Journal of Cleaner Production 179 (2018) 325–334

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

The effects of environmental regulation on China's total factor productivity: An empirical study of carbon-intensive industries

Xiaomeng Zhao [a, b], Chuanjiang Liu [a, b], Mian Yang [a, c, *]

[a] Center of Economic Development Research, Wuhan University, Wuhan 430072, China
[b] Center of Population, Resource & Environmental Economics Research, Wuhan University, Wuhan 430072, China
[c] Economics and Management School, Wuhan University, Wuhan 430072, China

ARTICLE INFO

Article history:
Received 20 July 2017
Received in revised form
28 November 2017
Accepted 13 January 2018
Available online 16 January 2018

Keywords:
Environmental regulation
Total factor productivity
Strong Porter-hypothesis
Carbon-intensive industries

ABSTRACT

In this paper, we first identify China's carbon-intensive industries (CIIs) by constructing a carbon intensive index taking both the scale and intensity of CO_2 emission into account. Then the strong version of Porter Hypothesis (PH), i.e., the positive effect of environmental regulation on total factor productivity (TFP) of China's CIIs is tested. In order to overcome the endogenous issue of model specification, two-stage least squares (2SLS) method is employed. The results indicate that there is a significant inverted U-shape relationship between environmental regulation intensity and the TFP of China's CIIs, demonstrating the inexistence of strong PH effect in a long run, and the impact of environmental regulation on CIIs is changing gradually from innovation offsets to compliance costs. In addition, optimal environmental regulation intensities for different CIIs are also studied according to their locations on the inverted U-shaped curve: the Production and Supply of Electric Power and Heat Power Industry has exceeded the optimal environmental regulation intensity, while the remaining CIIs have not reached their inflection points. Therefore, specific policy proposals should be formulated according to the different stages of environmental regulation in various industries.

1. Introduction

Serving as the mainstay of national economy, the carbon-intensive industries in China emit nearly 80% of the total CO_2 emissions in 2010 (Yuan and Zhao, 2016). In order to fulfill the "Intended Nationally Determined Contribution" submitted to the United Nations in June 2015 stating that China's total CO_2 emissions would peak around 2030 or even earlier, and its carbon emission intensity would decrease by 60–65% compared with 2005 (Liu et al., 2017), the central government has attached more importance to the industries with both large scale and high intensity of CO_2 emissions when formulating and carrying out its current environmental regulations. In this context, the following two issues arise: (i) what are the impacts of China's environmental regulations have imposed on the TFP of the carbon-intensive industries (CIIs) over the past decade? Is it serving as a roll booster or a stumbling block? (ii) Given the obvious heterogeneity in terms of technological level and development phases among the CIIs, one-size-fits-all environmental regulation may bring about very different impacts; so what are the optimal environmental regulation intensities for each CII?

The standard neoclassical paradigm holds that strict environmental regulation will exacerbate the competitiveness and productivity by constraining industry behavior (Denison, 1981; Gollop and Roberts, 1983). At the end of the twentieth century, Michael Porter (1991) and Porter and Van Der Linde (1995) challenged this view and proposed the "Porter Hypothesis" (PH), which argued that more stringent but properly designed environmental regulation can trigger innovation that may offset compliance costs and enhance firm's productivity. Jaffe and Palmer (1997) were the first to classify the PH effects into three categories: (1) the weak PH stating that properly designed environmental regulation may lead to innovation, though it is not known whether the innovation is good or bad for firms; (2) the strong PH stating that in most cases, environmental regulation can not only offset the costs of compliance, but also improve the competitiveness of firms; (3) the narrow PH arguing that flexible

* Corresponding author. Economics and Management School, Wuhan University, Wuhan 430072, China.
E-mail addresses: ximzhao@163.com (X. Zhao), chjliu@whu.edu.cn (C. Liu), yangmian909@163.com (M. Yang).

https://doi.org/10.1016/j.jclepro.2018.01.100
0959-6526/

regulatory policies are more likely to increase firm's incentives to innovate than prescriptive forms of regulation.

The formation mechanism of PH is illustrated in Fig. 1. When there was no environmental regulation, firms seek to maximize their economic profits without considering the pollutant discharge costs. After environmental regulation policies are implemented by the government, the costs for pollutant emissions reduction will increase significantly (Denison, 1981; Gollop and Roberts, 1983), which would compel firms to engage in environment-friendly innovation (Porter and Van Der Linde, 1995; Rubashkina et al., 2015). Technological innovations for emissions reduction increase the operating cost of firm inevitably, but it reduces the pollution emission cost conversely. As the environmental regulation becomes more and more stringent, the compliance cost may rise, while the innovation offsets raise faster (Porter and Van Der Linde, 1995; Lanoie et al., 2008). Therefore, the impacts of environmental regulations on business costs could be positive or negative, resulting in a non-linear relationship between environmental regulation and firms' total factor productivity.

Up to now, scholars such as Brunnermeier and Cohen (2003), Zhao and Sun (2016), Lanoie et al. (2011) and Rubashkina et al. (2015) have reached relatively consistent conclusions on the existence of weak and narrow versions of Porter-hypothesis, that is, environmental regulation is positively related to enterprise innovation. In contrast, there is not a consistency on the existence of strong PH. Denison (1981), Gray and Shadbegian (1995) concluded that environmental regulation policy has led to a reduction in productivity. On the contrary, Hamamoto (2006) found that environmental regulations have led to an increase in innovation (R&D spending) and productivity of five Japanese manufacturing sectors in the 1960s and 1970s. Yang et al. (2012), Jorge et al. (2015) and Qiu et al. (2017) insisted the positive effects of environmental regulation tightening on productivity. The discrepancy between the results of different scholars is caused by the fact that there is no uniform standard on the measurement of environmental regulation intensity (Albrizio et al., 2017). In fact, the impact of environmental regulation on TFP depends on the predominance of the positive "innovation offsets" effect and the negative "compliance costs" effect, and so more recent studies have therefore focused on the non-linear relationship between environmental regulation and TFP (Li and Tao, 2012; Yuan et al., 2017; Johnstone et al., 2017; Albrizio et al., 2017).

In domestic, the initial researches focused on weak version of Potter-hypothesis testing and most studies supported the existence of weak PH (Xu et al., 1995; Jiang et al., 2013). With the rapid development of Chinese economy and the worsening environment, there has been an increasing interest in strong PH testing. Relevant research literature can be divided into two categories. On the one hand, some scholars have calculated China's green total factor productivity by taking pollutant emissions into consideration (Chen, 2010; Wang and Liu, 2015; Yang and Yang, 2016). On the other hand, the studies focused on the effect of environmental regulation on total factor productivity (Hu et al., 2017; Li and Wu, 2017). Most of them test strong PH based on regional perspective analysis while a few based on industry perspective analysis (Wang and Wang, 2011; Bi et al., 2014). What's more, there are few studies on high CO_2 emission industries, especially for CIIs.

CIIs are the main sources of China's total CO_2 emissions as well as the key areas targeted by environmental regulation of the central government. Therefore, it is of great significance to analyze the relationship between environmental regulation intensity and TFP for China's CIIs. At present, scholars have identified CIIs according to the scale, intensity, and leakage of carbon emissions (Farla et al., 1995; Chen, 2009; Fu and Zhang, 2014; Johan and Filip, 2015), but there is no uniform standard regarding the definition and measurement of CIIs. In this paper, we aim to define China's CIIs rationally and scientifically by constructing a carbon intensive index taking both the intensity and scale of CO_2 emissions into account. Subsequently, the strong Porter Hypothesis (PH) effect of China's CIIs is tested; in order to overcome the endogenous issue of model specification, two-stage least squares (2SLS) method is employed. At last, the optimal environmental regulation intensities for each CII are also studied.

The remainder of this paper is structured as follows: Section 2 defines the carbon-intensive industries (CIIs) by constructing a carbon intensive index; Section 3 describes the model specification, data source and variables; Section 4 presents the empirical results on the link between environmental regulation intensity and total factor productivity of CIIs, and plots the specific locations of current environmental regulation intensities for each CII on the inverted U-shaped curve; Section 5 concludes and puts forward some useful policy recommendations.

2. Identification of CIIs

2.1. Definition of CIIs

In general, CIIs refer to the sectors having a larger scale or higher intensity of CO_2 emission, or both, which lead to more intensive carbon emissions either directly or indirectly in production process if they were not well treated. Therefore, they should be defined from the perspectives of scale and intensity of industrial carbon emission. The scale of carbon emission is closely related to the total industrial output value and it does not reflect the carbon-intensive characteristic of the industry; similarly, the intensity of carbon emission does not reflect the impact of an industry on the environment as a whole. In this paper, we define China's CIIs by constructing a carbon intensive index taking both the scale and the

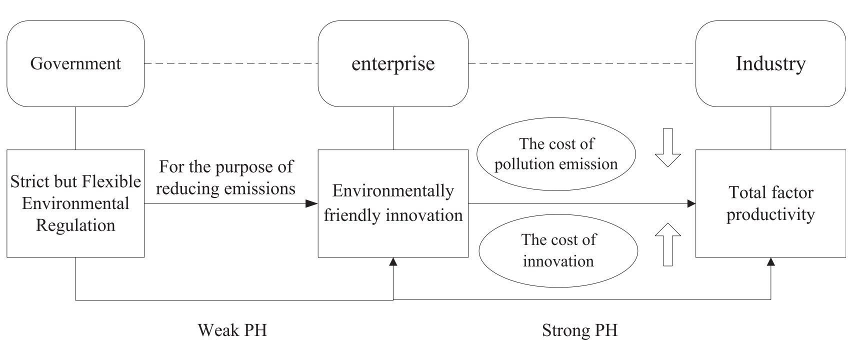

Fig. 1. The formation mechanism of Porter hypothesis.