Application of threshold regression analysis to study the impact of regional technological innovation level on sustainable development

Su Yi[a,b,c,*], An Xiao-li[d]

[a] School of Economics and Management, Harbin Engineering University, 150001, PR China
[b] School of Management, University of Bradford, BD9 4JL, UK
[c] School of Economics and Management, Tsinghua University, 10010, PR China
[d] School of Economics and Management, Harbin Engineering University, 150001, PR China

ABSTRACT

This paper applies a panel threshold regression model to explore the impact of the regional technological innovation level on regional sustainable development using the regional economic development level as the threshold variable and panel data from 31 Chinese provinces from 2009 to 2015. The empirical research results show a significant double threshold effect of the regional technological innovation level on regional sustainable development. Positive interrelationships are observed between the regional technological innovation level and regional sustainable development when the regional economic development level does not exceed 0.301. The regional technological innovation level plays a significant role in promoting regional sustainable development when the former is between 0.301 and 0.438, but regional innovation otherwise has a minimal promotional effect. This research enriches the scholarship on regional innovation and lays a theoretical foundation that governments can use in policy development.

1. Introduction

China's recent rapid economic growth has been accompanied by serious problems, such as environmental pollution and resource shortages. Therefore, coordinating the needs of economic development, resource management, and the environment is a major strategic issue that urgently requires a solution. Green innovation, which is based on the core concepts of energy conservation, innovation, and environmental optimization, combines green development with innovation-driven development. In recent years, many scholars have paid close attention to green innovation [1]. Scholars have thoroughly researched such aspects as green innovation connotation, index systems, ability appraisal, and theory models, and today, many countries are pursuing sustainable development through green innovation. Especially in the new environment of slowing economic growth in China, green innovation is an important strategic tool to overcome resource constraints and achieve sustainable development [2,3]. Consequently, green innovation is the focus of sustainable development, which has long been widely discussed in many countries [4,5].

The most effective methods of achieving sustainable development include limiting population growth and economic development, while simultaneously enhancing technological innovation to decrease the environmental impact per unit of production output [6]. The level of technological innovation is one of the keys to overcoming the environmental constraints that enable sustainable development. As technological innovation can improve resource use efficiency, it can save resources. Moreover, the environmental protection technology brought by technological innovation can reduce emissions of pollutants [7]. Thus, technological innovation is central to sustainable development [8,9].

While regional innovation systems are effective carriers of technological innovation, regional differences, particularly economic differences, cause sustainable development to present varied trajectories. Accordingly, it is useful to study sustainable development at the regional level. Solutions to problems of sustainable development can be refined by adopting regional innovation systems as a focus, which can then enable countries to adopt specific sustainable development measures in different regions [10,11]. Regional technological innovation is an important driver of regional sustainable development, and the improvement of the level of regional technological innovation is an important way to promote the capacity of regional sustainable development. However, the regional economic development level should limit any such promotion effect. Therefore, this paper explores how improvements in the economic development level influences the regional

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technological innovation level on sustainable development, thereby providing a useful reference for better understanding sustainable development.

2. Literature review

Scholarly research on sustainable development focuses mainly on concept analysis, regional sustainable development capacity evaluation, value analysis, dynamic mechanisms, and regional management. Scholars have further analyzed the concept of sustainable development and conducted detailed studies regarding sustainable development indexes (Sabin-Ioan Irimie et al., 2014) [12]. Furthermore, they have constructed evaluation indexes of regional sustainable development based on different dimensions and have evaluated the ability of regional sustainable development using factor analysis, analytic hierarchy processes, nonlinear principal component analysis, Gram Schmidt orthogonal integration, ecological footprint analysis, and data envelopment analysis (Yao Xiaodong et al., 2008; Deng Baozhong, 2009; Li Zhaoqi et al., 2009; Hu Lin, 2012; Li Houcheng et al., 2016; Feifei Tan et al., 2016; Jia He et al., 2016; Aslihan Karatas et al., 2015) [13–20]. Other related studies have analyzed the factors that affect regional sustainable development ability (Liu Zongxin et al., 2015; Bin Yang et al., 2017) [21,22], extracted common factors, and performed cluster analysis (Wang Shaoying, 2016) [23]. Shao Jianping et al. (2008) used the cost income method to analyze sustainable development ability and constructed a three-stage growth model to analyze the value of this ability [24]. Zhang Qin et al. (2013) studied the dynamic formation mechanism of regional sustainable development ability and determined that it involves, primarily, the interactions between induced factors and propulsion factors. The main inducing factors are the evolution of human needs, while the main propulsion factors are informatization, new industrialization, marketization, technological progress, and institutional arrangements [25]. Xu Xiaoxin et al. (2015) studied regional sustainable development management from a multidisciplinary perspective and identified three major shifts in the management of sustainable development, namely, from idea to action, from country to domestic region, and from a single environmental dimension to the coordination of multiple dimensions. The same study identified three characteristic strands of research on sustainable development, namely, research on the dynamic mechanism of regional sustainable development, research on strategic management, and research on public management [26]. Lei Chen et al. (2017) studied investment in sustainable development in China and obtained results that can help the Chinese government increase resource use efficiency and thus achieve sustainable development [27].

Scholars have also studied the relationship between technological innovation and sustainable development. Some believe that regional technological innovation is the driver of regional sustainable development (Ye Minqiang et al., 2001; Mihaela Kardos, 2012; Jining Chen, 2016) [28–30]. In the short term, technological innovation promotes sustainable development, while in the long term, the pair maintain a dynamic equilibrium (Nie Qiao, 2015) [31]. Accordingly, scholars have constructed a technological innovation model related to sustainable development (Bai Junhong, 2007) [32]. Simultaneously, other scholars have examined the important differences between technological innovation and sustainable development despite being related concepts. Technological innovation has a dual effect on sustainable development that is characterized by positive and negative aspects, with the positive effects occurring faster than the negative effects (Zou Zhaohui et al., 1998; Fan Xu et al., 2001; Cheng Jianlin et al., 2008) [6,33,34].

Thus, the consensus among researchers is that technological innovation exerts a positive effect or a dual effect on sustainable development, but because most researchers have conducted only theoretical research, quantitative research is lacking. In reality, the economic development level, industrial structure, and investment in industrial pollution control all affect regional sustainable development ability.

Simultaneously, economic development harms the environment and increases demand for energy, thus seriously restricting the pursuit of sustainable development in many regions [31]. This paper adopts a quantitative approach to study the impact of the regional technical innovation level on sustainable development ability by specifically using threshold regression analysis and a nonlinear analysis tool with regional economic development level as the threshold variable. The Hansen panel threshold regression model is applied to provincial panel data for the period 2009–2015 to test whether a threshold effect exists between regional technological innovation and regional sustainable development in relation to the improvement of the regional economic development level. The mechanism between regional technological innovation and regional sustainable development is studied in detail, and corresponding countermeasures and suggestions are proposed according to the empirical results, thus providing a strong reference for policy development relevant to the sustainable development of China's regional innovation system.

3. Research design

3.1. Variable selection

Focused on ecological systems and environmental resources, this paper draws on the literature on regional sustainable development ability to divide the evaluation index applied to regional sustainable development into the three dimensions of environmental pollution, environmental governance, and resources [16]. The environmental pollution dimension is characterized by total waste water discharge, solid waste production, and emissions of major pollutants in exhaust gas. The environmental governance dimension is characterized by the rates of comprehensive utilization of solid waste and of harmless treatment of household garbage (i.e., sanitary landfill, composting, and waste-to-energy). The resources dimension is characterized by electric power consumption. In this paper, the reverse index has been translated into a forward index using the extreme difference method. Furthermore, this paper uses the entropy method to evaluate regional sustainable development ability as an explanatory variable.

The indicators commonly used to characterize the level of regional technological innovation are patent application quantity and patent licensing quantity [35,36]. Patent application quantity explains the degree of effort that a region invests in technological innovation. Patent licensing quantity, however, is a more practical indicator because patent licensing is governed by a strict review process [31,36]. Thus, this paper selects regional patent licensing quantity as the indicator used to measure the regional technological innovation level.

Scholars often adopt the regional GDP as a measure of the regional development level, regional economic development level, and economic growth [37–39]. Drawing lessons from scholarly practice, this paper adopts the regional GDP as the measure of the economic development level.

This paper selects the regional economic development level as the threshold variable. However, other factors, such as industrial structure and industrial pollution treatment investment, also affect the impact of technological innovation on sustainable development [37,38]. Different industrial structures affect pollution emissions differently, and regional pollution worsens with increasing proportions of polluting industries [34,40,41]. Accordingly, this paper uses the relative contribution of secondary industries to the GDP to measure industrial structure. Investments in industrial pollution treatment represent regional efforts in the treatment of industrial pollution and are important drivers of regional sustainable development ability. Hence, this paper selects the production value of the secondary industry as a proportion of the GDP and investments in industrial pollution treatment as indexes that can characterize the control variables.