# Chapter 7
# Human Capital, Green Energy, and Technological Innovations: Firm-Level Analysis

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**Abstract** The study had three overarching objectives. The first aim of the study was to comprehensively review the role that a firm's human capital played in promoting energy efficiency and green energy. Second aim was to review the role of technological innovation in the relationship between a firm's human capital and energy consumption (green and non-green). Third aim was to provide any empirical evidence on the relationship between human capital and energy consumption keeping technological innovation as moderator. After reviewing the literature, we developed two equations to examine the quadratic relationship between HC and energy consumption by taking technological innovation as a moderating variable. Pakistan's manufacturing sector was taken as a case, and data from 635 manufacturing firms were used for analysis. The study employed the panel feasible generalized square approach for the analysis. The results confirmed the existence of EKC-type inverted U-shape relationship between HC and non-green energy and an inverted U-shape curve in the relationship of HC and green energy consumption. Our results concurred broadly with the other studies conducted on the HC-energy consumption dyad. Our findings imply that industries with a higher level of HC and technology innovation can quickly substitute non-green energy with green energy consumption.

**Keywords** Human capital · Green energy · Non-green energy · Panel feasible generalized square · Quadratic relationship · EKC

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## 7.1 Introduction

It is a proven fact that energy plays a critical role in the industrial development of nations. However, what are the various sources of that energy is a key concern worldwide. Due to the devastating effects of non-green energy (non-renewable energy) on the environment, it is being globally emphasized to substitute it with green energy (renewable energy). In Paris accord, leaders from all the nations agreed to take the sustainable measures to decrease the global temperature to the level of the pre-industrialization era (Salim et al. 2017; IPCC 2014). Firms in every country are facing the increasing pressures to either abandon or reduce their dependence upon non-green energy and switch toward the consumption of green energy. To do so, a number of firms are revisiting their energy policies and trying to take all the possible measures to reduce the non-green energy consumption. Firms are considering both external and internal factors to go green. Human capital (HC), in this context, is appearing as a critical internal factor of a firm that profoundly influences a firm's energy consumption patterns (Lutz et al. 2014). Researchers (e.g., Munro and Lan 2013; Shahbaz et al. 2018) consider HC a major precursor for reducing the non-green energy consumption and turn a firm sustainable. Munro and Lan (2013) argue that a firm's human capital—Munro and Lan (2013) termed it internal human capital—pushes it to use green energy. Studies (e.g., Wheeler and Pargal 1999; Dasgupta et al. 2000; Goldarand and Banerjee 2004; Munro and Lan 2013; Lee et al. 2015; Shahbaz et al. 2018) argue that human capital has a profound effect on a firm's energy consumption. These studies explain that organizations with a higher level of human capital tend to adopt those technologies which are energy efficient and are compatible with green energy sources. Further, the firms with a higher level of human capital may have a higher tendency to use green energy.

Surprisingly, a great body of literature focuses upon the association of human capital and energy consumption at a macro level; however, this relationship has been lesser discussed at the firm level. Particularly, the question as to how human capital development is linked with the consumption of renewable energy is yet to be addressed. Anecdotal evidence and inferences from macro literature (Shahbaz et al. 2018, 2019) suggest a U-shape relationship between human capital and green energy[1] consumption and inverted U-shape between human capital and non-renewable energy consumption. Nevertheless, it is hard to find any scholastic work explicitly studying these relationships at the firm level. This may be one of the reasons that firm-level policies on green energy hardly take into account this paradox. Against this backdrop, we argue that without knowing as to how the green and non-green energy consumption will increase in response to an increase in the human capital of a firm, all the efforts to turn a firm green may not be truly fruitful. This book chapter undertakes this task and doing so contributes to the literature on green energy in the following ways. First, the chapter elucidates on the impacts of a firm's human capital on its energy consumption (both green and non-green). Second, it integrates the work on human

[1] From here onward word "green energy" will be used as substitute of renewable energy, until unless specified.

capital at macro-level with firm-level literature and presents a model to study the association between human capital and energy consumption (green and non-green). Thirdly, the study examines the role of technological innovation in the relationship between human capital and energy consumption. Fourthly, by taking Pakistan as a case, the study provides the empirical evidence on modeled relationships.

The rest of the chapter has been divided into four sections. The subsequent section reviews the literature on human capital, energy consumption, and technological innovation. Section 7.3, methodology, undertakes the research methodology applied to test the proposed framework. The last section concludes the chapter by providing theoretical, managerial, and policy implications.

## 7.2 Literature Review

### *7.2.1 Green Energy and Human Capital*

Human capital is an essential factor that influences both the demand and supply of energy (green and non-green) in an organization. A number of researchers (e.g., Gangadharan 2006; Blackman and Kildegaard 2010; Manderson and Kneller 2012) argue that an increase in human capital leads to increase consumption of green energy and tends to decrease the consumption of non-green energy. For example, Blackman and Kildegaard (2010), using firm-level data, consider the human capital one of the major factors influencing to firm's choice of technologies. They showed that Mexican firms with a higher level of human capital preferred adopting clean and energy-efficient technologies. In such a case, an increase in the level of human capital tends to decrease the non-green energy consumption. Their argument is rooted in the fact that better-educated workers could be more instrumental in adopting the energy efficiency practices and policies. Contrarily, according to Özçiçek and Ağpak (2017), employees with low human capital (unskilled and low-educated) may possess insensitive behavior toward green energy consumption and may act as a barrier to energy efficiency. On the same lines, Manderson and Kneller (2012) assert that organizations with a greater stock of human capital tend to use the technologies which are energy efficient, compatible with green energy usage, and abate pollution.

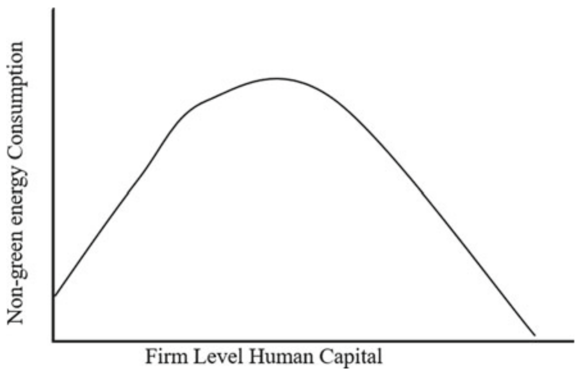
Nevertheless, some of the studies (e.g., Fang and Chen 2017; Shahbaz et al. 2019) claim that an increase in human capital increases the consumption of non-green energy. They argue that increasing levels of human capital requires to undertake more tasks requiring more energy to consume. Since the immediate, accessible, and cheaper source of energy is non-green, it is used to meet the increase in energy demand.

Further, some of the researchers (e.g., Kargbo et al. 2016; Fang and Chen 2017) assert that human capital also affects a firm's supply of green energy. Kargbo et al. (2016) mention that the quality of human capital along with financial development and technological management plays a critical role in a firm's supply of green energy.

They claim that firms in large sizes have the capacity to develop green energy generation systems coherent to their needs by collaborating with the local green energy industry. In doing so, these firms can take lead in the drive toward greenness through green energy innovation. After reviewing the literature on human capital and energy consumption, we can find a few major research gaps. First, the majority of the studies discussing human capital-energy association do not differentiate between the firm-level and country-level human capital. These studies generalize the results obtained using the national or cross-national data on the firm-level human capital. In reality, the crude generalization of these results is not only risky but can lead firms toward the ineffective policy formulation and execution. Second, researchers studying the HC-energy association can be divided into two groups. First, the group of researchers claims that the increase in human capital increases the consumption of non-green energy as the increasing levels of HC require to undertake new tasks, which require energy consumption. The immediate, cheaper, and accessible source of energy is non-green energy which is then used to perform new tasks. This leads to an increase in the consumption of energy. The second group of researchers claims that increasing levels of human capital lead to an increase in environmental awareness, knowledge, and skills. It helps organizations to be energy efficient and to substitute the non-green energy consumption with that of green energy. Researchers (Ahmed et al. 2016; Shahbaz et al. 2018) argue that environmental awareness among employees makes tend to change their energy consumption behavior. Employees with higher human capital consume energy more efficiently and also push the organization to adopt green energy. Such employees can also be instrumental in adopting technologies that are more energy efficient and compatible with green energy sources.

The apparently contrasting findings of the studies cited above require referring back to the environmental Kuznets curve (EKC) of Grossman and Krueger (1991). For EKC, the association between environmental degradation and economic development is an inverted U shape. Here, we claim that the relationship between firm-level human capital and the non-green energy consumption is inverted U-shape (Fig. 7.1). It implies that with the increase in a firm's human capital, its consumption of non-green energy increases at the initial stage. After a specific turning point, the consumption

**Fig. 7.1** Firm-level human capital and non-green energy consumption. *Source* author



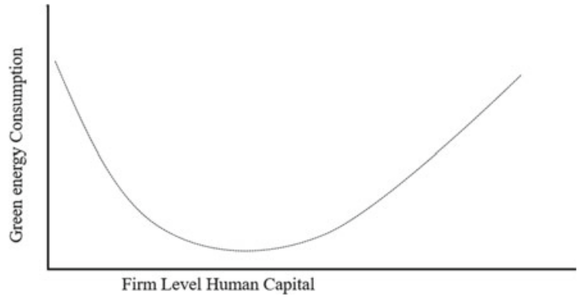



**Fig. 7.2** Firm-level human capital and green energy consumption. *Source* author

of non-green energy tends to decrease with every unit increase in a firm's human capital. Further, we claim that the association between a firm's human capital and green energy is U-shape (Fig. 7.2). It implies that at the initial stage, an increase in human capital decreases the proportion of green energy consumption in total energy consumption. After a specific turning point, this relationship becomes direct.

### *7.2.2 Technological Innovation in Energy-Human Capital Dyad*

For the promotion of energy efficiency and green energy, three important factors are required to be looked at. These are human behavioral issues, appliances (technology), and design (Hussaini and Majid 2014). Human capital in interaction with technological innovation can profoundly overcome these three important issues. First, a higher level of human capital—education, awareness, skills, ability—makes employees aware as to why the energy efficiency and shift toward green energy are essential required. By developing employees green behaviors, it overcomes the behavioral issues. Second, the dyad of human capital-technological innovation results in energy effects and green energy compatible technology and designs.

Third, human capital in interaction with technological innovation could produce renewable energy at low costs, which in turn causes energy efficiency. The literature on energy efficiency applauds the role that technological innovation pays in reducing the consumption of non-green energy; however, it becomes more effective when interacting with human capital. This greatly influences firms to shift toward energy-efficient technologies and adopting green energy sources (Li and Lin 2016; Kalim et al. 2019). For Li and Lin (2016), human capital through higher R&D for the latest green energy sources may lead to a quick shift to energy-efficient technologies. Particularly, education being the central dimensions of human capital augments human resources learning capacities, awareness, technological adoption, and innovation. Therefore, individuals possessing a higher level of education may tend to adopt green technological innovations. This may increase the usage of green energy.

Human capital in interaction with technological innovation affects both demand and supply side of green energy. Seetharaman et al. (2016) underscore the lack of human capital and technological innovation as the major hurdles in the way of green energy adoption. Concurring to Seetharman et al. (2016), Shove (2017) mentioned the lack of human capital (measured as knowledge) and a lesser understanding of green energy technologies as the major reasons for inadequate demand of green energy.

From the supply-side perspective, the juxtaposition of HC and the supply of green energy depends upon technological development and innovation capacity and the ability to manage technology diffusion. From a broader perspective, the triad of human capital, technological innovation, and green energy goes hand-in-hand. Where improved human capital may increase the level of innovations, there higher level of technological innovation may result in the consumption of green energy.

Putting together, the literature on the role of technological innovation (e.g., International Energy Agency 2008; Fisher-Vaden et al. 2004; Ke et al. 2013; Li and Lin 2016; Wilson and Tyfield 2018; Kalim et al. 2019) argues that technological innovation influences the human capital's energy consumption patterns. It leads us to draw the argument that technological innovation plays a profound role as a context in HC-energy (non-green and green) consumption patterns.

## 7.3 Model and Variables

We have developed the following two models to analyze the relationship of human capital with energy consumption (green and non-green) (Table 7.1).

$$\begin{aligned} NRE_{it} = \beta + \delta_1 HCI_{it} + \delta_2 HCI^2_{it_2} + \delta_3 HCI * TIN_{it} \\ + \delta_4 XCH_{it} + \delta_5 OP_{it} + \varnothing_{it} \end{aligned} \tag{7.1}$$

$$RE_{it} = \beta + \delta_1 HCI_{it} + \delta_2\, HCI^2_{it_2} + \delta_3 HCI * TIN_{it} + \delta_4 XCH_{it} + \delta_5 OP_{it} + \varnothing_{it} \tag{7.2}$$

### *7.3.1 Data*

We collected the firm-level data from 635 manufacturing sector firms for the last 04 years 2014–2018. The data of these firms are collected each year by Mohammad Ali Jinnah University, Pakistan's Business Research Centre (Table 7.2).

**Table 7.1** Measurement of variables

| Variable | Measurement | Past researches |
|---|---|---|
| Renewable energy consumption | Share of renewable energy in the total final energy consumption (% of total energy consumption) | Hanif et al. (2019) |
| Non-renewable energy consumption | Share of non-renewable energy (such as fossil fuel) in the total final energy consumption (% of total energy consumption) | Hanif et al. (2019) |
| Human Capital Index | Average of employees related experience, education, number of training received in a year | Mubarik (2015), Mubarik et al. (2018) |
| Technology innovation | Average of number of new products introduced in the market, number of patents registered, total patent applications counts | Mubarik (2015), Li et al. (2013), Smith et al. (2005) |
| Firm size | Log of number of employees | |

**Table 7.2** Breakup of sample

| Industry | Number | % |
|---|---|---|
| Textile | 188 | 30 |
| Leather | 125 | 20 |
| Food | 139 | 22 |
| Small-scale engineering | 101 | 16 |
| Sports | 82 | 13 |
| Total | 635 | |

## *7.3.2 Method*

We applied panel FGLS (feasible generalized square) model to estimate the developed equations. In panel FGLS, changes in the standard errors are used to incorporate the variances in the cross sections (Davidson and MacKinnon 1993). The performance of FGLS to control heteroscedasticity is robust as compared to other peer models like panel random effect or panel fixed effect model (Hassan et al. 2019). Likewise, due to the modification in standard errors of cross sections, FGLS could be improved to better control the issues of heteroscedasticity and autocorrelation. Below is the mathematical representation of the model:

$$\alpha_{FGLS} = (Y'\varnothing^{-1}Y)^{-1}Y'\varnothing^{-1}z$$

$$Var(\alpha_{FGLS}) = (Y'\varnothing^{-1}Y)^{-1}$$

$$\varnothing = \sum_{n*n} \otimes M_{K_i x K_i}$$

$$\sum_{i,k} = \partial_i \partial_k / T$$

*Here, ∅ is adjusted to include heteroscedasticity and autocorrelation, while computing the coefficients and their standard errors.*

## 7.4 Results and Discussion

FGLS results are exhibited in Tables 7.3 and 7.4. The results of the Wald test confirm the fitness of both models (renewable and renewable). Looking into the positive intercept of renewable energy and the negative intercept of non-renewable energy, it can be easily inferred that the manufacturing sector of Pakistan is shifting toward the usage of renewable energy sources. This can be further triangulated with the fact that a considerable number of textile and leather factories are trying to shift their ancillary activities on renewable energy sources. Further, in case of the role of human capital forms, an inverted U-shape curve as the sign of HCI is positive and the sign of $HCI^2$ is negative. It shows that increasing human capital first increases the consumption of non-renewable energy sources, and then, after a threshold point, it tends to decrease

**Table 7.3** Renewable energy

| Variable(s) | Total sample | By industry | | | | | |
|---|---|---|---|---|---|---|---|
| | | Textile | Leather | Food | Sports | Metal | Furniture |
| C | 124.31 (0.000) | 54.88 (0.000) | 93.27 (0.000) | 103.29 (0.000) | 219 (0.000) | 145 (0.000) | 176.25 (0.000) |
| HCI | −1.21 (0.000) | −0.49 (0.000) | −0.41 (0.000) | −0.61 (0.000) | −0.45 (0.001) | −0.89 (0.000) | −0.74 (0.000) |
| HCI square | 0.19 (0.000) | 0.17 (0.000) | 0.09 (0.000) | 0.14 (0.000) | 0.08 (0.000) | 0.06 (0.001) | 0.03 (0.000) |
| HCI*TIN | 0.07 (0.001) | 0.08 (0.000) | 0.04 (0.008) | 0.18 (0.000) | 0.06 (0.001) | 0.05 (0.004) | 0.1 (0.071) |
| Size | 0.12 (0.000) | 0.22 (0.000) | 0.09 (0.001) | 0.18 (0.000) | 0.09 (0.001) | 0.13 (0.000) | 0.05 (0.041) |
| R square | 0.76 | 0.77 | 0.63 | 0.71 | 0.58 | 0.55 | 0.67 |
| Wald test | 64.21 (0.000) | 82.5 (0.000) | 59.21 (0.000) | 69.35 (0.000) | 52 (0.000) | 49.9 (0.000) | 67.28 (0.000) |

**Table 7.4** Non-renewable energy

| Variable(s) | Total sample | By industry | | | | | |
|---|---|---|---|---|---|---|---|
| | | Textile | Leather | Food | Sports | Metal | Furniture |
| C | −3.12 (0.000) | −1.98 (0.000) | −2.14 (0.000) | −2.86 (0.000) | −2.45 (0.000) | −3.54 (0.000) | −2.74 (0.000) |
| HCI | 1.76 (0.000) | 1.24 (0.000) | 0.89 (0.000) | 1.51 (0.000) | 0.65 (0.000) | 1.05 (0.000) | 0.97 (0.000) |
| HCI square | −0.05 (0.000) | −0.07 (0.000) | −0.12 (0.000) | −0.09 (0.000) | −0.03 (0.000) | −0.04 (0.000) | −0.09 (0.000) |
| HCI*TIN | −0.13 (0.005) | −0.05 (0.000) | −0.09 (0.000) | −0.11 (0.000) | −0.07 (0.000) | −0.06 (0.000) | −0.11 (0.000) |
| Size | 0.09 (0.005) | 0.11 (0.000) | 0.05 (0.000) | 0.14 (0.000) | 0.05 (0.000) | 0.07 (0.000) | 0.08 (0.000) |
| R square | 0.81 | 0.86 | 0.79 | 0.81 | 0.77 | 0.73 | 0.75 |
| Wald test | 147.92 (0.001) | 271.49 (0.000) | 187.12 (0.000) | 203.25 (0.000) | 176.23 (0.000) | 177.00 (0.000) | 127.42 (0.000) |

the usage of non-renewable energy. Although there is scant literature at the micro-level on the effect of human capital development on non-renewable energy usage, our results concur with the studies conducted at the national level. For example, Ruhul et al. (2017) found a percentage increase in the level of human capital which could reduce the usage of non-renewable energy between 0.20 and 0.45%.

The results of model 2 are exhibited in Table 7.3. The signs of HCI coefficients are inverse to that of model 1. The coefficient of HCI is positive, and the coefficient sign of $HCI^2$ is negative. It forms a U-shape relationship between human capital and renewable energy consumption. At the macro level, this is well in line with the environmental Kuznets curve (EKC). It implies that increasing the level of human capital at the initial level raises the non-renewable energy consumption. Researchers (e.g. Katircioğlu 2014; Fang and Chen 2017; Auty 2001; Adams-Kane and Lim 2016) claim that total energy consumption increases with the increase in human capital.

The increasing level of human capital increases the requirement of energy and non-renewable energy that could be the cheaper and immediately available source. After reaching human capital, it tends to substitute non-renewable energy consumption with renewable sources (Doğan and Değer 2018). Our results show a significant interacting role of technological innovation ($\beta = 0.07$, $p < 0.05$) in the relationship between human capital and energy consumption. It implies that the increase in technological innovation leads human capital to consume more green energy. However, results in Table 7.2 show that an increase in technological innovation ($\beta = -0.13$, $p < 0.05$) discourages the usage of non-renewable energy. In condense form, innovation in interaction with human capital increases the use of renewable energy and makes non-renewable energy less attractive. These results concur with the study of Shove (2017). Further, as expected, an increase in the size of the firms leads to an increase in the consumption of both renewable and non-renewable energy.

**Table 7.5** Threshold point of HCI

| | Upper threshold point of HCI | | | |
|---|---|---|---|---|
| | Green energy consumption | | Non-green energy consumption | |
| | Coefficient of HCI | Coefficient of $HCI^2$ | Coefficient of HCI | Coefficient of $HCI^2$ |
| Total sample | −1.21 | 0.19 | 1.76 | –0.05 |
| Textile | −0.49 | 0.17 | 1.24 | –0.07 |
| Leather | −0.41 | 0.09 | 0.89 | –0.12 |
| Food | −0.61 | 0.14 | 1.51 | –0.09 |
| Sports | −0.45 | 0.08 | 0.65 | –0.03 |
| Metal | −0.89 | 0.06 | 1.05 | –0.04 |
| Furniture | −0.74 | 0.03 | 0.97 | –0.09 |

The turning point values of HCI are exhibited in Table 7.5. Comparing inter-industry results of green and non-energy consumption, it could be observed that the sports sector's turning point comes earlier as compared to the rest of the industries. It implies that a moderate improvement in human capital in the sports industry can decrease the consumption of non-green energy by substituting it with that of green energy. On the other hand, turning points in the metal industry are at a quite higher side, depicting that a substantial increase in human capital is required in order to substitute the non-green energy consumption with green energy consumption. The results of the metal industry show that a moderate increase in the level of human capital will increase the consumption of non-green energy and will increase emissions. Our findings are well aligned with the Mubarik et al. (2016, 2018). Particularly, Mubarik et al. (2016) argue that levels of human capital in metal and leather industries are low. Owing to these low levels of human capital, developing human capital in the first stage will increase the consumption of non-green energy. Subsequently, it will lead to a decrease the consumption of non-green energy. On the broader canvas, the results confirm the presence of an inverted U-shape relationship between HC and non-green energy. Our findings also confirm the presence of an inverted U-shape curve in the relationship between HC and green energy consumption.

## 7.5 Conclusion

The chapter has three overarching objectives. The first objective was to comprehensively review the role that a firm's human capital plays in promoting energy efficiency and green energy. Second objective was to review the role of technological innovation in the relationship between a firm's human capital and energy consumption (green and non-green). Third objective was to provide any empirical evidence on the relationships modeled in objective one and two. In doing so, we took Pakistan as a case. After reviewing the literature from the last 30 years from the major repositories, we could found that human capital-energy consumption juxtaposition captivated the attention of scholars around 02 decades ago. Since then, a plethora of scholastic work has been done in this area; however, the majority of the literature focused on human capital at a macro-level without differentiating the firm-level human capital. Further, on the basis of the review, we could unveil that firm human capital can have an inverted U-shape relationship with non-green energy consumption and U-shape relationship with green energy consumption. Some of the researchers named it human capital Kuznet curve getting inspiration from environment Kuznet curve (EKC). The previous studies also depicted that human capital in interaction with technological innovation can be better instrumental in reducing energy consumption. This led us to model the technological innovation as the moderator in the out model. After reviewing the literature, we developed two equations. The first equation modeled green energy as the dependent variable by taking human capital as the independent variable and technological innovation as moderator, whereas the second equation modeled non-green energy as depending on a variable by taking the same independent and moderating variables. To test the model, we took the manufacturing sector of Pakistan as case, and data from 635 manufacturing sector firms were used. By applying FGLS, we examine the quadratic relationship of human capital with green and non-green energy consumptions. Our results confirmed the presence of inverted U-shape relation between human capital and non-green energy consumption in all selected manufacturing industries of Pakistan. Results also confirmed a U-shape relationship between human capital and green energy consumption in the same sample. Our results concurred broadly with the other studies conducted on the HC-energy consumption dyad. Our findings imply that industries with a higher level of HC and technology innovation can quickly substitute non-green energy with green energy consumption.

## 7.6 Implications

Based on the findings of a study, we offer some practical implications. First and foremost is the need to conduct research studies on the role of firm-level human capital in green and non-green energy consumption. These studies can take into account the cross country industries to examine as to how developing human capital can help a firm to substitute green energy with non-green energy consumption. Secondly, on the basis of our findings, we argue that industries with a comparatively high level of capital are close to the turning points from where the increase in human capital will lead to an increase in the green energy consumption and decrease in non-green energy consumption. For example in Pakistan, according to Mubarik (2016) and Mubarik et al. (2018), the textile sector and food sector have comparatively higher levels of human capital. Working in such sectors can yield some immediate results in the shape of energy efficiency. In short, a nation can gauge the level of human capital across industries, and the industries with a higher level of human capital can be incentivized to further develop their human capital. Thirdly, employers can be given certain incentives to hire employees with a post-school education (human capital).

## 7.7 Limitations and Future Research Direction

Since the developed models have been examined in the context of Pakistan, the results may be generalized cautiously. Our measure of human capital may not be compressive enough to encapsulate all of its aspects. Therefore, we suggest future researchers take the HC index taking the behavioral aspects of employees as well. We included only firm size as the control variable in the study. Future researchers can add other variables like firm ownership and age for more robust results.

In addition to energy efficiency, we suggest future researchers to examine the role of human capital in energy sufficiency. The debate on the HC-energy sufficiency dyad is absent from major policy debates. Reducing energy usage with the help of firm human capital development, energy sufficiency is equally important. Energy sufficiency strategy aims to reduce and control the usage of electricity at a sustainable level. The firms need to set the optimal level of energy conservation keeping in view the environmental limitations (Rockström et al. 2009; IPCC 2014). Along with energy efficiency and the sustainable green energy supply, using various renewable sources of energy, energy sufficiency appears to be a third strategic pillar of the sustainable energy sector. Energy sufficiency contrasts with energy efficiency. The former focuses on reducing energy input through changing the quality or quantity of utilities, whereas the later aims to reduce energy input without changing the utilities (Brischke et al. 2015). The usage of energy is largely dependent upon a firm's business processes, machinery, and type of infrastructure (Shove 2017). Hence, while examining a firm's energy sufficiency, a single product or machine is not the unit of analysis. Instead, the analysis focus on a bunch of needs requiring technical services and consequently energy inputs. In this context, energy sufficiency also considers basic changes in the employees' behavior, production patterns, and organizational practices having an influence on energy consumption.

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