

Minimum wage and green productivity in the textile industry: policy linkages and regional heterogeneity

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ABSTRACT – REZUMAT

Minimum wage and green productivity in the textile industry: policy linkages and regional heterogeneity

Enhancing green total factor productivity (GTFP) is essential for achieving high-quality development in the textile industry, necessitating both theoretical insights and effective policy measures. The purpose of this study is to examine how minimum wage policies affect environmental and economic efficiency in China's textile sector, providing empirical evidence to inform policy decisions that balance worker welfare with sustainable industrial development. This research examines the influence of the minimum wage on GTFP within the textile sector, utilising manually assembled minimum wage data along with panel data from 276 Chinese cities spanning the years 2004 to 2023. A fixed-effects model was employed to investigate the relationship between the minimum wage and GTFP. The results indicate that an increase in the minimum wage exerts a detrimental effect on GTFP in the textile industry. Further mechanism tests reveal that the minimum wage impacts GTFP growth in the textile sector through two primary channels: technological innovation and factor substitution. Heterogeneity analysis shows that the negative impact of the minimum wage on GTFP varies across different regions, city sizes, and administrative levels, with a more pronounced effect observed in the western regions, smaller cities, and cities with lower administrative status. These findings offer significant implications for improving GTFP in the textile industry and fostering high-quality economic development in China.

Keywords: minimum wage, textile industry, green total factor productivity, technological innovation, high-quality economic development

Salariul minim și productivitatea ecologică în industria textilă: măsuri politice și eterogenitate regională

Creșterea productivității totale a factorilor ecologici (GTFP) este esențială pentru realizarea unei dezvoltări de înaltă calitate în industria textilă, necesitând atât cunoștințe teoretice, cât și măsuri politice eficiente. Scopul acestui studiu este de a examina modul în care politicile privind salariul minim afectează eficiența economică și de mediu în sectorul textil din China, furnizând dovezi empirice pentru a informa deciziile politice care echilibrează bunăstarea lucrătorilor cu dezvoltarea industrială durabilă. Această cercetare examinează influența salariului minim asupra GTFP în sectorul textil, utilizând date privind salariul minim colectate manual, împreună cu date panel din 276 de orașe din China, acoperind perioada 2004–2023. A fost utilizat un model cu efecte fixe pentru a investiga relația dintre salariul minim și GTFP. Rezultatele indică faptul că o creștere a salariului minim are un efect negativ asupra GTFP în industria textilă. Teste suplimentare ale mecanismului relevă faptul că salariul minim influențează creșterea GTFP în sectorul textil prin două canale principale: inovarea tehnologică și substituția factorilor. Analiza eterogenității arată că impactul negativ al salariului minim asupra GTFP variază în funcție de regiuni, dimensiunea orașelor și nivelurile administrative, cu un efect mai pronunțat observat în regiunile vestice, orașele mai mici și orașele cu statut administrativ inferior. Aceste constatări au implicații semnificative pentru îmbunătățirea GTFP în industria textilă și pentru promovarea unei dezvoltări economice de înaltă calitate în China.

Cuvinte-cheie: salariul minim, industria textilă, productivitatea totală a factorilor ecologici, inovație tehnologică, dezvoltare economică de înaltă calitate

INTRODUCTION

In the context of global economic integration and increasing emphasis on sustainable development, labour policies have become critical factors influencing industrial competitiveness and environmental performance worldwide. As countries seek to balance social equity with economic efficiency, minimum wage policies have emerged as important policy instruments that affect not only worker welfare but also industrial productivity and environmental sustainability across different sectors globally.

Since the implementation of the Minimum Wage Regulations in 2004, China's minimum wage standards have seen increasing adjustment magnitudes and enforcement rigour, with regional minimum wages rising at an average annual rate of 10% in recent years. This trend aligns with global patterns, as many developing and developed countries have similarly adjusted their minimum wage policies to address income inequality and improve living standards, while grappling with the potential impacts on industrial competitiveness in an increasingly

globalised market. As a factor endowment, the rising cost of labour induces changes in relative factor prices, thereby generating factor substitution effects. Against this backdrop, profit-maximising firms are compelled to adjust their input decisions by substituting capital or technology for labour. This, in turn, affects technological progress and efficiency within firms, ultimately influencing green total factor productivity [1].

The concept of green total factor productivity has gained international prominence as countries worldwide strive to achieve sustainable development goals while maintaining economic growth. The challenge of “green transformation” is particularly acute in traditional manufacturing industries, where the tension between environmental protection and economic competitiveness is most pronounced. Green total factor productivity is an inexhaustible driver of economic development and a key component of China’s supply-side structural reforms. From an industry perspective, identifying factors influencing GTFP is of significant importance for expanding industry scale and improving development levels. GTFP in an industry is constrained by the institutional environment, with studies demonstrating that fiscal policies, investment attraction policies, and industrial policies all impact industry GTFP. The minimum wage is a government-mandated, enforceable institution that safeguards workers’ remuneration. It stipulates the minimum wage that firms must provide to workers who are employed lawfully [2].

Research on the minimum wage has primarily focused on employment, wage, and export effects. Recently, scholars have begun examining its impact on GTFP. Studies have found that increases in the minimum wage may influence GTFP through two main pathways. First, rising labour costs may force firms to innovate technologically, thereby enhancing GTFP [3, 4]. Second, increases in the minimum wage may improve GTFP by promoting the exit of low-productivity firms and restricting the entry of firms with low production potential [5].

Another body of related literature examines the measurement methods and influencing factors of GTFP. Current methods for measuring GTFP mainly include the SBM model, the ML index, and the SBM directional distance function combined with the Luenberger productivity indicator [6]. Numerous scholars have investigated the impact of environmental regulations, foreign direct investment, and innovation on GTFP. However, no consensus has been reached on the effects of environmental regulations and foreign direct investment [7]. In contrast, innovation, as a significant driver of GTFP, affects it through technological progress and efficiency. Technology imports from abroad and firm-level R&D both enhance GTFP, while domestic technology purchases may, to some extent, inhibit GTFP growth [8].

The textile industry represents a particularly important case study in the global context, as it is one of the most internationally integrated manufacturing sectors and faces increasing pressure from both

labour standards and environmental regulations worldwide. International trade patterns in textiles are significantly influenced by labour costs, making minimum wage policies a crucial determinant of global competitiveness. The impact of minimum wage increases varies across industries, with the textile industry being one of the most affected [9]. As a traditional labour-intensive sector, the textile industry has long relied on its capacity to absorb large numbers of workers with low entry barriers [10, 11]. Understanding how minimum wage policies affect green productivity in this sector has implications beyond China’s borders, as it can inform policy decisions in other developing countries seeking to upgrade their textile industries while improving labour standards and environmental performance. Existing literature has predominantly focused on the manufacturing sector, with limited attention paid to the textile industry and the pathways through which minimum wage standards exert their influence.

This study employs a sample of Chinese cities to conduct an empirical examination of how minimum wage standards affect green total factor productivity (GTFP) in the textile industry, the underlying mechanisms involved, and whether significant differences exist across regions, city sizes, and administrative levels. This research contributes to the broader international discourse on sustainable industrial development and provides insights relevant to policymakers worldwide who are navigating the complex relationship between social policies and environmental outcomes. This research is crucial for achieving high-quality economic development in China.

While prior studies have yielded substantial findings, few scholars have explored the impact of minimum wage standards on GTFP in the textile industry. This study makes the following contributions: First, it links minimum wage standards to GTFP in the textile industry by matching city-level minimum wage data with panel data from Chinese cities to empirically analyse the impact of minimum wage standards on textile industry GTFP. Second, it theoretically examines how minimum wage standards influence GTFP in the textile industry and the channels through which this impact is transmitted. Third, it investigates the heterogeneous effects of minimum wage standards on GTFP across regions, city sizes, and administrative levels, discussing the urban disparities in China’s economic growth quality and their sources.

The following articles are arranged as follows: the second part introduces the theoretical analysis and research hypothesis, the third part is the research design of this paper, the fourth part is the empirical test and result analysis of this paper, the fifth part is the heterogeneity analysis, and the sixth part is the research conclusions and policy implications of this paper.

THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

According to the literature, growth in green total factor productivity (GTFP) primarily relies on technological progress and efficiency improvements. First, minimum wage standards can influence firm innovation through cost and selection effects, potentially promoting GTFP growth in the textile industry. However, these standards may also inhibit industry innovation through crowding-out and employment effects, thereby impeding GTFP growth in China's textile sector [12]. Second, increases in minimum wage standards can lead to factor substitution, where capital replaces labour. This shift is often driven by heavy industries that sacrifice the environment, resulting in a negative impact on industry GTFP [13].

Mechanisms through which minimum wage standards influence the textile industry GTFP via innovation

Minimum wage standards can affect GTFP through two primary mechanisms. As China's overall living standards improved, employment opportunities increased, and the demographic dividend diminished, the textile industry, a labour-intensive sector, gradually lost its competitive edge based on low-cost labour [14].

On the one hand, minimum wage standards can force firms to innovate, thereby enhancing GTFP. First, the cost-effect suggests that increases in minimum wage standards raise absolute labour costs, compelling firms to shift towards technology-driven growth. This, in turn, promotes GTFP growth and green transformation in China's textile industry [15]. Second, the selection effect indicates that higher minimum wages encourage low-productivity firms to exit the market while deterring potential entrants with low production potential. Efficient firms typically engage in innovation to maintain their competitive edge, and increased R&D investment and innovation activities contribute to GTFP improvements [16, 17]. Third, according to the efficiency wage theory, minimum wages can reduce worker shirking, incentivise employees to pursue education and training, and attract higher-calibre talent. These factors enhance human capital within firms, leading to improved labour productivity and innovation motivation [18]. Fourth, minimum wage standards can enhance resource allocation efficiency. The mobility of capital and labour across regions improves resource utilisation, technical efficiency, and overall GTFP [19]. Finally, from the demand side, higher minimum wages increase average income levels, promoting consumption upgrades. As local consumers' purchasing power strengthens, their demand for innovative products rises, incentivising firms to innovate and boost GTFP [20].

On the other hand, while minimum wage standards can promote firm innovation and GTFP through these mechanisms, they may also inhibit innovation and GTFP growth. First, increases in minimum wages

can crowd out innovation funding. To compensate for higher wage costs, firms may reduce R&D budgets. Given the high risks and vulnerability of innovation to infringement, especially in China's underdeveloped intellectual property protection regime, this can create a double squeeze on firm profits, discouraging innovation [21, 22]. Second, the employment effect of minimum wages is significant. Innovation relies on diverse, non-redundant information and resources, often sourced from lower-level employees who support R&D activities. However, higher minimum wages can lead to job losses among low-skilled workers, disrupting the balance of skills within firms and impeding technological progress [23, 24]. Third, according to the export learning hypothesis, firms facing intense international competition often learn from global experiences to improve technology and efficiency. However, higher minimum wages can reduce exports and lower product quality, weakening the export learning effect and inhibiting innovation and GTFP growth in the textile industry [25, 26]. Fourth, minimum wage increases can spill over to employees earning above the minimum wage, raising overall labour costs and reducing firms' R&D investment [27]. Finally, according to the social exchange theory, firms may reduce non-wage benefits such as training to offset higher wage costs. This can weaken employee loyalty and increase work intensity, reducing workers' motivation to innovate and negatively impacting GTFP. Based on the above analysis, the following hypothesis is proposed:

H1: When the "inhibitory" effect of minimum wage standards on technological innovation outweighs the "forcing" effect, it is detrimental to GTFP growth in the textile industry.

Mechanisms through which minimum wage standards influence the textile industry GTFP via factor substitution effects

Increases in minimum wage standards generate factor substitution effects, meaning that higher minimum wages lead to a relative price increase for labour. This compels profit-maximising firms to substitute capital or technology for labour [28]. The extent to which firms substitute capital or technology for labour depends not only on the price ratio between the substituting factor and labour but also on the elasticity of substitution between these factors [29].

On the one hand, minimum wage increases have a compensating effect on low-wage workers [28]. Firms are required to pay low-skilled workers wages above the market-clearing level, resulting in higher total wage payments to this group. As the price ratio between substituting factors and labour decreases, firms' incentives to substitute capital or technology for labour increase.

On the other hand, minimum wage increases also produce spillover effects on workers' earnings above the minimum wage [30]. This occurs because higher minimum wages increase the relative cost of low-skilled labour, prompting firms to substitute high-skilled labour for low-skilled labour. The increased

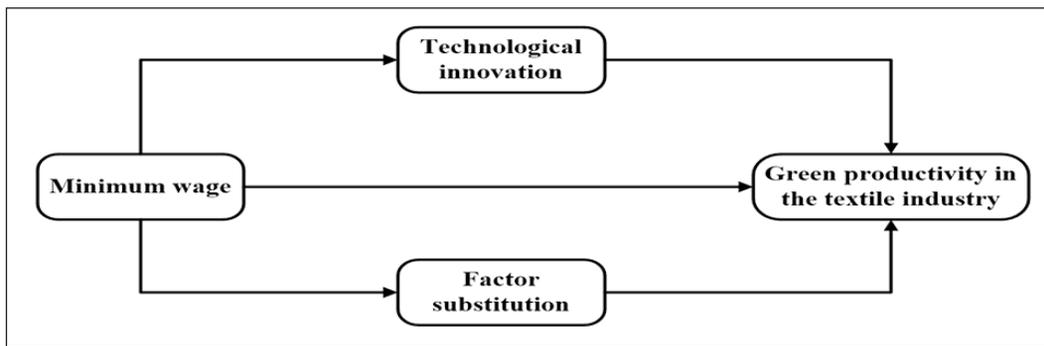


Fig. 1. Theoretical framework

demand for high-skilled workers leads to higher wages for this group [31]. Consequently, as the cost of labour-intensive production rises rapidly, firms are more inclined to substitute capital for labour and high-skilled workers for low-skilled workers [32]. For example, the “machine-for-human” strategy implemented by coastal firms involves replacing labour with advanced fixed assets. This not only accesses the embedded cutting-edge production technologies within machinery but also significantly improves production efficiency and reduces costs. While this appears to be a substitution of equipment and technology for labour, it is essentially a substitution of capital for labour. This factor substitution effect is more pronounced when the elasticity of substitution between capital and labour is high [33].

However, the sustained increase in the capital-to-labour ratio in China has primarily been driven by extensive industrial scale expansion, particularly in heavy and chemical industries [34]. The heavy industrialisation characteristic exacerbates environmental degradation, which in turn has a negative impact on green total factor productivity. Based on the above analysis, the following hypothesis is proposed:

H2: Minimum wage standards inhibit GTFP growth in the textile industry through factor substitution effects. The theoretical framework of this paper is shown in figure 1.

RESEARCH DESIGN

Model specification

Drawing on prior research, it has been established that, in addition to minimum wage standards, factors such as the level of economic development, government actions, industrial structure, consumer demand, foreign direct investment, and human capital levels all influence green total factor productivity (GTFP) in the textile industry [35]. Based on these findings, we denote textile green total factor productivity as CGTFP and minimum wage standards as MW. We also select the following control variables: level of economic development (GDP), government actions (GOV), industrial structure (STRU), consumer demand (CR), foreign direct investment (FDI), and human capital levels (HCL). Using these variables, we construct Model (1) to assess the impact of

minimum wage standards on green total factor productivity in the textile industry:

$$CTFP_{it} = \alpha_0 + \alpha_1 MW_{it} + \gamma Control + \mu_i + \varphi_t + \varepsilon_{it} \quad (1)$$

In equation 1, i denotes the city, and t denotes the time period ($t = 2004\text{--}2023$). The terms α_1 and γ represent the corresponding elasticity coefficients, while α_0 and ε_{it} represent the intercept and error term, respectively. *Control* is a set of control variables. μ_i represents the city fixed effects, and φ_t represents the year fixed effects, which are included to control for unobservable city-specific and time-specific factors.

Data sources and processing

Data from 276 prefecture-level and above cities in China over the period 2004–2023 were employed for analysis, yielding a total sample size of 5,264 observations. The following section provides details on the data sources, processing methods, and relevant statistical yearbooks for the variables used in this study.

Dependent variable

The dependent variable in this study was measured in two ways. First, the ACF method was used to measure productivity, with each city serving as a decision-making unit to assess green total factor productivity (GTFP) in the textile industry across Chinese regions. This measure of textile GTFP is denoted as CGTFP1 [36]. Given the availability of textile industry data, the following proxies were used: textile value-added to measure total output; net fixed asset investment (original value of fixed assets minus accumulated depreciation) to measure capital stock [37]; the number of employees in the textile industry in each city to measure labour input; and the total amount of coal input to measure intermediate inputs in the textile industry [38].

The second method employed the GML (Generalised Malmquist Luenberger) index for measurement. The panel data encompassed K ($k = 1, 2, \dots, 256$) provinces (autonomous regions, municipalities directly under the central government) and t ($t = 1, 2, \dots, 15$) time periods. The variables x , y , and b represent input variables, desired output variables, and undesired output variables, respectively. Each decision-making unit includes N types of inputs, $x \in R_+^N$, M types of desired outputs, $y \in R_+^M$, and J types of

undesired outputs, $b \in R_+^J$. The production possibility set $P(x)$ can be expressed as $P(x) = \{(y, b) \mid \text{inputs } x \text{ produce } (y, b)\}$. The set $P(x)$ must satisfy the following conditions: $(0, 0) \in P(x)$, $x \in R_+^M$. If $x' \geq x$, then $P(x') \supseteq P(x)$. If $(y, b) \in P(x)$ and $0 \leq \theta \leq 1$, $(\theta y, \theta b) \in P(x)$. If $(y, b) \in P(x)$ and $b = 0$, then $y = 0$. The formula for the GML index is as follows:

$$GML^{t,t+1}(x^t, y^t, b^t, x^{t+1}, y^{t+1}, b^{t+1}) = \frac{1 + D^G(x^t, y^t, b^t)}{1 + D^G(x^{t+1}, y^{t+1}, b^{t+1})} \quad (2)$$

In the formula, $D^G(x, y, b)$ represents the directional distance function, defined as $D^G(x, y, b) = \max\{\beta \mid (y + \beta y, b - \beta b) \in P^G(x)\}$. This function seeks to maximise the increase in desired outputs while simultaneously reducing undesired outputs. The directional vector used is $g = (y, b)$, where $g \in R_+^M \times R_+^J$. The core of the GML index is to build on the ML index by utilising the entire set, that is, $P^G = P^1 \cup P^2 \cup \dots \cup P^T$, to construct the production frontier and address the issue of infeasible solutions. The formula is presented as follows:

$$GML^{t,t+1}(x^t, y^t, b^t, x^{t+1}, y^{t+1}, b^{t+1}) = \frac{1 + D^G(x^t, y^t, b^t)}{1 + D^G(x^{t+1}, y^{t+1}, b^{t+1})} = \frac{1 + D^t(x^t, y^t, b^t)}{1 + D^{t+1}(x^{t+1}, y^{t+1}, b^{t+1})} \times \frac{[1 + D^c(x^t, y^t, b^t)] / [1 + D^t(x^t, y^t, b^t)]}{[1 + D^G(x^{t+1}, y^{t+1}, b^{t+1})] / [1 + D^{t+1}(x^{t+1}, y^{t+1}, b^{t+1})]} = \frac{TE^{t+1}}{TE^t} \times \frac{BPG_{t+1}^{t,t+1}}{BPG_t^{t,t+1}} = TEC^{t,t+1} \times TC^{t,t+1} \quad (3)$$

In the formula, TE represents technical efficiency; BPG represents the technical change between two time periods; TEC represents the index of technical efficiency change; and TC represents the index of technical change.

Regarding the measurement of inputs and outputs for the green total factor productivity (CGTFP2) in the textile industry, existing literature varies in the selec-

tion of indicators for green total factor productivity. The CO₂ emissions of the textile industry were calculated based on the consumption of various types of energy, the standard coal conversion coefficients for these energies, and the CO₂ emission coefficients [39]. The measurement indicators for the GML index of the textile industry are presented in table 1.

Core explanatory variable

The minimum wage standard (MW) refers to the lowest remuneration that employers are legally required to pay workers for normal labour provided within the statutory working hours or the working hours stipulated in a legally binding employment contract [40], measured in yuan. Data on the minimum wage standard were manually collected and collated through various means, including browsing the websites of human resources and social security bureaus of prefecture-level cities, policy documents, statistical bulletins, and official newspapers. This process yielded minimum wage data for 276 cities from 2004 to 2023, which were subsequently log-transformed.

Other control variables

Factors that typically influence the dependent variable include the level of infrastructure, government actions, and external influences of economic development. The control variables selected in this study are as follows:

- Level of economic development (GDP): Measured by the gross regional product of each city (in ten thousand yuan), with log-transformation applied.
- Government actions (GOV): Measured by the ratio of educational and scientific expenditures in the city's fiscal spending to the regional gross product.
- Industrial structure (STRU): Measured by the proportion of employees in the secondary industry relative to the total number of employees in the region.
- Consumer demand level (CR): Measured by the retail sales of consumer goods in each city (in ten thousand yuan), with log-transformation applied.
- Foreign direct investment (FDI): Measured by the total amount of foreign direct investment in China

Table 1

MEASUREMENT INDICATORS FOR THE GML INDEX OF THE TEXTILE INDUSTRY IN EACH CITY			
Type of indicators	Name	Units	Calculation method
Factor inputs	Energy inputs to the textile sector	Ten thousand tonnes	Energy consumption of various types of energy in the textile industry × the coefficient of converted standard coal for various types of energy
	Employees of textile enterprises	Millions of people	Number of employees in textile enterprises
	Total assets of textile enterprises	Billions of yuan	Textile industry enterprise assets
Desired outputs	Gross value of textile output	Ten billions of yuan	Gross textile output
Undesired outputs	CO ₂ emissions from the textile industry	Ten thousand tonnes	Σ Energy consumption by type in the textile industry × standard coal factor for each type of energy conversion × CO ₂ emission factor

Table 2

VARIABLE PROCESSING AND DESCRIPTIVE STATISTICS							
Variable	Name	Abbreviation	Obs	SD	Mean	Min	Max
Explanatory variables	Green total factor productivity in textile (ACF)	CGTFP1	1264	2.224	13.988	3.210	25.544
	Green total factor productivity in textile (GML)	CGTFP2	1264	0.872	2.678	0.078	6.153
Explained variable	Minimum wage standard	MW	1264	4.293	4.101	3.372	7.782
Control variables	Level of economic development	GDP	1264	3.308	6.984	4.263	8.909
	Government behaviour	GOV	1264	6.110	9.402	7.877	12.984
	Industrial structure	STRU	1264	0.783	4.953	4.004	7.922
	Consumer demand level	CR	1264	11.024	1.980	0.782	4.376
	Foreign direct investment	FDI	1264	2.872	9.290	4.555	13.089
	Human capital level	HCL	1264	4.444	1.454	0.117	3.562
Mechanism variables	Technological innovation	CII	1264	16.235	1.781	0.545	3.987
	Labour input	ZL	1264	8.820	3.765	2.897	6.113

(in ten thousand US dollars), with log-transformation applied.

- Human capital level (HCL): Measured by the ratio of the number of students enrolled in higher education institutions to the regional population.

Data for the above control variables were sourced from the China Urban Statistical Yearbook. Specific variables and descriptive statistics are presented in table 2.

EMPIRICAL TESTS AND RESULTS ANALYSIS

Benchmark regression results

Table 3 reports the benchmark regression results of the impact of the minimum wage standard on green total factor productivity (GTFP) in the textile industry. Columns (1) and (3) present the regression results considering only the changes in the minimum wage standard (MW), while controlling for city and time effects. Columns (2) and (4) present the results after including all city-level control variables. The findings indicate that the estimated coefficient of the minimum wage standard is significantly negative, suggesting that increases in the minimum wage standard are detrimental to the growth of GTFP in the textile industry. Theoretically, higher minimum wages may inhibit corporate technological innovation and induce factor substitution effects. The continuous increase in the capital-to-labour ratio, driven by the “inhibitory” effect of technological innovation, further exacerbates pollution, energy consumption and pollutant emissions in the textile industry, thereby impeding the improvement of GTFP.

Robustness tests

Robustness tests were conducted in two main aspects. First, the sample was adjusted. Regions with high levels of industrial agglomeration typically exhibit higher minimum wages and greater innovation output. These areas differ significantly from other

Table 3

BENCHMARK REGRESSION RESULTS				
Variable	(1)	(2)	(3)	(4)
	GGTFP1	GGTFP1	GGTFP2	GGTFP2
MW	-0.217*** (-3.056)	-0.309*** (-3.587)	-0.188*** (-3.924)	-0.255*** (-4.100)
GDP		0.032** (2.158)		0.019*** (3.343)
GOV		0.239** (2.255)		0.188*** (3.017)
STRU		-0.333 (-1.277)		-0.416*** (-3.300)
CR		-0.089** (-2.155)		-0.067*** (-2.940)
FDI		0.190** (2.079)		0.216*** (3.080)
HCL		0.136* (1.921)		0.234*** (3.455)
Control	NO	YES	NO	YES
City fixed	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES
N	1264	1264	1264	1264
R ²	0.0382	0.0205	0.0680	0.0441

Note: Parentheses indicate robust standard errors. *, **, *** denote significance levels of 1%, 5%, and 10%, respectively. This notation applies to the following tables.

cities in terms of economic development, environmental regulation, and the efficiency and level of technological innovation. Given that a large number of high-tech company headquarters in China are concentrated in Beijing, Shanghai, Guangzhou, and Shenzhen, samples from these cities were excluded. The model was then re-estimated based on the adjusted sample, with results shown in columns (1) and (2) of table 4. The regression coefficient for the

minimum wage standard remained significantly negative.

Second, the impact of the COVID-19 pandemic was considered. The data period was set as 2004–2019 and 2023 to exclude the influence of the pandemic. During the pandemic, economic activities were severely disrupted, and the textile industry faced issues such as work stoppages, supply chain interruptions, and labour shortages. These factors obscured or distorted the relationship between green total factor productivity (GGTFP) fluctuations and the minimum wage standard. After excluding samples from the relevant years, the model was re-estimated based on the adjusted sample, with results shown in columns (3) and (4) of table 4. The regression coefficient for the minimum wage standard remained significantly negative.

Third, outliers were removed. To mitigate the impact of outliers on the empirical results, a 1% truncation and winsorisation were applied to the green total factor productivity in the textile industry at both ends of the distribution. As shown in columns (5) to (8) of table 4, the estimated coefficient for the minimum wage standard remained significantly negative after both truncation and winsorisation.

In summary, after a series of robustness tests, the conclusion remained valid: increases in the minimum wage standard were detrimental to the growth of green total factor productivity in the textile industry.

Endogeneity tests

Endogeneity tests were conducted in two main aspects. First, to address the potential reverse causality between green total factor productivity (GGTFP) in the textile industry and the control variables, all control variables were lagged by one period and included in the estimation of equation 1. The results, shown in columns (1) and (2) of table 5, indicate that the estimated coefficient for the minimum wage standard remained significantly negative.

Second, to mitigate estimation bias arising from endogeneity, we followed the approach of Li et al. and selected the average of the highest and lowest minimum wage standards within the province where the city is located (LZ) as an instrumental variable [41]. The estimation was conducted using Two-Stage Least Squares (2SLS). The first-stage regression results of the 2SLS, shown in columns (3) and (4), demonstrate that the instrumental variable (LZ) is significant at the 1% level, with an F-statistic of 23.45, indicating no weak instrument problem. The second-stage regression results of the 2SLS, shown in columns (5) and (6), reveal that the estimated coefficient for the minimum wage standard remains significantly negative at the 5% level.

The above results confirm that, after controlling for endogeneity, the conclusion that the minimum wage standard inhibits the improvement of green total factor productivity in the textile industry still holds.

Table 4

ROBUSTNESS TESTS								
Variable	Sample adjustments		Year of removal of the epidemic		Bilateral cut-offs		Bilateral indentations	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	GGTFP1	GGTFP2	GGTFP1	GGTFP2	GGTFP1	GGTFP2	GGTFP1	GGTFP2
MW	-0.0243*** (-3.111)	-0.0450*** (-3.499)	-0.0389*** (-4.045)	-0.0211*** (-4.230)	-0.0155** (-2.140)	-0.0171*** (-3.077)	-0.0158** (-2.167)	-0.0188*** (-3.178)
GDP	0.175*** (3.719)	0.222 (1.123)	0.210 (1.288)	0.114*** (2.982)	0.236** (2.100)	0.159*** (3.100)	0.188** (2.341)	0.149*** (3.123)
GOV	0.116** (2.104)	0.245*** (3.278)	-0.560 (-1.245)	0.555 (1.544)	0.222** (2.133)	0.299** (2.031)	0.227** (2.183)	0.253** (2.149)
STRU	-0.072*** (-3.115)	-0.054 (-1.026)	-0.039** (-2.203)	0.041 (1.490)	-0.030*** (-3.155)	-0.055** (-2.180)	-0.028** (-2.167)	-0.065*** (-3.109)
CR	-0.121*** (-2.889)	-0.139 (-1.155)	-0.224*** (-3.180)	-0.318 (-1.246)	0.360** (2.044)	0.225 (1.330)	-0.360* (-1.844)	-0.222* (-1.840)
FDI	0.176*** (3.012)	0.155* (1.871)	0.209** (2.174)	0.330*** (3.215)	0.222** (2.033)	-0.266 (-1.115)	0.129*** (3.160)	0.234 (1.068)
HCL	0.365*** (3.879)	0.278** (2.021)	0.166*** (3.300)	0.199 (1.244)	-0.190 (-1.186)	0.222* (1.855)	0.135** (2.066)	0.144 (1.567)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1180	1180	986	986	1064	1064	1088	1088
R ²	0.039	0.045	0.028	0.034	0.041	0.049	0.027	0.032

ENDOGENEITY TESTS						
Variable	(1)	(2)	(3)	(4)	(5)	(6)
	GGTFP1	GGTFP2	MW	MW	GGTFP1	GGTFP2
MW	-0.044*** (-4.123)	-0.050** (-4.315)			-0.049** (-2.177)	-0.056** (-2.285)
AW			0.367*** (4.108)	0.430*** (4.322)		
GDP	0.123*** (2.799)	-0.245 (-1.110)	0.144*** (3.214)	0.150** (2.339)	0.257*** (3.122)	0.339*** (2.890)
GOV	0.255*** (3.046)	0.230** (2.311)	-0.115 (-1.344)	0.122** (2.169)	-0.136 (-1.800)	0.158** (2.045)
STRU	-0.045*** (-3.167)	-0.022*** (-2.919)	-0.102 (-1.125)	-0.119*** (-3.031)	-0.066** (-3.350)	0.072 (3.211)
CR	-0.221*** (-3.190)	-0.233*** (-3.228)	-0.121** (-2.093)	-0.144*** (-2.855)	-0.326** (-2.199)	0.310 (1.585)
FDI	0.188*** (3.123)	0.217 (1.175)	0.145** (2.180)	0.166** (2.012)	0.190* (1.851)	0.202** (2.139)
HCL	1.065*** (5.175)	0.322** (2.009)	0.289** (2.050)	0.199*** (2.928)	0.256 (1.230)	-0.178 (-1.555)
Control	YES	YES	YES	YES	YES	YES
City fixed	YES	YES	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES	YES	YES
N	1042	1042	1264	1264	1264	1264
R ²	0.013	0.082	0.066	0.024	0.075	0.080

Note: The F-statistic for the first-stage 2SLS regression results in columns (3) and (4) is 23.45.

Mechanism tests

The preceding sections have thoroughly examined the impact of the minimum wage standard on green total factor productivity (GTFP) in the textile industry. To further elucidate the intrinsic relationship between the minimum wage standard and GTFP in the textile industry, Equations 4 and 5 were formulated. For technological innovation, the city innovation index (CII) was used as a measure, with data sourced from the China City and Industry Innovation Report 2024. For the capital-to-labour ratio change (ZL), following the common practice in the literature, the perpetual inventory method was employed to estimate the capital stock of each city from 2004 to 2023. The total number of employees, including private and individual workers, at the end of each year from 2004 to 2023, was used as the measure of labour input. In equation 4, Med represents the mediating variables, namely the city innovation index and the capital-to-labour ratio change, with other variables defined consistently with Equation (1). This approach was used to investigate the roles of technological innovation and factor substitution effects in the impact of the minimum wage standard on GTFP in the textile industry.

$$Med_{it} = \alpha_0 + \alpha_1 MW_{it} + \gamma Control + \mu_j + \varphi_t + \varepsilon_{it} \quad (4)$$

$$CTFP_{it} = \alpha_0 + \alpha_1 MW_{it} + \alpha_1 Med_{it} + \gamma Control + \mu_j + \varphi_t + \varepsilon_{it} \quad (5)$$

Table 6, column (1), reports that the minimum wage standard has a significantly positive effect on the city innovation index. This suggests that the “inhibitory” effect of the minimum wage standard on technological innovation outweighs its “forcing” effect, thereby impeding the improvement of GTFP in the textile industry. Thus, Hypothesis 1 (H1) is empirically supported.

Column (2) shows that the minimum wage standard has a significantly negative effect on the capital-to-labour ratio change. This indicates that the minimum wage standard also inhibits the improvement of GTFP in the textile industry through an increase in the capital-to-labour ratio. Therefore, Hypothesis 2 (H2) is confirmed.

HETEROGENEITY ANALYSIS

Regional heterogeneity

Given the significant differences in economic development levels and locational advantages among cities in different regions, the impact of the minimum wage standard on green total factor productivity (GTFP) in the textile industry may vary across regions [42]. To examine this, cities were categorised into eastern, central, and western regions. As shown in table 7, the minimum wage standard had a significantly negative effect on GTFP in the textile industry in the western region, while no significant impact was observed in the eastern and central regions.

Table 6

MECHANISM TESTS						
Variable	(1)	(2)	(3)	(4)	(5)	(6)
	CII	CGTFP1	CGTFP2	ZL	CGTFP1	CGTFP2
MW	-0.211*** (-3.088)	-0.117*** (-3.155)	-0.098** (-2.220)	0.380*** (3.192)	-0.244*** (-3.053)	-0.367*** (-3.148)
CII		-0.123*** (-3.561)	-0.350*** (-3.788)			
ZL					-0.355*** (-3.058)	-0.417*** (-3.113)
GDP	0.398** (2.143)	0.224*** (2.865)	0.310 (1.122)	0.255*** (2.719)	0.176** (2.054)	0.409 (1.146)
GOV	0.267** (2.011)	0.145** (2.065)	0.333 (1.446)	0.299*** (3.200)	0.311 (1.104)	0.288*** (3.221)
STRU	-0.102** (-2.132)	-0.095 (-1.268)	-0.088*** (-3.200)	-0.079*** (-3.117)	-0.066 (-1.365)	-0.114 (-1.101)
CR	-0.131** (-2.220)	-0.227** (-2.119)	-0.208*** (-3.355)	-0.129*** (-3.004)	-0.115 (-1.106)	-0.233*** (-3.199)
FDI	0.181*** (3.730)	0.174*** (3.501)	0.216** (2.111)	0.209* (1.899)	0.313*** (5.022)	0.255 (1.215)
HCL	0.365 (1.167)	0.442 (1.122)	0.228** (2.109)	0.254 (1.465)	0.349** (2.215)	0.444*** (3.775)
Control	YES	YES	YES	YES	YES	YES
City fixed	YES	YES	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES	YES	YES
N	1264	1264	1264	1264	1264	1264
R ²	0.022	0.018	0.035	0.055	0.040	0.033

Table 7

REGIONAL HETEROGENEITY						
Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Eastern	Central	Western	Eastern	Central	Western
	CGTFP1	CGTFP1	CGTFP1	CGTFP2	CGTFP2	CGTFP2
MW	0.037 (1.144)	0.024 (1.183)	-0.058** (-3.562)	0.055 (1.237)	-0.062 (-1.208)	-0.045*** (-3.455)
GDP	0.198 (1.344)	0.220** (2.050)	0.311** (2.122)	0.255*** (3.067)	0.229 (1.448)	0.333 (1.100)
GOV	0.167 (1.130)	0.311 (1.255)	0.422*** (3.789)	0.235** (2.021)	0.336 (1.577)	0.244** (2.154)
STRU	0.312*** (3.211)	-0.178** (-2.055)	-0.221 (-1.034)	-0.165 (-1.110)	-0.237** (-2.187)	-0.244** (-2.030)
CR	-0.145** (-2.341)	-0.231 (-1.410)	-0.220*** (-2.088)	-0.187** (-2.154)	-0.334* (-1.872)	0.131 (1.310)
FDI	0.229* (1.871)	0.188*** (3.124)	0.193*** (3.164)	0.215 (1.610)	0.313** (2.065)	0.234** (2.113)
HCL	0.312*** (3.289)	0.443** (2.166)	0.116 (1.100)	0.252** (2.066)	0.440 (1.222)	0.225** (2.141)
Control	YES	YES	YES	YES	YES	YES
City fixed	YES	YES	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES	YES	YES
N	386	536	342	386	536	342
R ²	0.043	0.082	0.055	0.016	0.037	0.044

The likely reason is that the eastern and central regions of China can mitigate the dual pressures of rising labour costs and increasingly stringent environmental regulations, both caused by increases in the minimum wage, through industrial relocation. Moreover, these regions have higher technological progress efficiency compared to the Western region. Additionally, the green transformation of the textile industry is still in its developmental stage across all regions, which further explains the insignificant impact of the minimum wage standard on GTFP in the textile industry in these regions. In contrast, the western region has a relatively lower level of economic development. The setting and adjustment of the minimum wage standard are closely related to the regional economic development level. The relatively low labour costs in the western region attract the relocation of labour-intensive and polluting industries from the eastern and central regions. Coupled with a development model that relies on resource endowments to boost economic growth and low pollution control technology levels, these factors collectively exert a more adverse impact on GTFP in the textile industry.

Urban scale heterogeneity

Given the significant differences among cities of varying scales in terms of agglomeration economies and economies of scale, the impact of the minimum wage standard on green total factor productivity (GTFP) in the textile industry may vary across cities of different

sizes. To investigate this, following the approach of Zou et al., cities were categorised into small and medium-sized cities [43], Type II large cities, Type I large cities, and megacities or special large cities, based on the total population at the end of 2023 in each city's jurisdiction. As shown in columns (1) to (8) of table 8, the minimum wage standard had a significantly negative effect on GTFP in the textile industry in small and medium-sized cities and Type II large cities, while no significant impact was observed in Type I large cities and megacities or special large cities.

The reason is that China's megacities, special large cities, and Type I large cities tend to relocate high-energy-consuming and highly polluting industries to Type II large cities and small and medium-sized cities. Therefore, the impact of the minimum wage standard on these larger cities is insignificant. In contrast, small and medium-sized cities and Type II large cities, which receive the transfer of polluting industries, suffer from irrational industrial structures and imperfect environmental regulatory systems. The continuous increase in pollution emissions significantly suppresses GTFP. This indicates that industrial relocation in China occurs not only between regions but also among cities of different scales.

Urban administrative heterogeneity

Given the significant differences among cities of varying administrative levels in terms of human capital reserves, technological development, preferential

Table 8

URBAN SCALE HETEROGENEITY								
Variable	Small and medium-sized cities	II large cities	I large cities	Super and mega cities	Small and medium-sized cities	II large cities	I large cities	Super and mega cities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MW	-0.156*** (-3.172)	-0.289** (-2.354)	-0.540 (-1.101)	-0.333 (-1.088)	-0.120** (-2.020)	-0.244* (-1.822)	-0.477 (-1.380)	-0.500 (-1.477)
GDP	0.155 (1.209)	0.255*** (3.333)	0.222 (1.562)	0.188*** (3.245)	0.311** (2.304)	0.255** (2.116)	0.410 (1.200)	0.211 (1.188)
GOV	0.222** (2.134)	0.311 (1.498)	0.145 (1.199)	0.220** (2.046)	0.306 (1.216)	0.189* (1.802)	0.421 (1.527)	0.509*** (3.871)
STRU	-0.111** (-2.232)	-0.165 (-1.309)	-0.120 (-1.045)	-0.244 (-1.440)	0.133 (1.124)	-0.289 (-0.934)	-0.252** (-2.110)	-0.200*** (-3.312)
CR	-0.055*** (-3.313)	-0.234 (-1.509)	0.387 (1.144)	-0.187** (-2.022)	-0.120* (-1.840)	-0.222 (-1.221)	-0.140** (-2.154)	-0.288*** (-3.100)
FDI	0.210*** (3.206)	0.333 (1.319)	0.406* (1.822)	0.199 (1.110)	0.311*** (3.610)	0.422 (1.514)	0.152 (1.019)	0.134** (2.115)
HCL	0.222** (2.165)	0.334*** (2.778)	0.252 (1.533)	0.252** (2.025)	0.344** (2.112)	0.213 (1.345)	0.240** (2.369)	0.188** (2.030)
Control	YES	YES	YES	YES	YES	YES	YES	YES
City fixed	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES	YES	YES	YES	YES
N	442	386	228	208	442	386	228	208
R ²	0.075	0.081	0.040	0.066	0.052	0.033	0.044	0.038

URBAN ADMINISTRATIVE HETEROGENEITY								
Variable	Prefecture-level Cities	Provincial Capital Cities	Sub-provincial Cities	National Centre Cities	Prefecture-level Cities	Provincial Capital Cities	Sub-provincial Cities	National Centre Cities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MW	-0.225*** (-2.790)	0.119 (1.154)	0.133 (1.226)	-0.222 (-1.208)	-0.091** (-2.110)	0.144 (0.829)	0.077 (1.176)	0.150 (1.245)
GDP	0.111*** (3.199)	0.167* (1.831)	0.200 (1.328)	0.128** (2.155)	0.360** (2.039)	-0.155 (-1.044)	0.222 (1.110)	0.310 (0.988)
GOV	0.310*** (3.219)	0.222 (1.288)	0.144** (2.111)	0.335*** (3.460)	0.166 (1.333)	0.218* (1.770)	0.192 (1.245)	0.333* (1.800)
STRU	-0.210*** (-3.167)	-0.178 (-1.200)	0.122 (1.144)	-0.156*** (-3.209)	0.222 (1.055)	-0.183 (-0.994)	-0.155** (-2.219)	-0.320*** (-3.013)
CR	-0.188*** (-3.011)	-0.234** (-1.999)	0.385 (1.141)	-0.127** (-2.100)	0.120 (0.888)	-0.222** (-2.120)	0.140 (1.315)	-0.288*** (-3.222)
FDI	0.089** (2.369)	0.131 (1.113)	0.076 (1.120)	0.119* (1.834)	0.082*** (3.212)	0.144 (1.312)	0.155 (1.201)	0.100*** (3.252)
HCL	0.129*** (3.154)	0.231** (2.189)	0.155 (1.430)	0.220** (2.115)	0.146*** (3.422)	0.117 (1.244)	0.233 (1.232)	0.188** (2.111)
Control	YES	YES	YES	YES	YES	YES	YES	YES
City fixed	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES	YES	YES	YES	YES
N	860	214	86	104	860	214	86	104
R ²	0.154	0.110	0.088	0.072	0.159	0.105	0.243	0.100

policies, and environmental regulations, the impact of the minimum wage standard on green total factor productivity (GTFP) in the textile industry may vary across cities. Therefore, following the approach of Qi & Deng, cities were categorised into prefecture-level cities, provincial capitals, sub-provincial cities, and national central cities [44]. Sub-provincial cities include Guangzhou, Wuhan, Harbin, Shenyang, Chengdu, Nanjing, Xi'an, Changchun, Jinan, Hangzhou, Dalian, Qingdao, Shenzhen, Xiamen, and Ningbo. Among these, Shenzhen, Dalian, Qingdao, Xiamen, and Ningbo are planned single-list cities, while the others are provincial capitals. National central cities include Shanghai, Beijing, Guangzhou, Tianjin, Chongqing, Chengdu, Wuhan, Zhengzhou, and Xi'an.

As shown in columns (1) to (8) of table 9, the minimum wage standard had a significantly negative effect on GTFP in the textile industry in prefecture-level cities, while its impact on provincial capitals, sub-provincial cities, and national central cities was positive but insignificant. The likely reason is that important production factors in China's urbanisation process, such as capital, infrastructure investment, human capital, advanced technology, and preferential policies, are allocated progressively from the central to local governments and from higher to lower-level cities. As a result, national central cities, sub-provincial cities, and provincial capitals have more developed transportation and information infrastructure, and they cluster universities and scientific research institutions. These factors make it

easier to stimulate agglomeration economies in cities, rendering the crowding-out and employment effects of the minimum wage insignificant. In contrast, for cities with lower administrative levels, as the minimum wage standard increased, local governments and enterprises mostly responded by increasing fiscal subsidies and capital investment to achieve economic growth targets and to alleviate market competition pressures caused by rising costs. The increased capital investment is likely to manifest directly as the development of heavy and chemical industries, which in turn has an adverse impact on GTFP in the textile industry.

CONCLUSIONS AND POLICY IMPLICATIONS

Conclusions

Based on manually collected data on minimum wage standards from 276 Chinese cities between 2004 and 2023, and panel data from these cities, this study examined the impact of the minimum wage standard on green total factor productivity (GTFP) in the textile industry in Chinese cities. The results indicate that the minimum wage standard has a significantly negative effect on GTFP in the textile industry. This conclusion remains valid after conducting multiple robustness tests and addressing endogeneity issues. Mechanism tests reveal that the minimum wage standard inhibits the growth of GTFP in the textile industry through two channels: technological innovation and factor substitution effects. Heterogeneity analysis shows that the impact of the minimum wage standard on GTFP in the textile industry varies by region,

city size, and administrative level. Specifically, it has a significantly negative effect on the western region but not on the eastern and central regions. The negative impact is more pronounced in smaller cities, particularly small and medium-sized cities and Type II large cities, while no significant effect is observed in Type I large cities and megacities or special large cities. Similarly, the negative impact is more significant in prefecture-level cities compared to provincial capitals, sub-provincial cities, and national central cities.

Policy implications

Refine the minimum wage system. Given the negative impact of the minimum wage standard on GTFP in the textile industry, it is essential to refine a minimum wage system that suits China's national conditions. This should promote a shift in the economic development model, encouraging a transition from factor-driven growth, such as reliance on labour, to innovation-driven growth. This will enhance energy-saving and emission reduction levels and improve GTFP in the textile industry.

Accelerate the transformation of factor endowment structure. Since the minimum wage standard has a more pronounced "inhibitory" effect on technological innovation compared to its "forcing" effect, and the current factor endowment structure exacerbates environmental burdens in cities, it is necessary to accelerate the transformation of the factor endowment structure. This can be achieved by enhancing

human capital and technological innovation capabilities to drive productivity changes. For example, tax exemptions and rebates on pollution fees for corporate innovation and energy-saving emission reductions can optimise the allocation of innovative factors and guide enterprises to shift from relying on resource and cost advantages to relying on technological and human capital advantages.

Implement regionally differentiated environmental regulations and technology upgrading policies. Adopt a "negative list" management model to restrict the transfer of highly polluting and energy-intensive industries to the western region. Implement talent development strategies to attract high-tech, low-pollution enterprises through preferential policies and incentive mechanisms.

Strengthen regional economic linkages and collaboratively promote the overall improvement of green GTFP. It is crucial to promote upstream and downstream industrial agglomeration between large cities and surrounding small and medium-sized cities, enhancing the division of labour and collaboration across regional industrial chains. Additionally, leveraging the human capital reserves and technological development levels of higher administrative level cities, cities should implement horizontal differentiated development and vertical division of labour to radiate and drive surrounding lower administrative level cities. This will achieve coordinated progress in improving GTFP in the textile industry across cities of all sizes.

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