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The Effect of Environmental Innovation on Employment Level: Evidence from China′s Manufacturing Industries

Wpływ innowacji ekologicznych na poziom zatrudnienia: przykład przemysłu w Chinach

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Abstract
This paper examines the effect of environmental innovation on employment level, using an industry-level panel dataset for the 2001-2010 period in China. Empirical results show that environmental process innovation has a positive effect on employment, but with a time lag. Furthermore, the relationship between environmental innovation and employment is heterogeneous across *dirty* industries and *clean* industries in China. Based on the empirical result, this study derives some policy implications.

Key words: environmental innovation, employment, manufacturing industries, panel data

Streszczenie
Artykuł dyskutuje wpływ innowacji środowiskowych na poziom zatrudnienia, w oparciu o bazę danych obejmującą lara 2001-2010, a odnoszącą się do Chin. Uzyskane rezultaty pokazują, że wprowadzanie ekologicznych innowacji ma pozytywny wpływ na zatrudnienie, jednak jest to widoczne dopiero w dłuższej perspektywie czasowej. Ponadto okazało się, że powiązania pomiędzy ekologicznymi innowacjami a zatrudnieniem są odmienne w odniesieniu do *brudnych* i *czystych* gałęzi przemysłu w Chinach. Przeprowadzone badania pozwalają na sformułowanie zaleceń na przyszłość.

Słowa kluczowe: innowacje ekologiczne, zatrudnienie, przemysł wytwórczy, bazy danych

1. Introduction

In recent decades, China has achieved a veritable economic miracle, but her rapid development of manufacturing industries leads to the deterioration of environment (Yu and Chen, 2015). China's environmental pollution is increasingly become an important issue both domestically and internationally. The rapid increase of many environmental problems calls for innovations that may reduce the environmental impact of economic activity, and therefore environmental innovation (EI) is portrayed to be one of the key approaches to solve environmental pollution. Due to increasing environmental regulations, public pressure and public scrutiny, many firms in China have adopted EI developments to attain competitiveness and environmental sustainability.

One of the topics commonly addressed during political debates concerns the question of how firms' transformations towards being green affect economic performance and employment (Rennings et al., 2004). Numerous contributions have tried to investigate the dynamics, characteristics and determinants of EI and their impact on economic systems and societies as a whole (Arundel and Kemp, 2011; Arundel et al., 2011; Beise and Rennings, 2005; Costantini and Mazzanti, 2012; Jaffe and Palmer, 1997; vanden Bergh et al., 2007; Wagner 2007). However, little attention has been paid to the consequences of EI on employment. The relationship is not particularly well known and the views and impacts indeed spur ongoing debate (Kunapatarawong, 2016).

The main purpose of the paper is to analyze the effects of EI on employment, using China's manufacturing industries panel data. As the largest developing country, the increasing relevance of environmental issues for the Chinese economy, its employment problem, and its innovation structure make China an interesting context to investigate.

This study contributes to the literature in the following ways. First, most studies testing the relationship between EI and employment focus on the advanced economies, only a few expand the study to other settings. China is an excellent case for newly industrialized economies. This study examines whether EI triggers employment in China, which can add new evidence to this line of research by providing data from NIEs. Second, it tries to fill the gap by providing more empirical evidence about the relationship between EI and employment at industry level. Third, this study examines the effects of different types of EI on employment in the 37 two-digit manufacturing industries as well as distinguishes the effects of EI on employment between clean industries and dirty industries.

The remainder of this paper is organized as follows: section 2 gives a short review of the literature on EI and employment. Section 3 proposes the empirical models and describes the dataset. Section 4 displays the empirical estimates and discusses the results. Section 5 contains concluding remarks and policy implications.

2. Literature review

2.1. The definition of environmental innovation

The terms eco-innovation, EI and green innovation have been used synonymously (Tietze et al., 2011). Following the Measuring Eco-Innovation (MEI) project, we adopt the definition of EI as following: *the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the firm [or organization] and which results, throughout its life cycle, in a reduction of environmental risk, pollution and pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives* (Kemp and Pontoglio,2007, p.10). This definition includes innovations that are not necessarily new to the world but are at least new to the organization adopting them, as the Oslo Manual on innovation suggests (OECD, 2005), so that not only new environmental technologies, but also any new/improved product or process or service has to be accounted for. Furthermore, this includes also *unintended* innovations when they result in environmental improvements as well.

2.2. Environmental innovation and employment

Most researchers pay more attention to the effects of standard innovation on employment. A detailed tailed overview of the existing literature is given by Chennells and Van Reenen (2002). Entorf and Pohlmeier (1990) and Zimmerman (1991) analyze German micro data. Entorf and Pohlmeier (1990) find a positive effect for product innovations, while process innovations show no significant effects. Zimmerman (1991) concludes that technological progress was important for the employment decrease in 1980, i.e. he finds a negative effect of innovation. But the definition of innovation he uses refers to a question asking explicitly for the implementation of labor-saving technological progress. Blanchflower and Burgess (1998), however, find a positive relation between process innovation and employment growth using innovation surveys from the UK in 1990 and Australia in 1989/1990. Lachenmaier and Rottmann (2007) use a static panel approach and also find significantly positive effects for both types of innovation.

In recent years, manufacturing industries have been pressured to adopt EI to achieve greening goals alongside economic goals. Despite its importance, the empirical evidences from advanced economy about the effects of EI on employment at the macroeconomic level are rare (Pfeiffer and Rennings, 2001; Rennings et al., 2004) and puzzled. On the one hand, environmental regulations have created many new firms and industries, such as those of *environmental industry* (Harrison et al., 2014). In this respect, the impact of EI on employment has been positive. On the other hand, EI, particularly cleaner productions, reduce demand for energy and/or material of certain industries. This reduces labor demand in these affected industries where material and energy demand is reduced (Pfeiffer and Rennings, 2001); particularly for certain workers who work with obsolete and so called dirty material or technologies. At the same time, there will be labor demand increase in industries with cleaner technologies. The net effect at the industry-level is therefore uncertain as EI reduces labor demand in some industries, while increases labor demand in other industries. Horbach (2010) and Gagliardi et al. (2016) find positive effects for EI while Licht and Peters (2013) observe positive but not significant differences between environmental and non-environmental product innovations. Kunapatarawong and Martínez-Ros (2016) find a positive relationship between EI and employment.

Another strand of literature focuses more specifically on the effects of different types of EI on employment. Their expected outcomes on employment are different. From a theoretical point of view, product innovations are expected to have a positive, demand-related, effect (Harrison et al., 2014) while process innovations to a negative effect due to increased labour productivity (Cainelli et al., 2011). Horbach and Rennings(2013) show that environmental product innovation does not trigger employment, but environmental process innovation does, particularly for environmental process innovations that lead to material and energy savings. Rennings et al., (2004) find that environmental product innovations have a positive effect on the probability of an employment increase, consistent with his prior work in Rennings and Zwick (2002). The shift from end-of-pipe technologies to cleaner production creates jobs (Rennings and Zwick, 2002).

Reviewing the literature, the impact of EI on employment has proved to be controversial. In fact, two points are worth examining with regard to the EI-employment nexus. First, most studies are based on the predominant U.S. and EU samples, while the relationship between EI and employment at industry level in developing countries like China has not been investigated. Second, the effects of different types of EI on employment distinguished between clean industries and dirty industries have not been adequately examined.

3. Empirical model and data sources

3.1. Econometric model

To examine the relationship between EI and employment, we follow the existing literature (Kunapatarawong and Martínez-Ros, 2016) in estimating a reduced-form regression, which takes the form:

$$Employment_{it} = \beta_0 + \beta_1 EI_{it-1} + \beta_2 X_{it-1} + \mu_i + \varepsilon_{it}$$

where *i* denotes industries and *t* years. *Employment* is a measure of the total number of employees in an industry. *EI* is a measure of environmental innovation in an industry. The following section discusses in detail the various alternative proxy variables used. X_{it} is a set of control variables. The terms μ_i and ε_{it} represent the unobserved industry-specific heterogeneity and white noise, respectively.

3.2. Dependent variable

The dependent variable is *Employment*. Referring to prior scholars (i.e. Harrison et al., 2014; Horbach and Rennings,2013; Lachenmaier and Rottmann, 2011; Rennings et al., 2004) this paper employs log of employees as measures of *Employment*. The paper aims to study the relationship between EI and employment level.

3.3. Explanatory variable

According to Hemmelskamp (1997), our independent variable, EI can be subdivided into environmental product innovation （$EI_{product}$） and environmental process innovation($EI_{process}$). $EI_{product}$ is measured by the ratio of energy consumption to new product output in an industry. Referring to Copeland and Taylor (2003), we use pollution discharge intensity as the proxy variable of environmental technology, specifically, $EI_{process}$ is measured by the ratio of industrial waste water discharged to gross industrial output value.

3.4. Control variables

To control for industry characteristics, we include a variety of control variables which have been shown elsewhere to be important determinants of industrial employment.

Firstly, we control for market characteristics by including industrial growth (*Sales growth*) per industry as a determinant of employment. A growing market provides incentives for firms, and thus increases employment. We measure *Sales growth* as the growth rate of industry sales. We deflate growth in nominal sales with consumer price index.

Secondly, we include industry value added (*Value Added*) which is measured by value added per industry, is the long-standing concern factor on influencing industry employment. Generally, a larger industry tends to employ more employees.

Thirdly, capital intensity(*Capi*) serves as an alternative determinant that might negatively correlate with employment, because capital-intensive industries generally need more capital investment and less labor demand compared to other industries with development of new technologies or processes.

Rennings et al.,(2004) claim firms first make decisions to invest in environmental innovation, and then employment adjustments during a second stage. Following their specification, EI enters the equation in the form of a 1-year lagged. Moreover, to avoid the endogenous problem, all other control variables are also specified in 1-year lagged forms.

3.5. Data sources

This paper selects the panel data of 37 two-digit manufacturing industries under China's industrial classification system from 2001-2010. Three manufacturing industries including Craftwork and other manufactures, Mining of Other Ores and Utilization of Waste Resources are omitted due to missing data, so we exclude the three manufacturing industries from the sample[1] (See Appendix: Table 6 for 37 two-digit industry category in China). The main dataset for this research comes from the China Industry Economy Statistical Yearbooks, the China Science and Technology Statistical Yearbooks and the China Environment Statistical Yearbooks. We deflate the data using industry-specific price deflators to obtain real series. Table 1 summarizes the definitions and summary statistics of all variables. All nominal variables are deflated into real variables by using manufacturing intermediate input-output price indices for the year 2001.

4. Empirical results

4.1 Correlation analysis

The correlation analysis in Table 2 shows the Variance Inflation Factor (VIF) of all explanatory va-

[1] See Appendix for 37 two-digit industry category in China.

Table 1. Definitions and summary statistics of all variables.

Varible	Denifitions	Mean	SD
Employment	The total number of employees in an industry(10 thousand person)	107.4864	102.2092
Energy consumption	Million tons of standard coal	4492.197	8415.612
New product	Output value of new products (RMB￥ 100 million）	944.2675	2110.36
$EI_{product}$	The ratio of energy consumption to new product output in an industry	80.91212	485.8611
Waste water discharge	Total volume of industrial waste water discharge（Ton 10 thousand）	54789.6	86364.68
Value Added	Gross industrial output value (RMB￥ 100 million）	5737.669	8068.133
$EI_{process}$	The ratio of industrial waste water discharged to gross industrial output value	2.112202	3.976517
Sales growth	Growth rate of industry sales (%)	0.349775	1.417504
Capi	Capital intensity: ratio of capital to labor employed (RMB￥ thousand/person)	203283.3	213157.9

Note: The summary statistics reported are reported by the pooling data of 34 China's manufacturing industries for the period of 2001-2010.

Table 2. Pearson correlation matrix
a) Model for the effect of $EI_{product}$ on employment

Variable	VIF	1/VIF
$EI_{product}$	1.03	0.973083
Value Added	1.17	0.856494
Capi	1.17	0.857225
Sales growth	1.00	0.998173
Mean VIF	1.09	

b) Model for the effect of $EI_{process}$ on employment

Variable	VIF	1/VIF
$EI_{product}$	1.05	0.95275
Value Added	1.20	0.832596
Capi	1.15	0.869616
Sales growth	1.00	0.997505
Mean VIF	1.10	

Table 3. Effects of environmental innovations on employment of all industries

Variable	Model 1 (RE)	Model 2 (RE)
$EI_{product}$	-0.0047844* (-1.68)	
$EI_{process}$		1.056749* (1.81)
Value Added	0.0076221*** (19.79)	0.007488*** (19.29)
Sales growth	1.870541** (2.19)	1.968815** (2.30)
Capi	-0.000151*** (-9.00)	-0.00014*** (-8.59)
Cons	119.2077*** (10.51)	116.2789*** (10.26)
Industry dummy	Yes	Yes
Time dummy	Yes	Yes
R-square	0.7405	0.7422
Hausman test	1.35	1.39
Observations	324	324

Note: Industry and year effects are included in all regressions. z statistics are in parentheses. R-squared defined as the squared correlation between the actual and predicted value of the dependent variable. All variables are in levels. *Significance at the 10% levels, **Significance at the 5% levels, ***Significance at the 1% levels.

riables and control variables in Pearson correlation matrix are less than 10, implying that the econometric models do not exist multicollinearity problems.

4.2 Baseline regression results

Table 3 reports the results obtained using linear panel data models to estimate econometric model, testing the effects of EI on employment for 37 two-digit manufacturing industries. Use of a *within* panel estimator, a fixed effect (FE) or random effect (RE) technique, to eliminate the individual effect is a standard estimation method in the panel dada model. As all Hausman test statistics are not significant at the 1% statistical level, suggesting that the random effect model is more appropriate, we only display the estimates of the random effect model.

Controlling for the time- and industry-specific effects, model (1) and model (2) are the main estimating results based on the relationship between environmental product innovation(EI_{product}) and employment, and between environmental process innovation(EI_{process}) and employment in China respectively. The estimated coefficient for environmental process innovation is positive and statistically significant at the 10% statistical level, suggesting that employment of all industries would be triggered by about 1% in case of a 1% increase in environmental process innovation. However, the estimated coefficient for environmental product innovation is negative and statistically significant at the 10%, moreover, the coefficient is -0.0047844; it implies that negative effect induced by environmental product innovation is not very significant. The result is consistent with findings by Horbach and Rennings (2013), that green product innovation does not trigger employment, but green process innovation does.

Why can environmental process innovation rather than environmental product innovation lead to a higher employment in manufacturing industries in China? The intuitive explanation is that environmental process innovations that induce material and energy savings can improve the competitiveness of firms, this has a positive effect on demand and thus also increases employment (Horbach and Rennings, 2013). While environmental product innovations may cause a monopolistic position leading to a reduction of output (Hall et al. 2006), thus the effect for employment is negative.

As for the influences of other control variables, the results obtained overall are consistent with theoretical estimations. An industry with much more *Value Added* and a higher sales growth rate tends to induce more employment, certis paribus. However, there are significantly negative effects of *Capi* on employment.

4.3 Industry heterogeneity

Baseline regression results considered thus far assume that the slope coefficients β in baseline regression is constant across industries. This assumption may be inappropriate. In particular, industries may be heterogeneous in their response to changes in employment to EI. This subsection further examines the impact of EI on employment in dirty and clean industries[2], using linear panel data models to estimate econometric model respectively.

4.3.1. Effects of environmental innovation on employment of dirty industries

Table 4 displays the estimate results of the effects of EI on employment in dirty industries. We can only show the results obtained using the fixed effect of panel data model, as all the Hausman tests reject the null hypothesis at the 1% statistical level.

Controlling for the time- and industry-specific effects, the coefficient of environmental process innovation in model (2) is positive and significant at the 5% level, but the coefficient of environmental product innovation is negative and insignificant in model (1), implying that environmental process innovation can promote employment in dirty industries in China, and environmental product innovation does not. The possible reason is that introduction of end-of-pipe measures may require additional staff as firm implement environmental process innovation in dirty industries.

4.3.2. Effects of environmental innovation on employment of clean industries

Table 5 shows the estimate results of the effects of EI on employment in clean industries. The Hausman test shows that the fixed effect model is more appropriate for model (1), while random effect model is more appropriate for model (2).

Are the effects of EI on the employment of clean industries the same as that of dirty industry? Controlling for the time- and industry-specific effects also, interestingly, we find the estimated coefficient of environmental process innovation in model (2) is positive but not statistically significant, however, the estimated coefficient of environmental product innovation in model (1) is negative and significant at the 1% level, employment would be decreased by about 0.03% in case of a 1% increase in environmental product innovation in clean industries in China, implying that environmental product innovation has a negative effect on employment in clean industries. This might be because substitution of more environmentally friendly products for highly-polluting products (product innovation accompanied by product innovation) arising from environmental product innovation brings about a decrease in employment demand in clean industries..

[2] See Appendix for dirty and clean industries in China.

Table 4. Effects of environmental innovations on employment of dirty industries

Variable	Model 1 (RE)	Model 2 (RE)
$EI_{product}$	-0.0011015 (-0.68)	
$EI_{process}$		0.8136084** (2.23)
Value Added	0.0023008*** (6.83)	0.0021168*** (6.22)
Sales growth	0.3675782 (0.77)	0.4794257 (1.02)
Capi	-0.0000226* (-1.88)	-0.0000182 (-1.56)
Cons	113.1165*** (5.91)	112.0016*** (5.89)
Industry dummy	Yes	Yes
Time dummy	Yes	Yes
R-square	0.7144	0.7264
Hausman test	0.92	1.05
Observations	153	153

Note: Industry and year effects are included in all regressions. z statistics are in parentheses. R-squared defined as the squared correlation between the actual and predicted value of the dependent variable. All variables are in levels. *Significance at the 10% levels, **Significance at the 5% levels, ***Significance at the 1% levels.

Table 5. Effects of environmental innovation on employment of clean industries

Variable	Model 1 (RE)	Model 2 (FE)
$EI_{product}$	-0.0307137*** (-3.20)	
$EI_{process}$		4.60094 (1.61)
Value Added	0.0109464*** (25.54)	0.0104771*** (23.47)
Sales growth	3.699714 (1.02)	3.635233 (0.98)
Capi	-0.0002046*** (-4.81)	-0.0001119*** (-3.41)
Cons	103.592*** (7.70)	88.48386*** (11.05)
Industry dummy	Yes	Yes
Time dummy	Yes	Yes
R-square	0.8995	0.8940
Hausman test	2.85	6.58
Observations	171	171

Concluding and policy implications

This study investigates whether EI would trigger employment in China. On the basis of a panel dataset of 37 manufacturing industries during the period 2001-2010, and we derive interesting and important findings. Baseline regression results show environmental process innovation has a positive effect on employment, while environmental product innovation does not. The result is consistent with findings by Horbach and Rennings (2013). Furthermore, we also identify that the relationship between EI and employment is heterogeneous across manufacturing industries in China.

Results show that environmental process innovation can trigger employment in dirty industries significantly, and the employment induced effect for clean industries is not significant. Nonetheless, environmental product innovation has a significant negative effect on employment in clean industries, while exhibits no significant negative influence on employment in dirty industries.

From the above analysis, this study derives two policy implications. First, EI helps manufacturing industries not only in terms of reducing resource and public scrutiny, but also in term of relationship with employment. Moreover, employment effects of different environmental innovation fields is different, especially environmental process innovation can induce employment significantly in manufacturing industry. Thus, to increase employment, the Chinese government should adjust its policy for enhancing EI in manufacturing industry, in particular, should place more emphasis on environmental process innovation. Second, as employment in dirty industries can be promoted by environmental process innovation in China, to achieve a win-win situation in which the dirty industries can simultaneously attain both goals of a reducing pollution and creating more jobs, more environmental process innovation should be adopted in dirty industries of China. In addition, given the significantly negative effect on employment brought by environmental product innovation in clean industries, the Chinese government should take measures to decrease the unfavorable influences of environmental product innovation on employment in clean industries to the most extent.

This work has several limitations that should be taken into account. To the best our knowledge, China has no nationwide statistics on environmental patent. Besides, it is very difficult to compile industry-level environmental patent data because of difference in industry and patent classifications. This study measure environmental product innovation and process innovation only by using the ratio of energy consumption to new product output and the ratio of industrial waste water discharged to gross industrial output value respectively. Moreover, empirical work on the EI-employment relationship can be influenced by a wealth of different factors, however, owing to the limitation of data source, only *Value added*, *Sales growth* and *Capi* are used as control variables in this study. Furthermore, we only provide industry-level analysis. It would be interesting to conduct a similar study for China using a firm level dataset to examine the robustness of our results.

Appendix A. Composition of industry categories

Table 1. Composition of industry categories in China

SIC code	Two-digit category
06	Coal mining and dressing
07	Extraction of Petroleum and Natural gas
08	Ferrous metal mining & dressing
09	Non-ferrous metal ores mining and dressing
10	Mining and Processing of Nonmetal Ores
11	Mining of Other Ores
13	Agriculture and sideline foods processing
14	Food production
15	Beverage production
16	Tobacco products processing
17	Textile industry
18	Clothes, shoes and hat manufacture
19	Leather, furs, down and related products
20	Timber processing, bamboo, cane, palm fiber and straw products
21	Furniture manufacturing
22	Papermaking and paper products
23	Printing and record medium reproduction
24	Cultural, educational and sports articles production
25	Petroleum processing, coking and nuclear fuel processing
26	Raw chemical material and chemical products
27	Medical and pharmaceutical products
28	Chemical fiber
29	Rubber products
30	Plastic products
31	Nonmetal mineral products
32	Smelting & pressing of ferrous metals
33	Smelting & pressing of non-ferrous metals
34	Metal products
35	Ordinary machinery manufacturing
36	Specialty equipment manufacturing
37	Transport equipment and manufacturing
39	Electric machines and apparatuses manufacturing
40	Communication equipment, computers, and other electronic equipment
41	Instruments, meters, cultural and office machinery manufacture
42	Craftwork and other manufactures
43	Utilization of Waste Resources
44	Electricity and heating production and supply
45	Fuel gas production and supply
46	Water production and supply

Note: Industry *Mining of Other Ores* (SIC code 11) , *Utilization of Waste Resources* (SIC code 43) and *Craftwork and other manufactures* (SIC code 42) are omitted due to missing data.

We partition industries into dirty and clean industries with respect to the level of pollution and toxin each industry is discharging into the environment, as shown in Table A2.

Table 2. Industry classification: dirty and clean in China

Dirty industries	
SCI Code	Two-digit category
6	Coal mining and dressing
7	Extraction of Petroleum and Natural gas
8	Ferrous metal mining & dressing
9	Non-ferrous metal ores mining and dressing
10	Mining and Processing of Nonmetal Ores
22	Papermaking and paper products
25	Petroleum processing, coking and nuclear fuel processing
26	Raw chemical material and chemical products
27	Medical and pharmaceutical products
28	Chemical fiber
29	Rubber products
30	Plastic products
31	Nonmetal mineral products
32	Smelting & pressing of ferrous metals
33	Smelting & pressing of non-ferrous metals
44	Electricity and heating production and supply
45	Fuel gas production and supply
Clean industries	
SCI Code	Two-digit category
13	Agriculture and sideline foods processing
14	Food production
15	Beverage production
16	Tobacco products processing
17	Textile industry
18	Clothes, shoes and hat manufacture
19	Leather, furs, down and related products
20	Timber processing, bamboo, cane, palm fiber and straw products
21	Furniture manufacturing
23	Printing and record medium reproduction
24	Cultural, educational and sports articles production
34	Metal products
35	Ordinary machinery manufacturing
36	Specialty equipment manufacturing
37	Transport equipment and manufacturing
39	Electric machines and apparatuses manufacturing
40	Communication equipment, computers, and other electronic equipment
41	Instruments, meters, cultural and office machinery manufacture
46	Water production and supply

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