Energy Economics 67 (2017) 49–59

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

# Does human capital matter for energy consumption in China?

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ARTICLE INFO

*Article history:*
Received 12 December 2016
Received in revised form 19 May 2017
Accepted 24 May 2017
Available online 1 June 2017

*JEL classification:*
C33
Q43
J24
O50

*Keywords:*
Energy consumption
Human capital
Panel data
China

ABSTRACT

This article investigates the dynamic relationship between human capital and energy consumption using Chinese provincial data over the period 1990–2010. Considering for cross-sectional dependence and parameter heterogeneity across space and over time, we identify a significant and negative human capital–energy consumption relationship in China. Specifically, we find that a 1% increase in human capital reduces energy consumption by a range between 0.18% and 0.45%. Furthermore, this negative relationship can be attributed to stronger accumulation of post-school human capital in eastern China. This finding suggests that energy conservation in China could be achieved by improving post-school human-capital components such as on-the-job training, experience and learning-by-doing.



## 1. Introduction

China's impressive growth record over the past three decades was accompanied by massive increases in energy consumption. Indeed, since 2009 China has replaced the United States as the world's leading energy consumer. To put this development into perspective, in 2014 China consumed 4260 million tons of standard coal equivalent (SCE) energy. With this backdrop, identifying the contributing factors behind China's unsatiated energy demand is quintessential to forecasting its energy need and energy security in the future (Odgaard and Delman, 2014). Furthermore, this knowledge is critical to predicting price volatilities brought about by China's active participation in the global energy market (Ratti and Vespignani, 2013). Last, but not the least, as China has consistently contributed to nearly one-third of global greenhouse gases emissions, an understanding of its energy-consumption pattern provides indispensable information to combat climate change (Li et al., 2016).

To date, a large body of literature exists concerning energy consumption in China, with many studies exploring its impacts on economic growth (Bloch et al., 2015; Yuan et al., 2008). Recently, a new strand of research has emerged that captures energy consumption through the perspective of industrialization, urbanization and economic transformation (Zhao et al., 2016). Surprisingly, despite its catalytic role in promoting economic development, only few studies have examined the effect of human capital on energy consumption in the extant literature. As one of the earliest attempts, Pachauri and Jiang (2008) report that better-educated households prefer energy-efficient domestic appliances. Meanwhile, Démurger and Fournier (2011) find that better-educated rural households in northern China often shift away from less energy-efficient firewood to commercial fuel sources like coal. Based on the meta-frontier demand analysis, Broadstock et al. (2016) conclude that better-educated Chinese households consume less electricity and emphasize on energy efficiency. In contrast, He and Reiner (2016) discover a positive association between income and electricity consumption among better-educated households in Beijing, Shanghai and Guangdong. Khanna et al. (2016) reach a similar conclusion after analyzing a much larger dataset from 1450 households in 27 Chinese provinces. From the perspective of the substitutability between labor input and energy sources in the production process, Ma et al. (2009) find that such substitutability only exists nationally but not regionally over the 1995–2004

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http://dx.doi.org/10.1016/j.eneco.2017.05.016
0140-9883/

period. Applying ridge regressions to the aggregated Chinese data from 1991 to 2013, Yang et al. (2017) confirm possible substitutions among human capital, fossil energy input and non-fossil energy input under a trans-log production function setting.[1]

Our brief review of the existing studies on the relationship between human capital and energy consumption in China has highlighted two major deficiencies. First, no existing studies, to the best of our knowledge, have directly examined this relationship at the macro level. In theory, while improvements in human capital may stimulate inventions and innovations in energy conservation, it can also raise energy consumption due to its growth-promoting effect on the economy. Clearly, an answer to this question carries important implications for the Chinese policy makers. Second, most studies in this genre measure human capital through the lens of literacy, school enrolment and average years of schooling. Although these indicators are intuitive and easy to obtain, they only capture information pertinent to formal education attainment and ignore "*on-the-job training, experience and learning-by-doing, usually they do not account for education equality and focus on academic education, overlooking vocational education*" (Benos and Zotou, 2014, p. 669). Similarly, Li et al. (2014) argue that the focus on formal education attainment may have grossly underestimated the effects of human capital on the Chinese economy.

This study seeks to address these deficiencies by investigating the human capital–energy consumption nexus across Chinese provinces from 1990 to 2010.[2] We have chosen China as the research subject not only because of its rapid growth in both human capital and energy consumption over the last three decades, but similar energy policy and initiatives across the Chinese provinces also minimize unobserved fixed effects commonly plaguing cross-country studies on this topical issue. Meanwhile, using sub-national dataset is also coincident with the recent suggestion from Smyth and Narayan (2015) to which regional heterogeneity in energy consumption is highlighted. Apart from being one of the first studies linking human capital and energy consumption at the macro level, our study extends the current body of knowledge by utilizing the recently available human-capital index compiled by the China Centre for Human Capital and Labor Market Research (CHLR). Unlike traditional human-capital measures, this new index is based on the lifetime-income approach and captures post-school human-capital accumulation related to factors such as on-the-job training, experience and learning-by-doing. Methodologically, we derive an accurate profile regarding the human capital–energy consumption relationship in China by considering cross-sectional dependence and parameter heterogeneity in our panel estimations and time series analysis. In general, we find evidence that a negative and significant long-run relationship exists between human capital and energy consumption. Furthermore, we identify this negative relationship to have been predominantly driven by economically-advanced provinces in eastern China.

The remaining part of this paper is structured as follows. Section 2 sets out the conceptual framework. Section 3 discusses construction of variables, data sources and the estimation techniques. Section 4 performs the empirical analysis and presents the results. The last section summaries and concludes.

## 2. Conceptual framework

This section sets out the conceptual framework underlying our empirical modeling strategy. In theory, human capital can influence energy consumption through the income effect and the technology effect. According to the endogenous growth theory, human-capital accumulation plays a catalytic role in supporting sustainable economic growth (Ang and Madsen, 2010; Benos and Zotou, 2014). Although the energy consumption–economic growth relationship is far from conclusive in the extant literature, ample empirical evidence has suggested a positive association between these two variables in many countries (Ozturk, 2010; Smyth and Narayan, 2015). In this regard, raising energy consumption may have been driven by higher income brought about by an improvement in human capital. However, it is important to note that human-capital accumulation also enables switching to energy-efficient technology, reducing energy consumption in the process (Li and Lin, 2016). Indeed, IEA (2008) estimates that a full realization of this technology effect may reduce global primary energy consumption by 18% to 26%.

Apart from the income and technology effects the third effect linking human capital and energy consumption stems from the degree of substitutability or complementarity among physical capital, human capital and energy inputs in the production function (Pablo-Romero and Sánchez-Braza, 2015; Salim et al., 2014). Specifically, if human capital and energy inputs are substitutable during production, then higher human-capital accumulation effectively reduces energy consumption, holding total output constant. In contrast, if complementarity exists between human capital and energy inputs, then an increase in human capital endowment raises energy consumption for a given level of output. Although whether human capital substitutes or complements energy consumption remains an open empirical question the level of economic development appears to be a deterministic factor. For example, the consensus indicates that complementarity is more common when the economy is undergoing rapid industrialization whereas substitutability often dominates in a service-orientated economy (Arbex and Perobelli, 2010).

Despite its long history as an important determinant of energy consumption, energy economists have frequently treated human capital as a control variable in the analysis. For instance, Huang et al. (2008) apply the system generalized methods of moments (GMM) estimator to a panel of 82 countries over the 1972–2002 period and find that human capital leads to energy consumption positively in low income countries but a negative causality running from human capital to energy consumption in high income countries. To control for the level of economic development, Coers and Sanders (2013) focus on a panel of 30 OECD countries over the 1960–2000 period. Using the Westerlund (2007) panel cointegration test with cross-sectional dependence, they cannot find a significant cointegrating relationship between energy consumption and economic growth in these countries once education attainment as a proxy of human capital is introduced into the analysis. In contrast, Fang and Chang (2016) measure human capital based on the years of schooling and the rates of schooling returns from the Penn World Table for 16 Asia-Pacific countries from 1970 to 2011. Applying the Westerlund (2007) test, they conclude that cointegration exists among human capital, energy consumption and economic growth in the region. From the perspective of a trans-log production function, Pablo-Romero and Sánchez-Braza (2015) apply the generalized least square and instrumental variable GMM estimators to 38 major economies during the 1995–2011 period and find significant substitutability between human capital and energy inputs. This finding suggests that greater investment in human capital could be an effective strategy for achieving energy conservation.

With the ambiguity over the effect of human capital on energy consumption, we set out to investigate the nature of this relationship using provincial data from China for the 1990–2010 period. To achieve that end, we incorporate the role of human capital into the following energy-consumption function:

$$E_{it} = f(Y_{it}, P_{it}, K_{it}, H_{it}) \tag{1}$$

where $i$ denotes the Chinese province and $t$ refers to the time period. $E$, $Y$, $P$, $K$, and $H$ stand for energy consumption per capita, real output

[1] The ridge regression represents a useful means for controlling multicollinearity among the selected variables in the trans-log production function. It belongs to "*a type of biased estimation regression method to analyze co-linear data that provides regression coefficients that are more realistic, more reliable, and superior to the least squares method*" Yang et al. (2017).

[2] This sample period was selected based on the availability of data pertinent to the measurements of human capital at the provincial level in China.