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The Effects of Environmental Regulation, Cooperation and Green Innovation on Regional Green Growth

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Abstract
Over past twenty years, green growth has been practiced by a lot of countries. Questions of factors driving green growth have become hot topic. Although some studies discuss determinants of green growth, a few studies integrate them in a methodological framework. In addition, innovation cooperation is considered as an effective method to improve green growth, but there is few significant attempt to investigate the relationship in quantity. As a result, this paper proposes an integrated model to explore determinants of green growth, including environmental regulation, innovation cooperation, and green innovation. Structural equation model is used to test the proposed model with research data of 30 Chinese provinces. In turn, we have several valuable findings. Firstly, new empirical relationship between innovation collaboration, green innovation and green growth development is examined. Our empirical results show that innovation collaboration significantly positively influences green innovation and green growth performance. Secondly, the findings display that environmental regulation is a significant positive determinant of innovation cooperation, green innovation and green growth performance respectively. Thirdly, the theoretical model is powerful and robust, which can make us advance the understanding of green growth performance in environmental regulation context. Finally, several implications are discussed while some limitations are also showed.
Keywords: Environmental regulation; innovation collaboration; green innovation; green growth; structural equation model

1. Introduction

In the past forty years, China has attained quickly economic development. Nevertheless, the rapid development is at the expense of resources and with increased environmental costs (Ren et al., 2018; Feng and Chen, 2018; Guo et al., 2017). China has been the biggest energy consumer country as it occupied 23% consumption of the whole world in 2016 (BP, 2017). At the same time, the total amount of carbon dioxide emissions was 9.123 billion, and the amount of waste water discharge was 71.1 billion tons. If China maintains a high growth rate in economy, there is no doubt that the amount of energy consumer and environmental costs will increase rapidly (Xie et al., 2014). These circumstances evidence makes central government take great efforts to the environment issues these years (Zhao and Sun, 2016).

Accordingly, green growth, which is regarded as one of the most important way to deal with environment pollution in economic development, attracts more and more attention in 21st century. In fact, regional green growth means that a region reduces or minimizes resource consumption and environmental damage while it achieves economic and social development (Feng and Chen, 2018).

In China, a series of green growth policies have been carried out, such as the construction of resource-saving and environment-friendly society, permit system for pollutants emissions and reform for promoting ecological progress. On the basis of 2015, energy consumption per unit of GDP will reduce 15% (National Development and Reform Commission, National Energy Board, 2016) while water consumption per unit of GDP will decrease 23% in 2020 (Ministry of Ecology and Environment of P.R.C, 2016). The importance of green development is unprecedented while establishing and practicing the concept of “Lucid waters and lush mountains are invaluable assets” has been written in the nineteenth CPC National Congress (the nineteenth CPC National Congress, 2017). However, have these policy measures achieved the aim of green development? It remains to be seen. Therefore, exploring determinants driving green growth from environmental regulation and innovation is important.

According to ecological modernization theory, technical innovation driven by environmental regulation can migrate environmental problems (Zhu et al., 2011; Guo et al., 2017). Up to now, some studies have applied the theoretical basis to explored determinants of green development from organization level and regional level. Organizational research shows that a lot of factors, such as regulations, collaboration, economic factors, firm integrative capability, competitiveness, customer demand, and firm performance, are discussed as driving forces of corporate eco-innovation or sustainable development (Cai and Zhou, 2014; Melander, 2017;Zhao and Sun, 2016).

On the other hand, a growing number of empirical studies about effects influencing on regional green development have been conducted (Ploeg and Withagen, 2013; Guo et al., 2017; Yang and Yang, 2015). Guo et al. (2017) explore the relationship among environmental regulation, technology innovation and regional green growth performance. Their results indicate that environmental regulation has a significant positive effect on technology innovation, and technology innovation significantly positively influences regional green growth performance while environmental regulation has a negative impact on regional green growth performance. Feng and Chen (2018) apply Spatial Durbin Model to examine the relationship among environmental regulation, green innovation and industrial green development and find that different types of environmental regulation have different regional influences.

Based on the above studies, we can find that environmental regulation, collaboration, technology innovation, and green innovation are main factors influencing green development. Nevertheless, few significant attempt to investigate the relationship between regional innovation collaboration and regional green development while a few studies argue the relationship between interorganization cooperation and sustainable development or eco-innovation at organizational level (Melander, 2017; Ryszko, 2016). In fact, interregional technological spillover plays an important role in green growth performance (Costantini et al., 2013). With limited resources and environmental carrying capacity, innovation cooperation is a good approach to achieving green innovation and growth.

In addition, few studies integrate environmental regulation, technology collaboration, green innovation, and regional green growth in a methodological framework (Ploeg and Withagen, 2013; Guo et al., 2017). To address this gap and finding out factors influencing regional green growth performance, we propose a theoretical model based on previous research. In the end, the purpose of the present paper is to: (1) evaluate which factors significantly affect regional green growth performance; (2) investigate the relationship among these determinants; (3) identify the weight of these determinants influencing regional green growth performance; (4) explore whether the proposed model could make contribution to a stable comprehensive model for understanding regional green growth performance.

The rest of this study is divided into four sections. Section two presents theoretical framework and research hypotheses. Measures and research method can be found in section three. Section four validates reliability of the measurement scales and theoretical model while section five is about discussing of finding and implications.

2. Theoretical framework and research hypotheses

2.1 Environmental regulation

Environmental regulation as a controversial and unavoidable issue can play a significant role in economic development and environment constraints. According to previous research (OECD, 2011), environmental policies are regarded as key factors to advance regional green development (Brito et al., 2008). However, the conventional viewpoint is that environmental regulation may increase enterprise cost burden and bring regional growing pressure (Hu et al., 2017). In other words, local government may not positively respond to policies of the central government. This viewpoint has been challenged by Potter Hypothesis, which pointed that proper environmental regulation can bring greater motivation of innovation (Porter, 1991; Porter and van der Linde, 1995; Desrochers and Haight, 2014).

In order to investigate the relationship between environment regulation and green development, some scholars carry out related research and get some interesting findings. At organization level, environmental regulation significantly positively influences on firm's innovation (Zhao and Sun, 2016; Chung et al., 2016). In addition, Ramanathan et al. (2017) use nine case studies in UK and China to find that if corporations take a positive respond to environmental regulation, they can be generally better able to gain private benefits of sustainability. At sector level, Bi et al. (2014) apply a slacks-based DEA model to show that environmental regulation has a positive effect on energy efficiency while Feng and Chen (2018) think that different types of environmental regulation have different regional influences on industrial green development. In addition, some studies focusing on regional level indicate that environmental regulation has s positive effect on the eco-innovation throughout in China (Chen et al., 2017; Ren et al., 2018). Although a few scholars find negative relationship between environment regulation and green growth (Guo et al., 2017), majority of research results support the positive relationship.

According to ecological modernization theory, environmental regulation can drive technical innovation (Zhu et al., 2011; Guo et al., 2017). In order to positively respond to environmental regulation, when firms develop new products, they have to take suitable innovation measure to reduce environmental impacts. With the rapid increasing of knowledge creation, innovation has become a complex activity (Guan et al., 2016). No firm acts in isolation. Instead, firms establish extensive network of cooperation relationship, which can decrease the risk and complexity of innovation. Environmental regulation may force firms to find cooperation partners (Wagner and Llerena, 2011). From regional level, organization cooperation embedded in region is a key part of regional innovation cooperation. It is a pity that there are few significant attempt to investigate the relationship between environmental regulation and innovation cooperation. To address this gap, we propose a hypothesis that environmental regulation has a positive effect on cooperation. According to above mentioned studies and research motivation, we hypothesis that:

H1a: environmental regulation will have a positive effect on regional green growth performance.
H1b: environmental regulation will positively influence regional green innovation.
H1c: environmental regulation will have a positive impact on regional innovation cooperation.

2.2. Innovation collaboration

Inter-organizational cooperation has been recognized as a significant way to acquire knowledge and technologies. Facing environmental challenges, firms may settle them with the help of collaboration (Hofmann et al., 2012). In testing the proposition, some scholars conduct valuable research. For instance, Higgins and Yarahmadi (2014) use Business Longitudinal Database in Australia to find that cooperating with external partners increases the likelihood of introducing environmental innovations. That is to say: cooperation can affect firms to establish partnerships with stakeholders and to use new environmentally friendly materials for green product and technology. Moreover, collaborating in green product innovation can help firms succeed sustainable development (Melander, 2017). At sector level, Söderholm et al. (2017) suggest that wide cooperation in environmental R&D project leads pulp industry to the transition to cleaner bleaching technologies.

The empirical research on relationship between innovation collaboration and regional green development is rather scarce. In fact, intra- and inter-regional innovation cooperation is achieved through organizations embedded in region, such as universities, research institutes, and companies (Sun and Cao, 2015). To some extent, the fact that organizations achieve green innovation or green growth through innovation cooperation actually means that the region has succeeded green growth. In order to succeed green growth, regions need to build a wide cooperation both inside and outside. Therefore, we assume that innovation collaboration has a positive effect on regional green growth performance.

On the other hand, cooperation is known as one determinant of innovation performance (Funk, 2014; Whittington et al., 2009). However, there are a few significant attempt to investigate the underlying mechanism linking cooperation and green innovation. Albort-Morant et al. (2018) think that firms with strong relations with stakeholders can assimilate and transfer new knowledge and thus enhance green innovation performance. Based on the study of Kong et al. (2018), internal environmental collaboration significantly positively influences green process innovation and green product innovation in advanced manufacturing technologies. Although little is known about the relationship between regional cooperation and regional green innovation, intra- and inter-regional innovation cooperation can be considered a unique regional capability, which can be expected to absorbing new green knowledge and green technology. With limited resources and environmental carrying capacity, innovation cooperation is a good approach to achieving regional green innovation. Thus, we hypothesized that:

H2a: innovation collaboration positively affects regional green growth performance.
H2b: innovation collaboration has a positive effect on regional green innovation.

2.3. Green innovation

Green innovation is often referred to as eco-innovation, environmental innovation and sustainable innovation (Xavier et al., 2017; Feng and Chen, 2018). Regional green innovation measures the extent to which regions develop innovations that help sustain the surrounding environment while optimizing the use of natural resources (Albort-Morant et al., 2017; Kunapatarawong and Martínez-Ros). From this point of view, green innovation play an important role in improving green growth performance. In fact, while organizations embedded in region develop new production and services, green innovation can help them save resources and reduce environmental pollution. Therefore, to achieve green development, regions should improve green innovation.

Previous research supports the relationship between green innovation and green growth. According questionnaire based interviews, Padilla-Perez and Gaudin (2014) find that science, technology and innovation can significantly positively influence sustainable economic growth in Central American countries. Moreover, OCED (2011) believes that technology innovation is important for improving regional green development while Guo et al. (2017) investigate the relationship. In addition, Feng and Chen (2018) find that both green product innovation and green craft innovation can positively significantly affect industrial green development. Based on the above analysis, we propose the following hypothesis. And the theoretical model is presented in Fig. 1.

H3: green innovation has a positive effect on regional green growth performance.

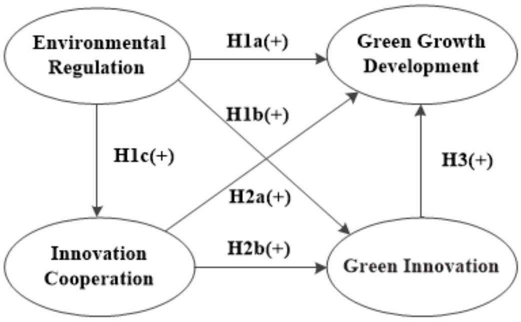

Figure 1. Hypotheses and research model.

3. Methodology

3.1. Variables selection

Regional green growth performance. Regional green growth means that region reduces or minimizes resource consumption and environmental damage while it achieves economic and social development (Feng and Chen, 2018). The studies by Kim et al. (2014) and Guo et al. (2017) use greenhouse gas emissions per unit of GDP and energy consumption per unit of GDP to measure regional green growth, while Mundaca et al. (2015) choose energy intensity and carbon intensity to represent performance of green energy economy in Sweden. As we all know, carbon dioxide emissions are calculated based on energy consumption. There are strong correlation between them. Therefore, this paper apply energy consumption per unit of GDP to measure one of regional green growth performance. From the view of resource consumption, green growth not only need to reduce energy consumption, but also need to decrease other nature resources, such as water consumption and land use. Therefore, except for energy consumption, we use the indicators of water consumption per unit of GDP and construction land utilization per unit of GDP to measure performant of regional green growth (Strategic Research Group for Sustainable Development of Chinese Academy of Sciences, 2006).

Environmental regulation. According to previous research (Guo et al., 2017), environment regulation is generally including command-and-control environmental regulation and market-based environmental regulation. Command-and-control environmental regulation can be represent by industrial waste discharge standard rate (such as waste water, waste gas and waste solid) while market-based environmental regulation is often measured by discharge fee and resource tax (Zhao and Sun, 2016; Ren et al., 2018). However, discharge fee in China is allowed to lapse from 2018, it shows that discharge fee may not research the policy aim reducing environment pollution. Therefore, maybe discharge fee is not very suitable in China. Based on research purpose and data availability, we focus on command-and-control environmental regulation, including industrial waste water discharge standards rate, industrial sulfur dioxide discharge standards rate, and comprehensive utilization rate of industrial solid waste.

Innovation collaboration. Intra- and inter-regional innovation cooperation are often measured by patents (Guan et al., 2016; Guan and Zhao, 2013). Precious studies frequently focus on cooperation relationship degree (like number of cooperation patents) and ignore cooperation organizational range (like number of cooperation organizations). In fact, if innovation collaborations in regions are concentrated on some organizations, it may not be good for regions to assimilate and transfer new knowledge. Thus, we integrate number of cooperation patents, number of cooperation organizations and technology diversity into the model. We use average cooperation frequency (cooperation patents divided by cooperation organizations) to represent cooperation breadth. Then, we use technical distribution of cooperation patents in 120 IPC categories to measure cooperation depth.

Green innovation. Green innovation is generally categorized into two kinds, namely, green product innovation and green craft innovation (Lin et al., 2014). Green product innovation refers to green product that reduces or minimizes resource consumption and environmental damage while green craft innovation focus on the innovation of production technology and technological equipment. According to previous research (Feng and Chen, 2018; Chen et al., 2017) , we use green product value to present green product innovation while the study uses number of green patent, expenditure for acquisition of foreign technology, and technical contract transaction amount to measure green craft innovation.

3.2 data and sample

Due to a lack of data in Tibet, Taiwan, Hong Kong, and Macau, we focus on other 30 provinces in China. Some indicators, such as industrial sulfur dioxide removal amount and industrial waste water standard discharge amount, are not unified before and after 2010 while some indicators are hard to access by 2003. According to reliability of data, we choose the research period of this paper is 2003–2010. All values are the second hand data and collected from statistics yearbook and special database. Besides innovation collaboration indicators, data of other investigation indicators is from annual yearbooks, including the China Statistical Yearbook, China Energy Statistics Yearbook, the China Statistical Yearbook on Science and Technology, China Environment Yearbook, China Environmental Statistics Yearbook.

Collaborative patents are collected from website of State Intellectual Property Office and incoPat patent database. The retrieval time is October 16, 2017. This paper analyzes more than 540,000 invention patents granted by 30 provinces, from 2003 to 2010, and selects at least two or more organizations (companies, universities, research institutions) as joint applicants for invention patents. Then we get a total of more than 49,000 collaborative patents. The existing patent registration regulation in China only contains the address of the first applicant, the address of the joint applicant is not recorded. Therefore, in order to acquire joint applicants' address information, we have to search them one by one. In addition, we count joint patents amount, collaborative organization amount and technology distribution in 30 provinces from 2003-2010. It takes us more than two months to deal with research indicators of cooperation innovation.

3.3. Research method

In order to investigate the determinants influencing regional green growth performance, structural equation model (SEM) is used to evaluate the proposed model. SEM is regarded as a good tool to investigate numerous path coefficients simultaneously, which meets the demand of this study that will test sit hypotheses at the same time. LISREL 8.80 software is used to conduct assessing the SEM, because it is recognized as the most professional analysis software of SEM. We apply SPSS 19.0 to get statistical calculation. The steps of implement are as follows: first, confirmatory factor analysis (CFA) is conducted to evaluate path loadings of measure items, composite reliability (CR), average variance extracted (AVE). Then, SEM is used to test proposed hypotheses and explore the determinants of regional green growth performance.

4. Results

4.1. Data processing

In order to make the indicators reflecting green growth easier to explain, we take the reciprocal of them, including energy consumption per unit of GDP, water consumption per unit of GDP and construction land utilization per unit of GDP. In addition, we use the logarithm of the research indicator data to eliminate the impact of data dimension and ensure the stability of the data.

4.2. Reliability and validity of the measurement scales

For all indicators, we conduct Cronbach's alpha test and Kaiser-Meyer-Olkin (KMO) test. Results show that Cronbach's alpha value and KMO value is more than 0.70 and Bartlett's sphericity test is significant. It suggests that the data is good. To ensure the reliability of the measurement scales, we check item loading values, the composite reliabilities (CR) and average variances extracted (AVE). Besides GGP2, all standardized loadings are significant and more than 0.5. Generally, an item loading value is better than 0.50, while some scholars suggest that a loading value can be accepted if it is significant. The path loading of GGP2 is 0.48, which is almost 0.5. As a consequence, we keep this item. The findings indicate that CR values are between 0.75-0.94 with confirmatory factor analysis, well exceeding the minimum acceptable level of 0.70 and AVE estimates for all constructs range from 0.51-0.81, exceeding the recommended minimum value of 0.5 by Bagozzi & Yi (1988).

Table 1. Construct reliability and convergent validity for the measurement model.

Construct	Item	loading	t-value	CR	AVE
Environmental regulation (ER)	ER1	0.84	15.18	0.79	0.56
	ER2	0.64	10.24		
	ER3	0.75	12.70		
Innovation collaboration (IC)	IC1	1.02	-	0.85	0.74
	IC2	0.69	13.72		
Green innovation (GI)	GI1	0.85	-	0.94	0.81
	GI2	0.84	17.05		
	GI3	0.97	22.72		
	GI4	0.93	19.38		
Green growth performance (GGP)	GGP1	0.90	-	0.75	0.51
	GGP2	0.48	6.70		
	GGP3	0.70	11.76		

Notes: "-"Initially fixed at 1.0 for estimation purposes

4.3. Hypothesis testing and results

Chin and Todd (1995) suggest that the ratio of chi-square/degrees of freedom ($\chi2/df$) should range from 1 to 3 for a good model fit. The ratio of our measurement model is 3.46, which is more than 3 but can be accepted.

Based on previous research, Goodness-of-fit Index (GFI), Normed Fit index (NFI), Comparative Fit Index (CFI), Incremental Fit Index (IFI), and Relative Fit Index (RFI) should be larger than 0.9 while Root Mean Square Residual (RMR) and Standardized RMR (SRMR) should be less than 0.05, and Root Mean Square Error of Approximation (RMSEA) should be less than 0.10 (Bagozzi & Yi, 1988; Hair et al., 2010; Xie et al., 2017). The results for goodness-of-fit indicators of the structure model (GFI of 0.91, NFI of 0.96, CFI of 0.97, IFI of 0.97, RFI of 0.95, SMR of 0.02, SRMR of 0.04, and RMSEA of 0.10) are within recommendation, which means the structural model reveals a good fit.

Table 2. Results of the goodness-of-fit for the structure model.

Fit index	$\chi 2/df$	GFI	NFI	CFI	IFI	RFI	SRMR	RMSEA
Recommended value	<3	>0.90	>0.90	>0.90	>0.90	>0.90	<0.05	<0.10
Model result	3.46	0.91	0.96	0.97	0.97	0.95	0.04	0.10

Table 3. Path coefficients and hypothesis testing

Hypothesis	Relation	Hypothesized direction	t-value	Path coefficient	Supported
H1a	ER→GGP	+	5.27	0.49***	Yes
H1b	ER→IC	+	11.13	0.67***	Yes
H1c	ER→GI	+	6.66	0.30***	Yes
H2a	IC→GI	+	2.12	0.73*	Yes
H2b	IC→GGP	+	13.20	0.28***	Yes
H3	GI→GGP	+	1.07	0.19	No

Notes: * P<0.05; ** p<0.01; ***p<0.001.

Furthermore, the standardized path coefficients are evaluated to represent the direction and significance of the hypothesized relationships in proposed model. As shown in Fig. 2 and Table 3, the results find that regional green growth performance is significantly directly affected by antecedent variables. Environmental regulation (β=0.49, p<0.001) and innovation collaboration (β=0.28, p<0.001) significantly positively influence regional green growth performance. However, green innovation is not a significant determinant of regional green growth performance, which is different from previous studies (Feng and Chen, 2018). Therefore, H1a and H2b is respectively supported while H3 is not confirmed.

With respect to green innovation, the results reveal that environmental regulation (β=0.30, p<0.001) and innovation collaboration (β=0.73, p<0.05) have a positive effect on green innovation. In addition, innovation collaboration is significantly influenced by environmental regulation (β=0.67, p<0.001). As a consequence, the results confirm H1c, H2a and H1b respectively.

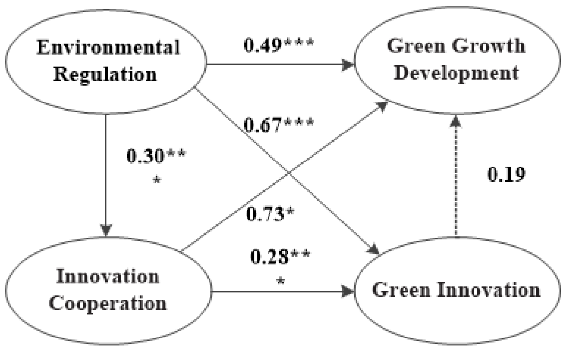

Figure 2. Standardized solution of the structural model.

5. Discussion and conclusion

Over past twenty years, green growth has been practiced by a lot of countries. China as biggest energy consumer and largest emissions country has carried out a series of policies about green development. However, have these policy measures achieved the aim of green growth? It remains to be seen. Therefore, we focus on determinants of green growth performance. In addition, some previous studies investigate the relationship between environmental regulation, innovation, and performance (Ploeg and Withagen, 2013; Guo et al., 2017), but few studies integrate them in a methodological framework. In fact, integrating them can make us advance the understanding of regional green growth performance. Moreover, although innovation cooperation is important for green innovation and green growth, there are few significant attempts to investigate the relationship between innovation collaboration and green growth performance. To address these gaps, this paper propose a theoretical model. In turn, this paper has some key findings. The succeeding paragraphs show the details.

Firstly, proposing a powerful and robust model. Based on previous research, we integrate environmental regulation, innovation collaboration, green innovation, and regional green growth in a methodological framework. We offer a theoretical model, which can make us advance the understanding of green growth performance in environmental regulation context. Using panel data of 30 provinces in China from 2003-2010 and structural equation model, we find that the proposed model with a good fit is powerful to explain determinants affecting regional green growth performance because the majority of hypotheses are confirmed. For future research, scholars can extend models based on our proposed to investigate determinants of green growth performance.

Secondly, the new relationship between intra- and inter-regional innovation collaboration, green innovation and green growth development is investigated. This extends the literature about green growth from the perspective of innovation cooperation. Our empirical results show that innovation collaboration significantly positively influences green innovation and green growth performance. This implies that innovation cooperation improves green knowledge and green technologies transfer inside and outside the region. In order to reduce and minimize resource consumption and environmental damage, green growth is an effective approach for region to achieve “win-win” of economy and environment. On the other hand, the new knowledge is rapid increasing, it is difficult to have all green knowledge and technologies within region (Melander, 2017). There is no doubt that cooperation is an excellent choice to achieve green growth. Consequently, establishing extensive cooperation relationship not only increase regional green innovation capacity, but also improve regional green growth development.

Thirdly, providing a deep understanding of green growth performance in Porter Hypothesis. Our findings display that environmental regulation is a significant positive determinant for innovation cooperation, green innovation and green growth performance respectively. In previous research, proper environmental regulation is regarded as a good approach to bring greater motivation of innovation (Porter, 1991; Porter and van der Linde,1995; Desrochers and Haight, 2014). Our results support the viewpoint in China background. In addition, we creatively investigate the relationship between environmental regulation and innovation cooperation. This finding show that environmental regulation can force firms to find cooperation partners (Wagner and Llerena, 2011), which can improve innovation cooperation. This conclusion can contribute to the ongoing literature about cooperation in context of the environmental regulation. Meanwhile, we do not find empirical evidence that green innovation significantly influences green growth performance. One reason is that green growth performance may mainly be driven by environmental regulation, cooperation and other determinants rather than green innovation. Future research can explore behind reasons.

Moreover, this study provide some practical implications. For local government, there is no doubt that cooperation is an excellent choice to achieve regional green growth. Therefore, policymakers should pay more attention to incentive measures that can encourage organizations embed in region to cooperate with other organizations, especially partners from outside the region. On the other hand, our results show that environment regulation can inspire innovation cooperation, green innovation and green growth performance to some extent. As a result, Chinese government and other developing country governments are supposed to continue to implement proper environmental regulation. With respect to firms, a good policy atmosphere for cooperation and environmental regulation can encourage them to reduce or minimize resource consumption and environmental damage while they develop new products and services.

This paper has its own limitations while it provides valuable insights. To some extent, our research period is not very long and the samples are not very large. Future studies can extend research period and use larger samples involving some other developing and developed countries. On the other hand, we does not have a large number of external factors and focus only on some key determinants of green growth performance, including environment regulation, innovation cooperation, and green innovation, which may lead to miss some important factors. Future research can consider a further expansion of external factors and examine their roles in green growth.

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