The impact of technological innovation from domestic innovation, import and FDI channels on carbon dioxide emissions of China's textile industry

INTRODUCTION

Global climate warming is a common problem faced by human beings. Reducing carbon dioxide (CO₂) emissions has become a key measure for all nations to combat climate warming. Xi Jinping, the president of China, announced at UN General Assembly in September 2020 that China “strives to peak carbon emissions by 2030 and achieve carbon neutrality by 2060”. At the Climate Ambition Summit in December 2020, Xi further promised that “by 2030, China’s CO₂ emissions per unit of GDP will drop by more than 65%, compared with 2005 and the proportion of non-fossil energy consumption will reach 25% of primary energy consumption”. These promises set clear time and quantity targets for China’s CO₂ emissions and reducing CO₂ emissions has become an urgent task for Chinese governments at all levels.

The textile industry is one of the traditional pillar industries of China’s economy and has made remarkable contributions to promoting economic growth and social development. The textile industry is also one of the important sources of China’s CO₂ emissions. In 2019, the CO₂ emissions of China’s textile industry (CTI) exceeded 22 million tons and it was still a large

ABSTRACT – REZUMAT

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Technological innovation is the key to reducing carbon dioxide (CO₂) emissions. In order to analyse the role of technological innovation from domestic innovation, import and FDI channels in the CO₂ emissions reduction of China’s textile industry (CTI), this study uses OLS models to study the impact of domestic innovation, import technology spillover and FDI technology spillover on CO₂ emissions and CO₂ emission intensity of CTI respectively. The research results show that domestic innovation has significantly reduced CTI’s CO₂ emissions and CO₂ emission intensity, while import technology spillover has increased them. FDI technology spillover has increased CO₂ emission intensity, but its impact on CO₂ emissions isn’t significant. Therefore, China should take domestic R&D investment as the key measure to reduce CTI’s CO₂ emissions in the future and continue to improve the level of independent innovation. China should also attract more low-carbon and green international investment and avoid becoming the “pollution heaven” for high-emission capital. The level of technology embedded in the imported textile products should be improved further. The use of various technological innovation strategies not only reduces CTI’s CO₂ emissions but also makes positive contributions to China’s goal of “carbon peaking and carbon neutralization”.

Keywords: China’s textile industry, carbon dioxide emissions, technological innovation, domestic innovation, import, FDI
one. Therefore, reducing CTI’s CO₂ emissions is of great significance for China to achieve the goal of “carbon peaking and carbon neutralization” and transfer to a green and low-carbon development model.

The key to reducing CO₂ emissions is technological innovation, which reduces energy consumption and CO₂ emissions by improving energy efficiency, producing more low-carbon products and optimizing industrial structure. In an open economy, the sources of technological innovation include not only domestic innovation activity but also technology spillovers from import and foreign direct investment (FDI) [1]. In the reduction of CTI’s CO₂ emissions, what role do these three channels of technological innovations play? What’s the difference between them? Therefore, it has great empirical significance to study the impact of technological innovation of these three channels on CTI’s CO₂ emissions for answering these questions. And it will provide a beneficial reference to guide CTI to rationally make use of their CO₂ emissions reduction effects.

The research on the impact of technological innovation on CO₂ emissions began with the study of the relationship between exogenous technological innovation and environmental problems. Then academia studied it under the framework of the endogenous growth model and the commonly used research methods include the STIRPAT model, EKC model, CGE model and LDMI method et al. Regarding the relationship between technological innovation and CO₂ emissions, most scholars believe that it has a positive impact on reducing CO₂ emissions. Lu [2] found that breakthrough low-carbon technological innovation had a reduced effect on CO₂ emissions by using China’s Provincial Spatial Panel data. Daniel [3] confirmed that environmental innovation did contribute to CO₂ emissions reduction in the EU-27 countries between 1992 and 2014. Meanwhile, some scholars believe that the CO₂ emissions reduction effect of technological innovation is inconclusive and it may even increase CO₂ emissions. The rebound effect explicitly reveals that technological innovation promotes the decrease of product cost and price, then increases external demand and will lead to an increase in CO₂ emissions, instead of a decrease [4]. The research of Li [5] proved that technological innovation had a rebound effect on China’s CO₂ emissions, about 9% – 75%. Chen [6] found that the impact of China’s general domestic technological progress on CO₂ emissions was complex. In Central and West China, it reduced CO₂ emissions, whereas in East China it slightly increased emissions.

On the impact of technological innovation from domestic innovation, import and FDI channels on CO₂ emissions, Chinese scholars have achieved some research findings. Bi [7] confirmed that the horizontal spillover effect, forward linkage spillover effect and backward linkage spillover effect of FDI all reduced the CO₂ emission intensity of China’s industry. Guo [8] found that import technology spillover reduced China’s CO₂ emissions. When it increased by 1%, the CO₂ emissions would decrease by 0.513%. But Alfred [9] held the opposite opinion based on the research on Turkey. Ma [10] studied the impact of technological innovation from domestic innovation activity, direct technology introduction and indirect technology introduction (FDI and import) channels on China’s CO₂ emission intensity for the first time. The results showed that domestic innovation activity, FDI and import reduced CO₂ emission intensity, while export increased that and the effect of direct technology introduction was not significant. Regarding the research on the impact of technological innovation from different channels on the CO₂ emissions of the textile industry, the literature is rare. Only Ignas [11] studied the impact of international trade on the CO₂ emissions of the EU clothing industry, excluding the textile industry. As to the research on CTI’s CO₂ emissions, existing literature focuses on the measurement of CO₂ emissions and their relationship with economic development. Lu [12] and Gong [13] proved the weak decoupling relationship between GDP and CO₂ emissions of textile and garment industry in China and Xinjiang respectively. There are some shortcomings in these researches, such as poor data timeliness and rough distinguish-ment between the textile industry and garment industry. Furthermore, previous research has not paid sufficient attention to the impact of technological innovation on CTI’s carbon emissions and there is also a lack of research from the channels of domestic innovation, import and FDI.

Under the overall requirements of innovative development and green development, it is of great practical urgency and value to explore the impact of technological innovation from domestic innovation, import and FDI channels on CTI’s CO₂ emissions. Meanwhile, academia has not yet done research in this field. Given this fact, this study first calculates and analyses CTI’s CO₂ emissions and CO₂ emission intensity from 2003 to 2019. Then it constructs OLS models to investigate the impact of domestic innovation, import technology spillover and FDI technology spillover on CTI’s CO₂ emissions and CO₂ emission intensity respectively. Analysing the different impacts of the three channels of technological innovation, can not only provide evidence suggesting policy recommendations targeting CTI’s CO₂ emissions reduction but also address the research gap in this field.

METHODOLOGY AND DATA SOURCES

Estimation model

Referring to the research method of Ma [10], this study takes CO₂ emissions and CO₂ emission intensity of CTI as dependent variables and domestic innovation, import technology spillover and FDI technology spillover as independent variables, then constructs regression equations to investigate the impact.
of domestic innovation, import technology spillover and FDI technology spillover on CTI’s CO₂ emissions (Model 1) and CO₂ emission intensity (Model 2) respectively. Thus, the impact of technological innovation from different channels on the CO₂ emissions of CTI can be comprehensively analysed. The equations are as follows:

\[ \ln(CM_t) = C + \ln(R&D_t) + \ln(FDI_t) + \ln(IMP_t) + \varepsilon \]  
\[ \ln(CMI_t) = \ln(CM_t) + FDI_t + \ln(IMP_t) + \varepsilon \]  

CM and CMI represent CTI’s CO₂ emissions and CO₂ emissions intensity in year t. R&D represents CTI’s domestic innovation in year t. FDI and IMP represent FDI technology spillover and import technology spillover of CTI in year t. C represents the constant and ε represents the residual.

**Variables explanation and data sources**

CO₂ emissions: Since there is no direct statistical data on CO₂ emissions in China, most scholars usually use the energy consumption of a specific industry to calculate CO₂ emissions indirectly. Referring to the method provided by IPCC [14], this study calculates CTI’s CO₂ emissions by adding up the CO₂ emissions of the nine main energy CTI consumes, including raw coal, coke, coke oven gas, crude oil, gasoline, kerosene, diesel oil, fuel oil and natural gas. The equation is as follows:

\[ CM = \sum E_i \times p_i \times \mu_i \]  

where CM represents CTI’s CO₂ emissions, \( E_i \) represents the consumption of energy \( i, i = 1,2,\ldots,9 \), \( p_i \) and \( \mu_i \) represent the coal equivalent coefficient and carbon emission coefficient of energy \( i \).

CO₂ emission intensity refers to the amount of CO₂ emitted per 10,000 CNY of GDP. It’s measured by the ratio of CTI’s CO₂ emissions to its total output to calculate CO₂ emission intensity.

Domestic innovation: It’s measured by the domestic R&D capital stock of CTI and calculated by the perpetual inventory method.

Import technology spillover: Import is a major channel of technology spillover. Referring to the LP model proposed by Lichtenberg [15], which is used to measure the foreign R&D capital stock split from international trade channels, this study uses the following formula to calculate import technology spillover:

\[ S_{imp}^t = \sum_{j \neq k} \frac{S_{rd}^j}{K_j^t} M_{jkt} \]  

\[ S_{imp}^t \] represents import technology spillover of CTI in year t. \( S_{rd}^j \) represents the domestic R&D capital stock of country j in year t. \( Y_j^t \) represents the GDP of textile industry products imported by country k from country j in year t. The bilateral trade between China and OECD countries accounts for a large proportion of China’s foreign trade and the world’s R&D investment is mainly concentrated in OECD countries, mostly in the United States, Japan, Germany, France, Italy, Britain, Canada, South Korea and other countries. Therefore, this study chooses these eight countries as the source countries for spilling R&D capital to China and then measures import technology spillover of CTI.

FDI technology spillover: FDI is another major channel of technology spillover. Similarly, referring to the LP model, the calculation formula for FDI technology spillover of CTI is as follows:

\[ S_{fdi}^t = \sum_{j \neq k} \frac{S_{rd}^j}{K_j^t} FDI_{jkt} \]  

\( S_{fdi}^t \) represents FDI technology spillover of CTI in year t. \( S_{rd}^j \) represents the domestic R&D capital stock of country j in year t. \( K_j^t \) represents the total fixed capital formation of country j in year t. \( FDI_{jkt} \) represents the textile industry FDI of country k from country j in year t.

The above data are obtained from China Statistical Yearbook, China Statistical Yearbook on Science and Technology, China Energy Statistical Yearbook and the UN Comtrade Database. The time series is 2003–2019.

## CO₂ EMISSIONS OF CHINA’S TEXTILE INDUSTRY

### CO₂ emissions and CO₂ emission Intensity

The CO₂ emissions of CTI declined from 28.81 million tons in 2003 to 22.72 million tons in 2019 (table 1), more than 20%. Its share in the industry had also been declining from 2.56% to 0.88%, lower...

| Year | CO₂ emissions (million tons) | Share in industry (%) | CO₂ emission intensity (kg/10,000 CNY) |
|------|-----------------------------|-----------------------|----------------------------------------|
| 2003 | 28.81                       | 2.56                  | 384                                    |
| 2004 | 33.38                       | 2.48                  | 333                                    |
| 2005 | 31.64                       | 2.02                  | 256                                    |
| 2006 | 32.89                       | 1.93                  | 220                                    |
| 2007 | 34.54                       | 1.90                  | 190                                    |
| 2008 | 31.58                       | 1.55                  | 152                                    |
| 2009 | 29.58                       | 1.42                  | 132                                    |
| 2010 | 27.76                       | 1.30                  | 99                                     |
| 2011 | 23.71                       | 1.04                  | 73                                     |
| 2012 | 19.31                       | 0.83                  | 60                                     |
| 2013 | 34.03                       | 0.90                  | 94                                     |
| 2014 | 25.34                       | 0.89                  | 66                                     |
| 2015 | 23.44                       | 0.87                  | 59                                     |
| 2016 | 24.97                       | 0.97                  | 61                                     |
| 2017 | 25.03                       | 1.00                  | 69                                     |
| 2018 | 22.60                       | 0.89                  | 81                                     |
| 2019 | 22.72                       | 0.88                  | 92                                     |
than the share of CTI’s total output (2.31%). This reveals that CTI has made remarkable achievements in reducing CO₂ emissions. In addition to eliminating the backward production capacity with high energy consumption and CO₂ emissions, a large part of the reduction is attributed to technological innovation activities, such as technological transformation and upgrading.

The CO₂ emission intensity of CTI showed a sharp decline and a slight rise during 2003–2019 (table 1). It first dropped from 384kg/10,000 CNY in 2003 to 59 in 2015. Then it slowly increased to 92 in 2019 and there was still more than 3/4 decline compared with 2003. CTI’s CO₂ emission intensity has always been lower than the industry average and is currently only 37.99% of it. This shows that the CO₂ emissions caused by per unit output of CTI are relatively low, compared to the industry. However, the slow increase of CO₂ emission intensity since 2016 reminds us that CTI must always put more emphasis on curbing CO₂ emissions and not relaxing.

**CO₂ emissions structure**

The CO₂ emissions structure of CTI has shifted from being dominated by raw coal and supplemented by fuel oil and diesel oil to mainly natural gas with raw coal as a supplement (table 2). In 2003, the main source of CO₂ emissions was raw coal, followed by fuel oil, diesel, gasoline and natural gas. The total CO₂ emissions of these five energies accounted for 99.35% of CTI and that of raw coal accounted for about 78.34%. From 2004 to 2015, the share of raw coal had been always higher than 80%, even reaching the maximum of 87.59% in 2015. It indicates that CTI relies heavily on raw coal and reducing the use of raw coal is the key to cutting down CTI’s CO₂ emissions. In 2016, as the use of natural gas (especially liquefied natural gas) increased significantly, the CO₂ emissions share of raw coal fell below 80% for the first time, to 66.95%. Then it dropped to 22.38% in 2019, while the CO₂ emissions from natural gas increased sharply to 69.68%. As a result, CTI’s CO₂ emissions have made a great structural adjustment from raw coal-based to natural gas-based with raw coal as a supplement. It also proves that optimizing energy structure is beneficial to CO₂ emissions reduction. The CO₂ emissions share of coke oven gas increased from 0.33% in 2003 to 4.86%, while fuel oil dropped from 8.17% to 0.69%. And gasoline and diesel both dropped to about 1%.

**EMPIRICAL RESULTS AND DISCUSSIONS**

**Robustness check and co-integration test**

This study first does a robustness check for each variable and the results show that they all pass the robustness check at a 10% significance level. The results of the co-integration test show that there is a co-integration relationship among the variables. Due to space limitations, the results of the robustness check and co-integration test are not presented here.

**Empirical results**

This study uses OLS models to analyse the impact of technological innovation from the channels of domestic innovation, import technology spillover and FDI technology spillover on CTI’s CO₂ emissions (Model 1) and CO₂ emission intensity (Model 2) respectively. The estimation results are shown in table 3.
Technological innovation from domestic innovation has significantly reduced CTI’s CO₂ emissions, while the import technology spillover has increased it and the effect of the FDI technology spillover isn’t significant. The impact coefficient of domestic innovation on CTI’s CO₂ emissions is −0.344, which demonstrates that improving the technological innovation level by increasing domestic R&D investment will help mitigate CTI’s CO₂ emissions. The reason is that textile enterprises attach more and more important to improving independent innovation capability. Through continuously increasing R&D investment, they’re able to alleviate the pressure from environmental regulations and maintain their competitive edge in the market. The impact coefficient of import technology spillover is 0.370, which means importing foreign textile products has a negative environmental externality and it plays a role in increasing CTI’s CO₂ emissions, instead of reducing them. The reason may be that level of technology embedded in the imported textile products is relatively low. The impact coefficient of the FDI channel is −0.182, not significant.

CONCLUSIONS AND POLICY SUGGESTIONS

This study uses OLS models to investigate the impact of domestic innovation, import technology spillover and FDI technology spillover on CTI’s CO₂ emissions and CO₂ emission intensity respectively, to analyze the differences in the effects of technological innovation through these three channels on CTI’s CO₂ emissions. The research results are as follows: Technological innovation from domestic innovation has significantly reduced CTI’s CO₂ emissions and CO₂ emission intensity, while import technology spillover has increased them. FDI technology spillover has increased CO₂ emission intensity, but its impact on CO₂ emissions isn’t significant. This demonstrates that increasing domestic R&D investment to promote technological innovation levels does reduce CTI’s CO₂ emissions. Importing foreign textile products has negative environmental externality and it aggravates environmental pollution by intensifying the carbon emissions. FDI in CTI has increased CO₂ emission intensity and has the effect of transferring pollution.

Therefore, China should take domestic R&D investment as the key measure to reduce CTI’s CO₂ emissions in the future and continue to improve the level of independent innovation. China should also attract more low-carbon and green international investment and avoid becoming the “pollution heaven” for high-emission capital. At the same time, the level of technology embedded in the imported textile products should be improved further. Thus, CTI’s CO₂ emissions can be further reduced and this can make positive contributions to China’s goal of “carbon peaking and carbon neutralization” eventually.

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