. (2015)
8.	NC	Natural capital	Per capita area of cultivated land	+	Mehmood et al. (2015)
9.	SC	Social capital	Output and dummy variable. NGO member or not	+	

3.3 Sampling Framework

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.

3.4 Household Survey

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 a large number of 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 implication.

3.5 Data Analysis

The data has 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.

3.6 Limitation of the Study

The study has been conducted carefully keeping in mind the consideration and intended objectives of the research. Therefore, there is some limitation. The research will be comprised of quantitative approach and all the results are based on the response of Household representatives subject to designed structured and semi-structured questions. There were also time and resource constraints as well. The sample size is also limited and better results can be get by increasing the sample size. The study is limited to only one District of Punjab, Pakistan.

CHAPTER IV

Results and Discussions

In this chapter 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" In section 4.1 there is demographic analysis, section 4.2 covers the estimates of measurement model and section 4.3 deals with the estimation of structural model.

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 4.1)

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 4.1)

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 4.1)

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 4.1)

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 4.1: 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 Descriptive statistics

Descriptive statistics of data set in this study is shown in table A given in appendix. It possesses the mean, standard deviation, maximum, minimum and statistics of all latent variables and their indicators. From all the variables only Total income is continuous variable thats why it mean and standard deviation is containing very large value. Other variables are treated as dummy variable having ordinal scale.

4.3 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 as discussed in chapter 3, section 3.2.

4.3.1 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 4.2). 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 4.2: Reliability of the latent construct.

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

4.3.2 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 4.3 gives the value of AVEs of all constructs and the actual estimation of all the indicators associated with specific construct (Table 4.4).

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 4.3 depict the square root of average variance extracted (AVEs) and correlation between these two latent variables (Table 4.4). We can observe that values of AVEs are greater than correlation between two constructs which ensure discriminant validity.

Table 4.3: 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 4.4: 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 4.5).

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 4.5: 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

4.4 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.

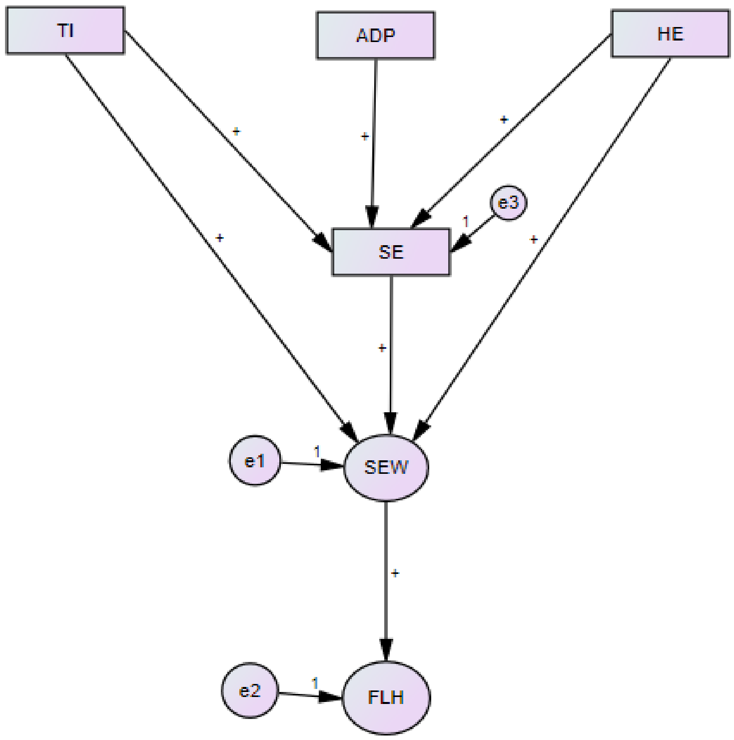


Fig. 4.1 The initial path diagram

Table 4.6: 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 4.1, there are three endogenous variables: farmer livelihood (FLH), socio-economic well-being (SEW) and solar energy (SE). The definition of all these variables has already mentioned is chapter 3 section 3.2. 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 4.6). 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.

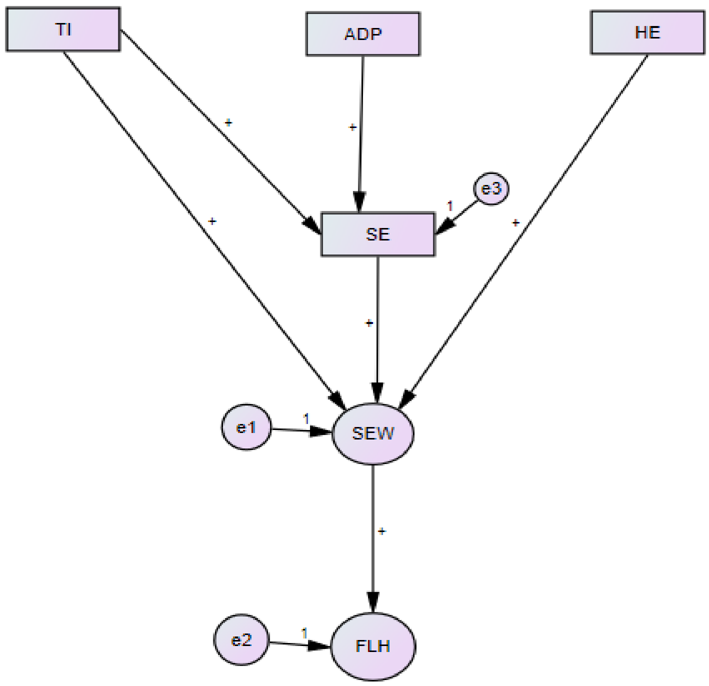


Fig. 4.2 The Finall path diagram

Table 4.7: 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 4.2. 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 4.7).

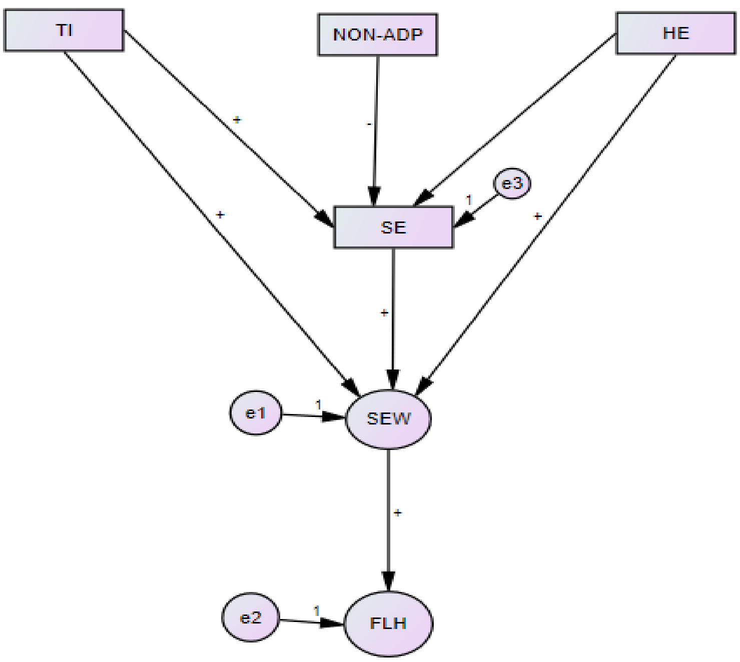


Fig. 4.3 The initial path diagram

Table 4.8: 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 4.3 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 4.8).

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 4.9).

Table 4.9: 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 4.9). So HE will be dropped in order to make model more parsimonious.

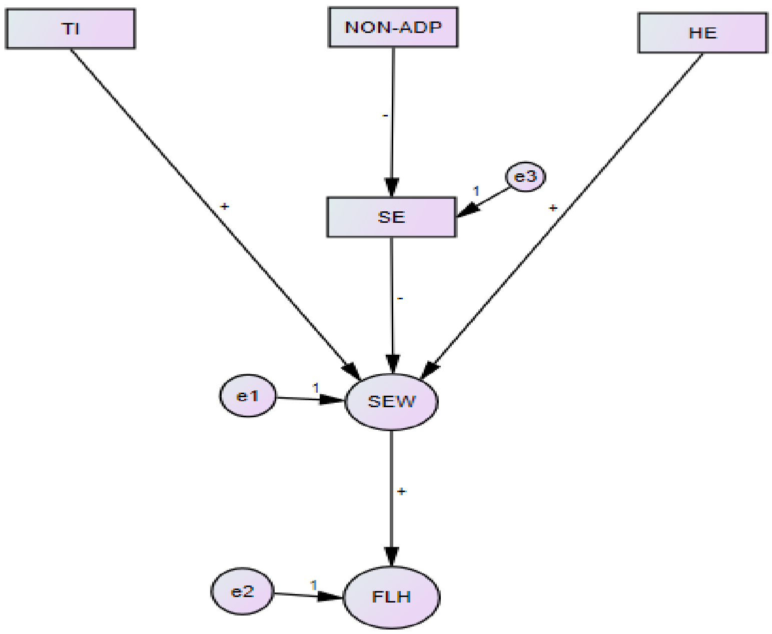


Fig. 4.4 The final path diagram

Table 4.10: 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 4.10).

4.4.1 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 our 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 4.11).

Table 4.11: 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 consider as total effect of it (Table 4.12).

Table 4.12: 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

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 4.13).

Table 4.13: 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 4.14 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 4.14: 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.

CHAPTER V

Conclusion and Recommendation

This chapter is divided into two sections. Section 1 described the conclusion of study and section 2 policy recommendations.

5.1 Conclusion

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.

5.2 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:
    1. Government should provide subsidized installation of solar plant.
    2. 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.
    3. Government should introduce the scheme of renewable energy credits. A user of solar energy can supply the extra energy to main stream of grid station and can earn reasonable profit.

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Appendix

Questionnaire

Name of respondent

Socio-Economic Profile of the Respondent

1. Age ______________________Years

2. Gender (a) Male ((b) Female

3. Year of schooling ______________________Years

4. Highest education in HH?

5. Household size?

6. How many acres do you have?
Total Land ______________Acres Cultivated Land _____________ Acres
Sowing within a year_____________ No.

7. Main source of family income
(i) Agriculture (ii) Business (iii) Skilled (iv) Remittances
(v) Other specified

8. Monthly income in PKR ______________________Rs/Month

Mediators

9. Do you install a solar panel?
(a) Yes (b) No

10. For what purpose you install the solar panel?

(a) For irrigation (b) For light (c) Both (d) Other (specify)

11. Cost of solar panel:

Cost type	**RS**
Installation Cost	
	RS (in month)
Operating Cost	
Fuel	
Maintenance Cost	
Labour Cost	
Permanent labour cost	
Temporary labour cost	
Kind payment to labour	

12. Cost of other sources of irrigation before installing solar panels:

Cost type	**RS**
Installation Cost	
	RS (in month)
Operating Cost	
Fuel	
Maintenance Cost	
Labour Cost	
Permanent labour cost	
Temporary labour cost	
Kind payment to labour	

13. What are the reason for installing the solar panel

Reason factor	Most important factor =1 Least important factor = 5				
Non availability of other irrigation sources	1	2	3	4	5
Economic benefits	1	2	3	4	5
Motivation from other farmer who have installed solar panel	1	2	3	4	5
The Subsidy provided by the program	1	2	3	4	5

14. Reasons for not using the solar energy

Reason factor	Most important factor =1 Least important factor = 5				
High cost of installation	1	2	3	4	5
Haven't any economic benefits	1	2	3	4	5

Not successful in my area	1	2	3	4	5
Someone told you that it is not beneficial	1	2	3	4	5
Waiting for subsidy	1	2	3	4	5

15. How many acres are irrigated with and without installing the solar panels

______________No. of acres was irrigated before installing

______________No. of acres are irrigated after installing

16. Does Solar Panel save your drudgery time? Which were spent on taking fuel for generator/tractor? (a) Yes (b) No

17. If yes then how many hours are saved?
___________Hours

18. Where do you spend your saved time?
(a) To generate more income from other sources (b) For the welfare of the society (c) Take rest /Do nothing (d) other (specify)

19. What type of fuel you use if solar panel is not installed
(a) Electricity (b) Petrol (c) diesel (d) LPG

20. How much time do you spend in irrigation and other activities per day? (minutes)
(a) 1-15 (b) 16-30 (c) 31-45 (d) 46-60

21. Is the water that you take from solar pump is sufficient for the irrigation of your crop? Yes/No

22. If yes, then what is the use of extra water?
(a) Supply to the neighbourhood (b) Sale the water (c) Do nothing (d) Other (specify)

23. Is your social relationship improved with the people of society after installing the solar panel?

	Most improved =1 Least improved = 5				
How much it has improved	1	2	3	4	5

24. Is there alternative use of solar panels for light? (a) Yes (b) No

25. If yes then how many hours do you allocate light for these purposes

Purpose	**Time (hours)**
Reading/Writing	
Media (TV/Radio)	
Mobile Charging	
Social meetings (gossip)	

26. How many times you/ your family member visit the hospital in month?

(a) 0-1 (b) 1-2 (c) 2-3 (d) 3-4

27. Is any family member is suffering from any following disease?

	Before installing Solar Panel	After installing Solar Panel
Asthma	Yes/No	Yes/No
Headache	Yes/No	Yes/No
Eye burning infection	Yes/No	Yes/No
Skin infection	Yes/No	Yes/No
Other (specify)	Yes/No	Yes/No

28. Do you think that the use of solar energy has any effect on your health?

(i) Positive (ii) Negative (iii) No effect

Livelihood asset

29. How much you are satisfied with the condition of human capital of you and yours family?

	Most satisfied =1 Least satisfied = 5				
Education	1	2	3	4	5
Health	1	2	3	4	5
Others	1	2	3	4	5

30. Total income that you earned from farm productivity? (Monthly) (In rupees)

Before using solar pump	After using solar pump

31. How much are you satisfied with current status of your farm productivity?

	Most satisfied =1 Least satisfied = 5				
Farm productivity	1	2	3	4	5

32. How much expenditure (operating cost) for irrigation you have to bear before and after using solar energy? (Monthly) (In rupees)

Before	After

33. What is the current value of your physical capital?

Assets	Current value (in rupees)
Tractor	
Machinery	
Car	
Others	

34. What is the current value of your natural capital?

Assets	Current value (in rupees)
Agri. Land	
Livestock	
Others	

35. Allocation of saved money on physical capital? (users, non-users)

	Mostly allocated=1 Least allocated = 5				
Tractor	1	2	3	4	5
Machinery	1	2	3	4	5
Car	1	2	3	4	5
Others	1	2	3	4	5

36. Allocation of saved money on natural capital? (users, non-users)

	Mostly allocated=1 Least allocated = 5				
Agri. Land	1	2	3	4	5
Livestock	1	2	3	4	5
Others	1	2	3	4	5

Table A: Descriptive Statistics

Variable	N	Mean	S.D.	S.D./Mean	Min.	Max.
Solar energy	116	0.33	0.47	1.42	0.00	1.00
Social capital	116	2.71	1.02	0.38	1.00	5.00
Time saving	116	0.27	0.45	1.65	0.00	1.00
Air polution	116	2.38	0.82	0.34	1.00	5.00
Savings	116	1.70	0.69	0.41	1.00	3.00
Farm productivity	116	3.14	0.97	0.31	1.00	5.00
Total income	116	91005.75	36073.54	0.40	40000.00	210000
Highest education	116	14.59	1.47	0.10	12.00	16.00
Human capital	116	2.45	0.63	0.26	1.00	4.00
Physical capital	116	3.54	0.76	0.21	1.67	5.00
Natural capital	116	3.69	0.86	0.23	1.67	5.00
Adoption	58	3.36	0.34	0.10	2.75	4.00
Non-adoption	58	3.15	0.56	0.18	1.75	4.50

Table: B bootstrapping outcome of model fittings

Following table gives the overall model fitting scenario compared with values generated from simulation. Chi square value in our proposed model lies in the range of following table.

ML discrepancy (implied vs sample) (Default model)

		--
	13.236	*
	16.269	***
	19.954	******
	22.130	*******************
N=1000	26.237	****************
Mean = 43.30	34.354	******************
	41.393	************
S. e. = 6.81	45.917	*********
	53.249	******
	57.192	***
	63.866	**
	77.104	**
	92.121	*
		--