Technological Forecasting & Social Change 133 (2018) 1–14

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

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

Environmental regulations, staff quality, green technology, R&D efficiency, and profit in manufacturing

Malin Song[a], Shuhong Wang[b,c,*], Jing Sun[d]

[a] Research Center of Statistics for Management, Anhui University of Finance and Economics, Bengbu 233030, PR China
[b] School of Economics, Ocean University of China, Qingdao 266100, PR China
[c] Institute of marine development, Qingdao 266100, PR China
[d] School of Business, Qingdao University, Qingdao 266100, PR China

ARTICLE INFO

Keywords:
Environmental regulations
Staff quality
R&D efficiency
Green technology

ABSTRACT

This paper examines the relationships among environmental regulations (ER), staff quality (SQ), R&D efficiency (RDE), green technology (GT), and profit. The research sample comprises 1197 firms in 16 manufacturing industries in China, during 2008 and 2015. DEA-based measures are employed to research firm RDEs, and the results show that SQ is essential for high RDE and GT (as expected), but the main effects of SQ are mixed. Importantly, we find that ER moderates the SQ-GT, SQ-RDE and SQ-profit relationships. Specifically, if ERs are eased, SQ is of limited benefit to GT or profit. However, at or above the ER threshold level, firms can improve SQ for further improvements in GT and profit. The implications of our findings on theory and practice are also discussed.

1. Introduction

In 2006, China surpassed the United States to become the world's largest carbon emitter, and also of SO2 and oxynitride. Areas severely afflicted by pollutant discharges are cities with industrial production facilities. Although China's *National Climate Change Regulation* (2014–2020) aimed to reduce the ratio of gross domestic product (GDP) to carbon emissions from 45% in 2005 to 40% by 2020 by strengthening the enforcement of environmental protection policies (e.g., eliminating pollutive industries and developing new pollution-reduced industries, improving technological innovation, optimizing industrial structure, and implementing an extensive economic growth pattern), environmental quality continues to decline, given the increasing number of polluted cities and intensity of pollution. However, the Chinese economy is in the stage of urbanization and industrialization and, as a result, there is rigid demand for traditional industries and energies. Therefore, the current energy consumption structure cannot be changed within a short period. Moreover, fast economic growth while also protecting the environment and maintaining social stability is the dilemma China is facing during new normal period. According to China's Statistical Bureau (NBSC, 2015), China's annual economic growth rate declined from 10% to 8% since 2012, indicating the onset of economic transformation. As such, at the 2014 Leadership Summit by the Asia-Pacific Economic Cooperation, Chairman Xi Jin Ping pointed out that China is gradually entering the new normal of rapid economic growth.

China had issued 358 environmental protection laws and regulations until 2013 and a further 67 environmental protection standards and requirements by March 2016. Consequently, firms have been facing stricter environmental regulations (ER), under increasingly heavy pressure. Moreover, firms have their own dilemmas to solve. On one hand, they need to improve production competitiveness to survive economic globalization. On the other, they have to pay attention to their pollution discharge to avoid extra production costs. As such, numerous firms choose to conceal their pollution discharges, work illegally or during night time, while some local governments turn a blind eye to some large tax payers that have unlawful production activities as to accomplish their own political performance tasks. There were also many pollutive firms inclined to move towards administrative borders (Cai et al., 2016), that is, governments in certain jurisdictions want both the increase in GDP brought by pollutive firms and the reduction of pollution treatment costs. In this respect, Tan (2006) pointed out that economic growth and environmental protection could be carried out simultaneously without conflict, as firms in the eastern coastal areas of China have intrinsic motivations for pollution reduction. Duvivier and Xiong (2013) put forward that many pollutive firms prefer to set plants on provincial administrative borders to reduce government administrative control, which reflects the pollution heaven effect (i.e., firms

* Corresponding author at: School of Economics, Ocean University of China, Qingdao 266100, PR China.
E-mail address: shwang01@sina.com (S. Wang).

https://doi.org/10.1016/j.techfore.2018.04.020
Received 25 January 2018; Received in revised form 31 March 2018; Accepted 13 April 2018
0040-1625/

choose to move to areas with weak ERs instead of making innovations to reduce environment treatment costs to avoid ERs) (Copeland and Taylor, 1999).

Under the condition that the demographic bonus decreases gradually and resource consumption increases, technological innovation has become an important driving force for China, transforming economic development mode, upgrading industrial structure, and promoting "supply side" reforms (Aghion et al., 2012). Nowadays, excessive investments in fixed assets not only aggravate firm homogeneity, but also provide contribution margins significantly below technological investments (Mikkelson and Partch, 2003). New technologies can optimize the production process, change the production possibility set, improve firms' production efficiency and construct an access barrier of the technological market (Hsiao, 2014), and improve market competitiveness. Under the guidance and incentives of both innovation strategies and relevant industrial policies, since 2010, total R&D firm inputs have increased from about CNY 700 billion in 2010 to about CNY 1.4 trillion in 2015. Their proportion to total R&D investments in China surpassed 70% continuously for the six years, becoming the most important micro body in R&D investment. The data are from the Ministry of Science and Technology of the People's Republic of China, and the Statistical Bulletins of National Sci-Technological Appropriation, the 2010 and 2015 editions.

Although total R&D investment in China increases rapidly compared to other developed countries, China's R&D efficiency (RDE) is still low.[1] This may result from both internal and external environmental factors. Many scholars found that macro factors, including macroeconomic fluctuation, regional environment, legal system, and industrial policy (Berchicci, 2013; Czarnitzki and Toole, 2011), and micro factors, including ownership nature, corporate governance, enterprise size, and financing restrictions (Belloc, 2012; Jacobs et al., 2016), could all affect firms' RDE. Acemoglu (2002) proposed the concept of biased technological progress. Acemoglu et al. (2015) further refined the concept into green technology (GT), and theoretically identified environment improvement determinants. According to Acemoglu et al. (2015), in practical production, if technological progress is divided into production and GTs, the R&D inputs of firms for GT would also inevitably reduce RDE. Consequently, the production management decision making and operational performance of firms would be affected (Song and Wang, 2016).

Blindly implementing energy policies could lead to considerable pollution treatment costs, reduce business profits, and hinder technological progress and regional economic growth. However, if firms do not satisfy emissions standards after the pollution treatment, the increased costs of treatment could result in firms collapses. Under increasingly strict ERs, how to maintain and improve firms' RDE to increase corporate profits is the focus of research for many scholars. This paper thus analyzes the improvement of RDE by staff quality (SQ) and then discusses influences of GT in RDE to provide references for firms to increase profits under strict ERs.

2. Background and literature review

We review the theoretical and empirical research on the relationships between ER, SQ, GT, RDE, and profit. We first focus on the literature of the independent effect of SQ on RDE in Section 2.1, and of ER on RDE, GT, and profit in Section 2.2. In Section 2.3, we provide theoretical support and motivation for the joint effects of ER, SQ, GT, RDE, and profit.

[1] Please refer to http://finance.ce.cn/rolling/201506/08/t20150608_5582361.shtml for relevant data.

2.1. Staff quality, R&D efficiency, and profit

The R&D activity of an enterprise is not a simple input-output function. In fact, it is a systematic project that contains factor input (human force, capital, and equipment) and technological R&D. As R&D activity in itself is a "link-loop" (Kline and Rosenberg, 1986), R&D results are a long-term process of knowledge accumulation and fund appropriation. This not only requires firms to input human capital continuously, but also required adequate financial conditions and cash flow levels. Moreover, with fast improvements of the technological level and continuous change of the external market environment, technological upgrade pressures and changes in consumer demand increase, along with technological and market risks (Jacobs et al., 2016). Under internal financial pressure and external uncertain environments, paying attention to human capital investments, improving their RDEs to gain technological advantage, and large profits are important for Chinese firms to obtain competitive advantages.

The essence of technological R&D is the innovative activity of science and technology by human beings. Technological innovation theory considers that high knowledge levels and professional competence are helpful to improve R&D staff's abilities to learn, digest, and innovate, and their efficiencies during research, development, and technological transformation. Therefore, improving SQ can be used to improve RDEs. Human capital theory points out as methods of improving SQ formal investment in education and in-service education (Becker, 1962; Sung and Choi, 2014). Formal education has the dominant function on improving SQ and can endow individuals with higher professional abilities and knowledge levels, providing basic conditions for firms to improve technological absorption and innovation abilities (Ødegaard and Roos, 2014). However, SQ improvement by formal education is generally staged and static. When the speed of knowledge updating is high, SQ needs timeliness and pertinence. Nazarov and Akhmedjonov (2012) even considered that for transitioning countries, the influence of SQ on corporate technological innovation abilities and performance is higher than for formal education investment. Therefore, under fierce technological competition and China's economic transformation, dependence on formal education investments can hardly provide SQ human and knowledge support for R&D activities. The functioning mechanism of SQ on firms' RDE is as follows. First, R&D activity is practical, meaning techniques and experience can hardly be obtained from formal education, thus requiring on-the-job training. Second, the systematicness, complexity, and professionalism of R&D activities requires participants maintain labor division-collaboration, information communication, and sharing, transmission, and supplementation of knowledge and experience to guarantee R&D efficiency, while carrying out on-the-job education and training can provide experience exchange and knowledge sharing. Third, the "link-loop" process of R&D activity results in following research needing to use previous knowledge and experience as a basis, meaning the R&D process is actually a process of continuous learning for the R&D staff, which requires employees to accumulate knowledge continuously and in the long term. Finally, the current speed of technological refreshing and monopoly competitive advantages of key technologies not only compel firms to focus on external technological development to counter competition, but also make them focus on confidentiality and efficiency on their own R&D activities. Therefore, from both the perspective of following and learning external advanced technologies or of improving RDEs, firms both need to improve SQ and stimulate employee's knowledge and experience accumulation. As such, the expansion of on-the-job training scale can improve innovation efficiency and firm effect (Ballot et al., 2001; Rupietta and Backes-Gellner, 2012). Accordingly, we posit:

Proposition 1. When other conditions remain unchanged, SQ is favorable to improving corporate RDE.

As carriers of contractual relationships, maximum efficiency and satisfying the interests of stakeholders are basic objectives of firms.