National Accounting Review

NAR, 7(3): 340–366.
DOI: 10.3934/NAR.2025015
Received: 13 April 2025
Revised: 09 July 2025
Accepted: 14 July 2025
Published: 04 August 2025

https://www.aimspress.com/journal/NAR

Research article

The social welfare effects of exports: Environmental and health impacts in China

Runmin Deng[1], Xinju He[2,*] and Yani Zhang[3]

[1] Faculty of Finance, City University of Macau, Macau, China
[2] School of Business, Guangxi University, Nanning, 530004, China
[3] School of Economics, Fudan University, Shanghai, China

* **Correspondence:** Email: hexinju@gxu.edu.cn.

Abstract: Export trade has significantly benefited China's economic growth since it joined the World Trade Organization (WTO). However, the literature predominantly emphasizes the economic benefits of trade, with comparatively less attention devoted to its broader social welfare implications. Amidst global health crises, trade stagnation, and diminishing demographic dividends, this paper examines the health consequences of trade, especially the impact of export trade on the health of Chinese residents. Utilizing microlevel data from the China Family Panel Studies (CFPS), integrated with regional macro-data, this paper finds that (1) the growth of export trade can significantly improve the overall health of regional residents, including both subjective and objective health. (2) An analysis of the mechanisms reveals that export trade can improve the health of residents by providing employment opportunities and increasing income levels. Contrary to expectations derived from the pollution haven hypothesis, this study finds that regional export activities are associated with improved local environmental quality through reduced pollutant emissions, which, in turn, improves the health of residents. (3) An exploration of heterogeneity suggests that exports have a greater impact on the health of rural residents, women, and the middle-aged and elderly. This paper contributes to the literature on health economics and trade liberalization, and provides insights that are relevant to the formulation of trade policy, public health, and health service policy in China.

Keywords: export; health; employment; environmental quality

JEL Codes: F160, F180, I120

1. Introduction

Exports have served as a primary engine of China's remarkable economic growth over recent decades. China's economic development has produced many miracles over the past few decades. Events like the COVID-19 pandemic and the US–China Trade War have had a significant detrimental impact on the import and export trade of nations worldwide in recent years (Gruszczynski, 2020). As the world's largest exporter with a vast labor force, China has historically championed globalization and opposed trade protectionism. The import and export scale of China's trade in goods exceeded 6 trillion dollars for the first time in 2022; the imports' and exports' scale of service exceeded 1 trillion dollars for the first time in 2024. Despite the significant economic gains from exports, concerns persist regarding the potential adverse consequences of trade liberalization. In particular, President Donald Trump has blamed free and open global trade for the decline in domestic manufacturing and high unemployment. With the outbreak of the Russo-Ukrainian war, the negative effects of dependence on foreign trade became a concern for the US, the European Union (EU), and other countries. In addition to the economic impact, economic inequality, difficult employment conditions, environmental pollution, and national security are also on the list for discussion (Jensen et al., 2019). Health, constituting a vital component of human capital and a fundamental aspect of social welfare, warrants greater attention alongside the economic analysis of trade liberalization. However, existing research predominantly focuses on the health impacts of trade liberalization, particularly import competition, within developed economies. To address this gap, this study investigates the impact of China's export expansion on population health and explores the underlying pathways.

Health is a crucial component of high social welfare, one of the key indicators of human capital and social welfare, and an essential prerequisite for China's high-quality economic development (Yang et al., 2022; Pangallo et al., 2024). While contributing to economic welfare, the expansion of China's exports has also facilitated the influx of foreign cultural influences and regulatory standards, such as the introduction of unhealthy foods like fast food, which has a detrimental effect on public health (Hawkes, 2006). According to pertinent data, about 20% of children and adolescents are overweight, while more than 50% of adults are overweight or obese. Furthermore, relevant studies have found that emerging nations will engage in highly polluting businesses from wealthy nations through trade or investment (Morris, 1996; Yasmeen et al., 2019), which will have a permanent detrimental influence on the region's environmental quality and raise the sickness and mortality rates of locals (Liang et al., 2017; Bombardini and Li, 2020). However, there are also studies show that greater trade openness also aids in lowering infant and child mortality rates and raising life expectancy in a nation (Owen and Wu, 2007; Byaro et al., 2021). Resolving this empirical question regarding the net health effect of exports is therefore critical. Understanding these pathways is essential for designing policies that mitigate potential harms and leverage potential benefits of export-led growth for population health.

As indicated above, in recent years, the relationship between trade and health has steadily drawn academics' attention. Researchers concentrated on the effect of trade openness (imports and exports as a percentage of gross domestic product (GDP)) on health at first, with samples chosen at the whole-country level, especially in developed countries (Herzer, 2017; Jawadi et al., 2018; Lang et al., 2018). Then, with research concentrating on the health of employees in manufacturing enterprises in both industrialized and developing nations, researchers have started to shift away from trade openness as an indicator to the imports (Guerrico, 2021). Some scholars have looked at the effects of variables like import tariffs and trade liberalization on the health of Chinese citizens in studies using samples from China (Feenstra and Hong, 2010; Chen and Wang, 2024). Collectively, the majority of pertinent studies continue to explore trade liberalization and the effects of imports on health, whereas the research about the effects of exports on health is still quite modest. Considering the national circumstances of China's export advantages, this article explores the unique effects of China's export activities on population health.

Here, we aimed to fully explore the impact direction and impact path of export commerce on the health of Chinese citizens, and to reexamine the environmental consequences of trade, specifically testing the applicability of the 'pollution haven' versus 'pollution halo' hypotheses. This paper relies on the microdata of the China Family Panel Studies (CFPS), combined with macrodata such as the China Customs Database and Statistical Yearbooks of various provinces and cities. Employing ordinary least squares (OLS) and logit regression models, we find evidence that export trade helps to improve citizens' subjective and physical health status. By using a different regression method, adding control variables, performing a placebo test, and talking about endogenous concerns, we use 2SLS (Two Stage Least Square) regression and robustness checks confirm the core findings. The heterogeneity reveals that exports have a significant impact on women's and rural dwellers' health. Besides, two influence mechanisms of the effect are identified. On the one hand, export trade can increase the number of employment possibilities, inhabitants' access to healthcare, and their level of income. Increased incomes can enable families to purchase nutritional goods and make use of medical care and prevention services, hence raising inhabitants' levels of health. Yet, this study also discovers that regional export activities improve the environmental quality by lowering pollutant emissions, which benefits locals' health rather than worsening the local ecological environment. This finding challenges the conventional pollution haven hypothesis and represents a novel contribution.

This study contributes to the literature in three primary ways. First, given China's unique position as a major surplus economy where exports exert a larger influence than imports, the majority of studies on the effects of trade on health have concentrated on the health effects of trade openness. The literature predicts both positive and negative health outcomes in developing and developed economies because of increasing trade. Levine and Rothman (2006), Owen and Wu (2007), Atkin (2013), Stevens et al. (2013), and Byaro et al. (2021) found that trade can boost economies, lower infant and child mortality, improve children's health, and extend life expectancy in a nation. Conversely, some studies have argued that trade liberalization improves health, especially in developed countries. According to Pierce and Schott (2016), places more impacted by trade liberalization have higher suicide rates among White men working in the industrial sector. McManus and Schaur (2016), who also focused on the same nation, discovered that the rise of Chinese imports into the US had a considerable impact on the injury and sickness rates among workers in industries that competed with manufacturing, in particular. Utilizing data from the Centers for Disease Control's telephone survey Behavioral Risk Factor Surveillance Survey (BRFSS), Lang et al. (2018) empirically studied the effect of Chinese imports in the US on the subjective health condition of US employees during 2000–2007 and discovered that the US was impacted by Chinese imports. According to the study's findings, the self-rated health status of American workers was worse in regions where Chinese imports were more prevalent. Regarding research aimed at developing nations. Guerrico (2021) used panel data from the manufacturing sector in Mexico from 1998 to 2013 to demonstrate that increases in trade liberalization lead to unemployment in this sector's workforce and that a decline in physical activity among this workforce is followed by obesity and diabetes, which, in turn, raises mortality rates (Hummels et al., 2016). Qadir and Majeed (2018), using data from Pakistan, found that a 1% increase in the trade to GDP ratio significantly decreases life expectancy by 0.05 years and significantly increases infant mortality by 0.47 deaths. Unlike other industrialized nations, China continues to have a significant trade surplus, and exports have a higher impact on the population than imports. So, the influence of export trade on population health will be examined in this paper, based on the current circumstances in China.

Second, the evidence utilized in most current articles examining the empirical analysis of trade on health is selected at the regional level (Were, 2015; Sakyi et al., 2015; Nguyen, 2015; Ou et al., 2023), and microlevel evidence based on individual residents remains relatively scarce. Most of the currently available literature on the measurement of population health chooses, due to sample size limitations (Qadir and Majeed, 2018; Byaro et al., 2021), the life expectancy and mortality rate of the population at the district level, etc., which ignores the individual microdifferences among residents and limiting the ability to capture individual heterogeneity and potentially weakening identification. Fewer studies have leveraged comprehensive Chinese microdatabases. Using the China Health and Nutrition Survey (CHNS) database, Fan et al. (2020) discovered that the reductions in import tariffs following China's World Trade Organization (WTO) membership will harm workers' health through lengthening working hours. Focusing on the impact of export expansion, Feng et al. (2021) found that reductions in export tariffs improved the health of working-age adults, using the CHNS database. However, because the most recent CHNS data only go as far as 2015, the timeliness of these findings is limited, given the recent societal and health changes. In light of the aforementioned, this research conducts empirical testing using multi-period panel data from the China Family Panel Studies (CFPS) household microdatabase, which has the benefit of removing endogeneity and third-factor drivers. Additionally, to assess the health level of individuals properly and thoroughly in an integrated manner, we combine subjective and objective health status. We also analyze the various effects of exports on the health level of urban and rural people, as well as men and women.

Third, while environmental quality has been a primary focus of the majority of recent studies on the mechanisms of trade's effects on health (Franzini et al., 2001; Cesur et al., 2013; Bombardini and Li, 2020). Most studies have found that exports hurt China's environmental quality, supporting the "pollution haven" hypothesis. And Morris (1996) illustrates, using data from rich and developing nations worldwide, that developing nations use international commerce or foreign investment to take over developed nations' highly polluting industries, which has an irreversible negative effect on the locals. Data from 189 nations were analyzed by Liang et al. (2017) to demonstrate that while international commerce benefits a nation economically, it also has unintended negative effects on the environment, particularly in developing nations like China and India, and harms the population's health. Data from Thailand were used by Jensen et al. (2019) to demonstrate how the promotion of tariff liberalization can degrade environmental quality and impair public health. Bombardini and Li (2020) found that export increases SO_2 concentrations, which increases infant mortality, especially infant mortality related to cardio-respiratory conditions. Zhao et al. (2023) and Li et al. (2025) argued that globalization has led a substantial transboundary transfer of air pollution and associated health burdens through international trade by developing different integrated frameworks. However, the specific mechanism linking exports to environmental quality in China warrants further investigation, particularly given heightened environmental awareness. Furthermore, this study incorporates employment and income as additional pathways through which exports may affect health. On the one hand, exports can improve the health of the population by increasing employment opportunities. On the other hand, exports can improve the health of the population by raising income levels. These considerations inform the three hypotheses below. In summary, this study provides a comprehensive analysis of how exports impact population health from different angles.

At the theoretical level, this paper focuses on the perspective of micropopulation health, which enriches the theoretical research in the field of trade liberalization and health economics. At the practical level, it clarifies the relationship between trade and health from the perspective of exports, and explores the mechanism of action and heterogeneity, which is of some significance for the formulation of China's foreign trade policy and the formulation of public health service policies.

The remainder of the paper is organized as follows. The pertinent formulation of the hypotheses is in Section 2. The data collection and the baseline regression model are discussed in Section 3. The findings of the initial regression and endogeneity test are further discussed in Section 4. Heterogeneity and robustness are other topics covered in this section. A further study suggests two mechanisms (Section 5). The conclusions and implications are compiled in the final section.

2. Theoretical analysis and research hypothesis

Scholarship dating back to the 1990s has explored the impact of international trade on employment based on David Ricardo's theory of comparative advantage and Keynes's foreign trade multiplier effect. Many empirical studies have shown that the growth of exports and foreign trade can significantly enhance a country's economic level and employment level. Humphrey et al. (2004), using data from the UK, showed that export trade effectively increases workers' motivation to work, and that the size of firms expands as a result of exporting, which, in turn, increases the number of jobs in the whole of society. Baldwin and Brown (2004), using Canadian regional-level data, showed that exports can significantly increase the stability of regional employment. In addition to the contribution of exports to employment levels in developed countries, studies have also reached the same conclusion using a sample of developing countries. Krueger et al. (1983) explored the impact of exports on employment in developing countries. The article used the data of 15 developing countries and regions to show that the export-oriented trade strategy has a significant positive effect on the employment level of developing countries. Milner and Wright (1998), using data from China and other developing countries, found that an increase in the volume of export trade is conducive to an increase in the overall level of employment in the country. With China's accession to the WTO in 2001, more studies began pay attention to the impact of exports in China. Feenstra and Hong (2010), using China's input-output tables for the years 2000–2005, estimated that China's exports could have created about 750 domestic jobs per year during these years. With the formation of global value chains nowadays, almost any job in every country is dependent on the international trade supply chain. The impact of exports on employment is even more self-evident.

The "healthy worker effect" posits that employed individuals exhibit better general health than their unemployed counterparts (McMichael et al., 1974). On the one hand, employers purchase health insurance, arrange for health care leave, and even provide fitness facilities for their employees. Because of this, the employees have a more stable and higher source of income than the unemployed, which can provide the necessary material insurance for maintaining and improving their health (Rogers et al., 2000). On the contrary, both economic and noneconomic variables can severely impact people's objective health state, as well as their psychological well-being when they are unemployed (Eliason and Storrie, 2006; Kuhn and Lalive, 2009; Kiran, 2021). In the US, the economic crisis of the 1970s was utilized as a shock by Sullivan and Wachter (2009) to demonstrate that those who have never been unemployed have a lower death rate than those who have. Deb et al. (2011) also pointed out that after unemployment, there is a significant increase in the frequency of obesity, smoking and alcohol abuse.

Consequently, export expansion generates additional employment opportunities. Stable employment facilitates access to essential goods like food and medicine, thereby improving population health. The following hypotheses are offered in light of the analysis presented above.

H1. *Export expansion improves population health by generating employment opportunities.*

Export development can enhance factor compensation, as suggested by factor endowment theory and the Stolper-Samuelson theorem. The significance of labor in export sectors underscores the impact of trade on wages as the major factor of production in export industries. Helpman et al. (2010), Davis and Harrigan (2007) found that firms will raise wages to incentivize workers to actively engage in productive activities, which, in turn, would improve the firm's exports. They did this by using a heterogeneous firm model. Amiti and Davis (2012), using a fair wage model, concluded that exporting leads to an increase in firms' profits, which, in turn, raises fair wages. In terms of empirical studies, Bernard and Jensen (1995) showed that whether before or after exporting, firms maintain high wage and income levels for employees, due to different motives, a finding which is based on data from the American manufacturing sector. Schank et al. (2007), using panel data from German firms, found that whether a firm exports or not significantly affects the pay levels of employees in that firm, after controlling for the personal characteristics of the employees. All the studies above show that trade openness, especially exports, can raise income levels and promote economic growth.

Grossman's (1972) health demand function (HDF) models health status as influenced by lifestyle decisions, access to medical care, income, education, and lifestyle demands. The model suggests that factors like wealth accumulation can mitigate the health depreciation associated with aging. This underpins the absolute income hypothesis, which states that income and health show a positive correlation. Based on Grossman's study, studies further put forward that health is a concave function of income. As the level of income rises, the effect of income on health improvement goes from strong to weak. Both the absolute income hypothesis and the relative income hypothesis suggest that higher incomes are conducive to better health, and this has been confirmed by many subsequent empirical studies. Lindahl (2005), using Swedish data, showed that an increase in income had a positive impact on the self-rated health of the population. Ettner (1996), using cross-sectional data from the US, found that an increase in the level of income had a significant improvement in both the self-rated health of the respondents and their chronic health status.

In summary, exports elevate income levels, enabling households to access better housing, sanitation, healthcare, and other necessities conducive to health (Alam et al., 2016; Levine and Rothman, 2006). In light of the aforementioned analysis, this paper offers the following hypothesis.

H2. *Export expansion improves population health by raising household income levels.*

Due to the ongoing expansion of international trade and the emergence of problems with global environmental degradation, studies have started to shift their focus away from the economic benefits of trade and toward the environmental difficulties associated with trade. The "pollution haven hypothesis" suggests that stringent environmental regulations in developed countries drive pollution-intensive industries to relocate to regions with weaker regulations (Copeland and Scott, 1994). Also, wealthier countries buy heavily polluting goods from less developed countries, which have either directly or indirectly exacerbated the environmental pollution issue in developing countries. However, empirical support has also emerged for the competing "pollution halo" hypothesis. This perspective contends that trade can lead to environmental improvements. On the one hand, international trade, and export trade in particular, is frequently fiercely competitive and can greatly boost the resource efficiency or total factor productivity of exporting firms, eliminating inefficient production losses, and fostering environmental protection. On the other hand, trade between countries can lead to the transfer of cutting-edge manufacturing and environmentally friendly technology, accelerate the rate at which resources are utilized, and improve a country's capacity to establish pollution control systems. Besides, export trade can boost a nation's economic standing, giving exporting nations more money to put into environmental protection or the advancement of environmental technologies, both of which can enhance the nation's ecological environment. Furthermore, emerging trade policies like the EU's Carbon Border Adjustment Mechanism (CBAM) incentivize green transitions among exporters.

Many studies have confirmed the "pollution halo" theory. Cole (1998), and Strutt and Anderson (1999), derived from the perspective of welfare economics, found that trade liberalization can solve the problem of inefficient allocation of environmental resources brought about by market distortions, and that, therefore, expanding trade openness is conducive to reducing environmental pollution and enhancing the level of environmental protection. Birdsall (1993), using panel data of 25 Latin American countries from 1960 to 1988, found that free trade did not promote the development of polluting industries in these countries. Xu (2000), using cross-country panel data of developed countries and an extended gravity model, found that the "pollution paradise" model was not a good solution. Although developed countries transferred domestic polluting firms to developing countries, their exports of pollution-intensive products did not decrease as a result. In terms of empirical studies on Chinese samples, Wang et al. (2016) found that China's stringent environmental regulations reduced firms' exports of pollution-intensive products, thus optimizing the export structure of China's products.

In the field of health economics, air pollution has been included as an influencing element in Grossman's (1972) health production function, which was developed by Cropper (1981), Gerking and Stanley (1986), and Alberini et al. (1997). They found that air pollution affects the level of health, which means that improvements in the quality of the environment can favor the health of the population. In terms of empirical studies, Franzini et al. (2001), using city-level data from 1987 to 1994 in the US, found that air pollution increases residential mortality rates. Troesken (2003), using data on water pollution in Massachusetts, pointed out that water pollution significantly improves the morbidity and mortality of infants and children. Conversely, Chay and Greenstone (2003), using a quasi-natural experiment on the decline in environmental pollution levels brought about by the 1981 recession in the US, found that the decline in environmental pollution levels significantly reduced residential mortality, and that improvements in environmental quality were particularly significant in improving the health of Black infants and children. Cesur et al. (2013), using regional panel data from Turkey, found that use of natural gas can lead to a reduction in pollution emissions, which, in turn, improves the health of the population. In terms of empirical studies on Chinese samples, Tanaka (2015) found that infant and child mortality rates decreased significantly in the areas covered by the 'two control zones', using the DID (Differences-in-Differences) method based on a policy experiment in China. Ebenstein (2012), on the basis of water pollution data from the Huaihe River Basin in China, found that an increase in water quality levels is conducive to a reduction in the number of deaths of residents due to digestive diseases. Chang et al. (2020), using data at the provincial level in China, demonstrated that under a national emissions trading system, air quality would be substantially improved and have positive impacts on the people's health.

All of these studies support the idea that export trade helps to reduce pollutant emissions, which, in turn, improves the environmental quality of the area and makes it healthier for residents to live and work there. In consideration of the analyses above, the following hypothesis is presented:

H3. *Export expansion improves population health by enhancing the local environmental quality.*

On the basis of the analysis above, we will empirically test these three hypotheses in the mechanisms section below by combining the effects of work, income, and pollution on exports. We expect the result to be that exports have a positive impact on employment, a positive impact on incomes, and a negative impact on pollution.

3. Data and methodology

3.1. Data sources

The CFPS database is a baseline survey that was started in 2010 with a follow-up survey that collects data at the individual, home, and community levels across the country. It offers the population and household statistics needed for this study. The China Customs Database, the *China Statistical Yearbook*, and the *China Finance, Energy, and Transport Statistics Yearbook* provided the province-level data for this study. Furthermore, we used the complete samples of tracking survey data from the years 2012, 2014, 2016, and 2018.

The collected samples for this study were subjected to the following screening procedures: (1) eliminating samples that lacked the primary independent and dependent variables, (2) eliminating samples that lacked years, and (3) excluding samples from respondents under the age of 18 and those over the age of 85 because these respondents have less developed cognitive abilities and their opinions have less of an impact on society. After the filtering, 62,300 sample observations were ultimately gathered for this paper.

3.2. Variable definition

3.2.1. Explained variables

The concept of "health" was first put forth by the World Health Organization in the late 1940s; it includes not only a person's physical condition but also their psychological and social well-being. Self-reported health is a common assessment method today. This is because when respondents self-assess their current health status, they not only give a direct picture of the overall state of their health, but also indirectly reflect their mental health and social adaptability, which is a more scientific and accurate way of assessment. And due to the development and improvement of microdatabases, more researchers have begun to use self-reported health as an indicator of individual health. In the CFPS questionnaire, respondents are asked to rate their degree of health, and the question is "How do you consider your health to be?", with five options: 1, excellent health; 2, very good health; 3, good health; 4, fair health; 5, poor health. The worse their assessment of their health, the higher the value of the set of options. We assign values to the objective health status indicator on the basis of the users' option answers.

Self-assessed health indicators are still somewhat subjective, so we also assessed the sample's actual health state to confirm that the regression results are applicable. Objective health assessments include the following. (1) The respondent's weight (kg)/height (m^2) were used to calculate their body mass index (BMI). The higher their BMI, the fatter and unhealthier they are likely to be. (2) They were also asked if they had experienced any illness in the previous two weeks (yes = 1, no = 0), (3) if the respondent had a chronic illness (yes = 1, no = 0), and (4) if they had been hospitalized in the last year (yes = 1, no = 0). We combined the respondents' subjective self-rated health and objective measurements of health status to determine the respondents' overall health status. For both the subjective and objective health measures, a higher value means that the respondent is less healthy; therefore, on the basis of the analysis above, we predict that the regression coefficient β should be significantly negative.

3.2.2. Explanatory variables

The independent variable in this paper is $Export_{p.t}$, which represents the export value of each province in RMB million for each of the years 2012, 2014, 2016, and 2018. The regression coefficients are handled as logarithms to make sure they are not too tiny.

3.2.3. Control variables

This article additionally accounts for the individuals' characteristic variables, citing Fan et al. (2020). The personal information variable $Peri_{p.t}$ includes the respondents' gender, age, marital status, place of residence, education level, exercise frequency, and life satisfaction. The household characteristic variable $Fam_{p.t}$ contains the respondents' household's water and electricity situation, including water and electricity, toilet conditions, lighting conditions, household size, etc. The province's characteristic variable Pro_t includes the value added of primary, secondary, and tertiary production and provincial expenditure on education, health care, and environmental protection in the respondent's province. Logarithms of these variables are used in this study. Table 1 displays the precise justifications for the variables.

Table 1. Description of the relevant variables.

Variable's name	Variable's meaning
Explanatory variables	
exp	Export value of the sample provinces in the year of observation. (In RMB million)
Explained variables	
subhealth	Respondents' self-assessed health status, from the dataset in the CFPS questionnaire with the alternative options 1–5, where the greater the option, the worse the health status
BMI	Respondent's BMI: the higher the BMI, the fatter and unhealthy the respondent tends to be
unwell	Whether the respondent has felt unwell in the past two weeks (yes = 1, no = 0)
chronic	Whether the respondent has a chronic illness (yes = 1, no = 0)
inhospital	Whether the respondent was hospitalized in the past year (yes = 1, no = 0)
Control variables	
age	Age of interviewees
gender	Gender of the interviewee (male = 1, female = 0)
married	Respondents' marital status

Continued on next page

Variable's name	Variable's meaning
education	Highest level of education of the respondents (1–9, indicating progressively higher levels of education)
urban	Type of residence of the respondents (urban = 1, rural = 0)
height	Height of interviewees (m)
weight	Weight of interviewees (kg)
exercise	Frequency of exercise by the respondent (the higher the number, the higher the frequency)
persatisfaction	Respondents' satisfaction with their lives
mealwater	Access to water for cooking in the households interviewed
mealfuel.	Fuel used for cooking by the households interviewed
electricity	Lighting conditions in the homes interviewed
bathroom	Toilets in the households interviewed
familysize	Population size of the households interviewed
perGDP	Regional GDP per capita. (In RMB/person)
firGDP	Value added of regional primary industries (in RMB billion)
secGDP	Value added to the regional secondary industry (in RMB billion)
thrGDP	Value added of the regional tertiary sector (in RMB billion)
eduexp	Regional financial expenditure on education (in RMB billion)
medexp	Regional financial health care expenditure (in RMB billion)
envexp	Regional financial expenditure on environmental protection (in RMB billion)
Mechanism variables	
work	Whether the respondent has a job (yes = 1, no = 0)
income	Personal income of the interviewees
so2	Regional emissions of sulfur dioxide from exhaust gases
no2	Regional emissions of nitrogen oxides in exhaust gases
PM_{25}	Regional emissions of smoke (dust) from exhaust gases
gufei	Regional solid waste emissions
weifei	Regional hazardous waste emissions
Robustness variables	
fat	Defining people with BMI > 24 as overweight and obese, generating the variable fat = 1 and not fat = 0
subhealth1	The variable subhealth1 = 1 is generated when the respondent selects "unhealthy" in the personal self-assessment of health (serial number 5), and 0 in the opposite case
soe	The number of legal entities of state-owned enterprises in the region
capacity	The foreign trade cargo throughput of regional ports (million tons)
transportation	Regional ownership of ocean-going carriers (number of vessels)

Note: Table 1 is about the description of relevant variables. Specifically, it includes explanatory variables, explanatory variables, control variables, variables required for mechanism, and variables required for robustness. Control variables are further divided into three dimensions: individual level, family level, and provincial level.

3.3. Methodology

The benchmark regression in this study uses linear OLS regression and binary choice logit regression because the dependent variables chosen comprise continuous, ordered, and 0–1 binary variables.

$$Hea_{i,p,t} = \alpha + \beta Export_{p,t} + c_1 Per_{i,p,t} + c_2 Fam_{p,t} + c_3 Pro_t + \mu_i + \theta_t + \epsilon_{i,t} \quad (1)$$

where i denotes the individual, p denotes the province, and t denotes the time.

The health status of person i in year t in province p is represented by the explanatory variables $Hea_{i.p.t}$ in the regression equation, which included the individual's BMI (OLS regression), self-rated health (OLS regression), presence of a chronic disease, hospitalization, and unwellness (logit regression). The primary explanatory factor is the volume of exports in year t from province p, and it is represented by $Export_{p.t}$. Additionally, the model accounts for the variable of individual characteristics $Peri_{p.t}$, the variable measuring household characteristics $Fam_{p.t}$, and the provincial characteristics variable Pro_t. Individual fixed effects (individual FE) are represented by μ_i, while time-fixed effects (year FE) are represented by θ_t, and the error term with unobservable effects is represented by $\epsilon_{i.t}$, which has a logistic distribution in the logit regression.

4. Main results

4.1. Baseline results

Table 2 presents the estimation results of Model (1), for which we choose OLS regression. Columns (1)–(3) are the estimation results with objective health status (BMI) as the explanatory variable. To ensure the robustness of the estimation results, Columns (1)–(3) include individual control variables (individual CV), household control variables (household CV), and provincial control variables (provincial CV), respectively, in the regression. With distinct control variables for each dimension, Columns (4)–(6) show the estimation results using subjective health status (subhealth) as the explanatory variable. In addition, all regressions control for individual and year-fixed effects using OLS regression.

Table 2. The health effects of exporting (1).

	BMI			*subhealth*		
	(1)	(2)	(3)	(4)	(5)	(6)
ln *exp*	−1.25*	−1.03*	−0.97**	−0.04*	−0.03**	−0.02***
	(0.96)	(0.82)	(0.63)	(0.02)	(0.02)	(0.03)
Individual CV	Y	Y	Y	Y	Y	Y
Household CV	N	Y	Y	N	Y	Y
Provincial CV	N	N	Y	N	N	Y
Year FE	Y	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y	Y
Constant	22.69***	22.70***	17.79***	3.06**	3.09**	6.09***
	(1.84)	(1.85)	(2.32)	(1.20)	(1.20)	(1.47)
Observations	61,189	61,025	61,025	61,189	61,025	61,025
R^2	0.03	0.03	0.03	0.01	0.01	0.01

Note: This table reports the results of exports on health. Columns (1)–(3) use the objective health status (BMI) as the explanatory variable. Columns (4)–(6) use subjective health status (subhealth) as the explanatory variable. ln exp is the logarithm of exports. The regression result shows that an increase in exports can improve the health of the population. Standard errors are clustered at the individual level and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively. FE, fixed effects.

As can be seen from Table 2, the regression coefficients for the number of exports are all significantly negative when the control variables are added in turn. For every percentage point increase in exports, BMI decreases by 0.01 units. It is similar to the effect on subhealth. The regression results are as expected: the higher the exports, the better the population's health status, because a greater value of the explained variables implies a less healthy status.

Additionally, we use logit regression to regress Model (1) with the binary dependent variable, which represents the people's actual health status. The three variables were whether the respondent felt unwell in the previous two weeks (unwell), whether the respondent has a chronic illness (chronic), and whether the respondent was in hospital in the previous year (inhospital). These three factors are used to measure the respondent's objective health status. Logit regression is used to analyze panel data in Columns (1)–(3) of Table 3. The regressions in Table 3 include all control variables and individual and year-fixed effects. The regression results show that the key explanatory variables' regression coefficients are strongly negative, indicating that an increase in exports is likely to result in an improvement in the population's overall health.

Table 3. The health effects of exporting (2).

	unwell	*chronic*	*inhospital*
	(1)	(2)	(3)
ln *exp*	−0.09*	−0.07*	−0.08***
	(0.06)	(0.08)	(0.09)
Individual CV	Y	Y	Y
Household CV	Y	Y	Y
Provincial CV	Y	Y	Y
Year FE	Y	Y	Y
Individual FE	Y	Y	Y
Observations	33,883	24,625	19,680

Note: The model is used to regress the people's actual health status (unwell, chronic, and inhospital). ln exp is the logarithm of exports. The regression result shows that the explanatory variables' regression coefficients are strongly negative, indicating that an increase in exports can improve the population's overall health. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively. FE, fixed effects.

4.2. Endogeneity test

When determining the reasons for exports and health using the abovementioned methods, there can be reverse causality and omitted variable bias. First off, if one region has a competitive advantage in producing a good in large quantities for export while the rest of the region does not, the endogeneity of the region's export volume will no longer exist. Second, exports may be tied to domestic demand. If domestic demand rises, production rises as well, leading to better levels of employment and income, which can enhance population health. There is a problem with missing variables because we do not have access to domestic demand data, which leads to a biased estimated coefficient. Even though we include a variety of controls in the regression and take each two-way fixed effect into account individually, the negative impact of omitted variables is still present. Moreover, factor endowment theory asserts that health capital, a significant form of human capital, influences the nature, volume, and structure of a nation's exports (Levin and Raut, 1997; Bond et al., 2003; Papageorgiou and Perez- Sebastian, 2006). As a result, exports and health also have a reverse causal relationship. Based on these concepts, this work uses instrumental factors and two-stage regression to further minimize endogeneity.

Both Hiyoshi et al. (2023) and Ghojagh et al. (2021 use historical factors as instrumental variables; however, historical variables may also be linked to other explanatory variables and error terms in the model. Following Li et al. (2023), we conducted a two-stage regression using the ocean-going transport ownership (transportation) and foreign trade cargo throughput (capacity) of provincial ports as the instrumental variables for regional exports. As these two parameters have a significant correlation with regional exports but no direct impact on population health, they can be used as pertinent instrumental factors. We performed a plus-one logarithmic treatment of these two instrumental variables because it is clear from the descriptive statistics that the foreign trade throughput and ownership of ocean-going means of transportation vary significantly across provincial ports, with some inland areas having zero numbers. In Table 4, Column (1) lists the outcomes of one-stage regression for the instrumental variables, and Columns (2) through (6) list the outcomes of two-stage least squares regression.

Table 4. Endogeneity test (1).

	ln exp	*BMI*	*subhealth*	*unwell*	*chronic*	*inhospital*
	(1)	(2)	(3)	(4)	(5)	(6)
ln *(capacity+1)*	0.04***					
	(0.001)					
ln *(transportation)*	0.01***					
	(0.002)					
ln *exp*		−1.73*	−0.67*	−0.32	−0.07**	−0.09**
		(1.06)	(0.43)	(0.20)	(0.17)	(0.17)
Individual CV	Y	Y	Y	Y	Y	Y
Household CV	Y	Y	Y	Y	Y	Y
Provincial CV	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y	Y
Constant	−1.55***	13.70***	4.89***	−0.95	0.17*	−0.17***
	(0.21)	(4.73)	(1.85)	(0.87)	(0.73)	(0.72)
Observations	61,025	61,025	61,025	61,025	61,025	61,025
R^2	0.89	0.05	0.09	0.04	0.07	0.06

Note: This section further eliminates endogeneity using instrumental variables and two-stage regression. We chose the ocean-going transport ownership (transportation) and foreign trade cargo throughput (capacity) of provincial ports as the instrumental variables. Column (1) lists the outcomes of a one-stage regression for the instrumental variables, and Columns (2) through (6) list the outcomes of two-stage least squares regression. The results show that the effect of exports on the subjective and objective health status of the population remains significant. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively. FE, fixed effects.

By testing, both Durbin and Wu-Hausman's *p*-values reject the original hypothesis at the 10% level, and the dependent variable is indeed endogenous, validating the conjecture above. The F-statistic values and R^2 of the weak correlation test are also consistent with the requirement for correlation of the instrumental variables. The econometric results of the first-stage regression in Column (1) of Table 4 demonstrate that there is a significant positive correlation between ports' foreign trade cargo throughput, ocean-going vehicle ownership, and regional exports. Furthermore, there is no direct influence on the health of the local population because most of the harm caused by ports' foreign commerce cargo throughput and ocean-going modes of transport comes from its impact on regional exports. The tests' findings also show that these two variables satisfy endogeneity requirements and do not experience overidentification issues, making them suitable for use as instrumental factors in population health assessments.

The effects of exports on the population's subjective and objective health status are still significant, as shown by the second-stage regression results in Table 4's Columns (2) through (6). This shows that the coefficient on exports is still considerably negative even after accounting for any potential endogeneity between exports and population health, which is largely consistent with the earlier findings. Additionally, it implies that a region's exports can make a sizable difference to the health of the local populace.

Table 5. Endogeneity test (2).

	ln exp (1)	*BMI* (2)	*subhealth* (3)	*unwell* (4)	*chronic* (5)	*inhospital* (6)
ln *barexp*	0.02***					
	(0.004)					
ln *exp*		−0.48*	−0.22*	−0.23**	0.12	0.13
		(0.63)	(0.23)	(0.10)	(0.09)	(0.08)
Individual CV	Y	Y	Y	Y	Y	Y
Household CV	Y	Y	Y	Y	Y	Y
Provincial CV	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y	Y
Constant	10.21***	28.54***	8.70**	2.49*	2.17	0.97
	(0.20)	(9.76)	(3.59)	(1.62)	(1.37)	(1.29)
Observations	45,653	45,653	45,653	45,653	45,653	45,653
R^2	0.90	0.06	0.10	0.05	0.07	0.06

Note: Furthermore, we chose $ExportShock_{pt}$ as the instrumental variable. Column (1) lists the outcomes of a one-stage regression for the instrumental variables, and Columns (2) through (6) list the outcomes of two-stage least squares regression. The results show that the effect of exports on the subjective and objective health status of the population remains significant. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively.

In addition, based on the classic Bartik (1991) method, and drawing on the methods used by Kovak (2013) and Autor et al. (2013) to construct regional import competition shocks, this paper utilizes the differences in the initial industrial structures of each region to construct regional export shock instrumental variables, as shown in Equation (2).

$$ExportShock_{pt} = \sum_{k} \frac{L_{pk,2008\sim2011}}{L_{k,2008\sim2011}} Export_{Rkt} \tag{2}$$

where p denotes the province, k denotes the industry, t denotes the time, $Export_{Rkt}$ represents China's exports to other countries in the world in industry k in year t, and $\frac{L_{pk,2008\sim2011}}{L_{k,2008\sim2011}}$ is the average proportion of employment in industry k in region p from 2008 to 2011 relative to the total employment in industry k in China. The initial employment structure of each region reflects the differences in the industrial structure of that region. $ExportShock_{pt}$ reflects the portion of the change in the export value of industry k from China to other countries that is allocated to region p. If the manufacturing industry in the region where the sample is located is concentrated in industries with high export expansion, then the demand shock brought about by export expansion will be greater. The Table 5 shows that the results of the two-stage regression using this instrumental variable are still robust.

4.3. Robustness tests

4.3.1. Change of regression method

To test the robustness of the baseline regression results, the OLS regression used in Table 2 is replaced with a logit regression in this paper. Besides, referring to the international classification standard for Asian BMI values, this paper defines people with BMI > 24 as overweight and obese people, generating the variable fat = 1. When BMI $\leq$ 24 is taken as normal, this generates fat = 0. When respondents select "unhealthy" in their self-assessment of health, which means subhealth=5, the variable subhealth1 = 1. When subhealth = 1 or 2 or 3 or 4, this generates subhealth1 = 0. Columns (1)–(2) of Table 5 are logit regressions with fat and subhealth1 as the explanatory variables, respectively, and the results show that the final coefficients remain negatively significant, confirming the robustness of the baseline regression results.

4.3.2. Adding more control variables

Dean et al. (2009) found that the number of state-owned enterprises (SOEs) in a region can hurt the health of the population because they are subject to less stringent environmental regulations and do not bear responsibility for environmental pollution. So, we added it as a control variable. The regression results are shown in Columns (3)–(7) of Table 6. They show that the regression coefficient of the number of regional SOEs is not significant, and the coefficient of exports is still negatively significant, so the regression results are robust.

Table 6. Robustness tests.

	fat (1)	*subhealth1* (2)	*BMI* (3)	*subhealth* (4)	*unwell* (5)	*chronic* (6)	*inhospital* (7)
ln *exp*	−0.16*	−0.28***	−0.02**	−0.03**	−0.09*	−0.05*	−0.11***
	(0.09)	(0.09)	(0.05)	(0.03)	(0.07)	(0.08)	(0.09)
soe			4.39e−05**	−5.18e−06	−7.95e−06	3.34e−05	−2.89e−05
			(1.83e−05)	(9.96e−06)	(2.73e−05)	(3.35e−05)	(3.87e−05)
Individual CV	Y	Y	Y	Y	Y	Y	Y
Household CV	Y	Y	Y	Y	Y	Y	Y
Provincial CV	Y	Y	Y	Y	Y	Y	Y

Continued on next page

	fat (1)	*subhealth1* (2)	*BMI* (3)	*subhealth* (4)	*unwell* (5)	*chronic* (6)	*inhospital* (7)
Year FE	Y	Y	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y	Y	Y
Constant			17.66***	6.03***			
			(2.33)	(1.48)			
Observations	18,296	18,218	61,025	61,025	33,883	24,625	19,680
R^2			0.03	0.01			

Note: We conducted some further robustness tests. First, we changed the regression method and used the logit regressions with fat and subhealth1 as explanatory variables. Columns (1) and (2) of Table 5 are the regression's results. Secondly, the paper adds more control variables: we added SOEs as a control variable. The regression's results are shown in Columns (3)–(7) of Table 5. They both show that the regression results are robust. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively.

4.3.3. Placebo test

This section provides a placebo test to rule out the possibility that the significance of the baseline regression estimates results from a relationship between the trend in the population's prior health status and the region's exports. We performed a regression analysis on the exports using the lagged terms of the explanatory factors (BMI, subhealth, ill, chronic, inhospital). The regression analysis's findings, which are presented in Table 7, demonstrate that there is no statistically significant negative correlation between exports and the trend in the population's prior health status for the lagged components of the explanatory variables.

Table 7. Placebo test.

	L.BMI (1)	*L.subhealth* (2)	*L.unwell* (3)	*L.chronic* (4)	*L.inhospital* (5)
ln *exp*	−0.09	−0.08	−0.15	−0.12	0.21
	(0.05)	(0.03)	(0.09)	(0.10)	(0.12)
Individual CV	Y	Y	Y	Y	Y
Household CV	Y	Y	Y	Y	Y
Provincial CV	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y
Constant	17.52*	2.45*			
	(2.53)	(1.34)			
Observations	45,581	45,581	20,117	14,518	10,747
R^2	0.02	0.01			

Note: We applied a placebo test as a further robustness test. We regressed the lagged terms of the explanatory variables (BMI, subhealth, unwell, chronic, inhospital) on exports. The results of the regression show that the effect of exports on the lagged terms of the explanatory variables does not show a significant negative relationship, proving that exports are not correlated with the trend in the previous health status of the population. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively.

4.4. Heterogeneity analysis

4.4.1. Urban–rural heterogeneity

Due to the disparity in economic development between urban and rural areas, there may also be discrepancies in the employment patterns and living conditions of these populations, as well as in how exporting may affect their health. This paper performs subsample regressions as a result. The model results in Table 8 indicate that exports have no meaningful impact on the general health of urban dwellers and may potentially hurt their subjective health. This may be because people who live in cities put in greater hours at work, and exports may increase wealth disparities, which, in turn, harm people's subjective health. Exporting has a significant positive contribution to the health of rural residents, similar to the results of the baseline regression, which may be because exporting activities can absorb more low-skilled labor from rural areas.

Table 8. Urban-rural heterogeneity.

	BMI		*subhealth*		*Unwell*	
	City	Rural	City	Rural	City	Rural
ln *exp*	0.05*	−0.07*	0.11***	−0.05***	−0.09	−0.13*
	(0.07)	(0.08)	(0.04)	(0.04)	(0.11)	(0.09)
Individual CV	Y	Y	Y	Y	Y	Y
Household CV	Y	Y	Y	Y	Y	Y
Provincial CV	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y	Y
Constant	27.71**	14.07***	11.28***	3.53**		
	(5.05)	(2.96)	(3.13)	(1.77)		
Observations	28,392	32,440	28,392	32,440	14,752	17,575
R^2	0.03	0.03	0.01	0.01		

Note: This table reports the heterogeneous effects of exports on health. We divided the samples according to urban and rural areas. The results in rural areas are more significantly positive. In contrast, the results in the city are insignificant. This evidence indicates the effects of exports on health are obvious in rural areas. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively.

4.4.2. Gender heterogeneity

The impact of exporting on men and women may differ somewhat due to the different positions of the labor force in the job market by gender. For this reason, this paper explores the heterogeneity of the impact of export trade on the health level between men and women in a subsample regression (see Table 9). The results show that the effect of exporting on the health of the female population is more significant, possibly because exporting activities create more jobs, especially in the manufacturing sector, absorbing many housewives who were previously unemployed, improving the income and status of women; therefore, exporting has a greater impact on women.

Table 9. Gender heterogeneity.

	BMI		*subhealth*		*unwell*	
	Male	Female	Male	Female	Male	Female
ln *exp*	0.12	−0.01***	−0.06	−0.01**	−0.01	−0.16**
	(0.06)	(0.07)	(0.04)	(0.04)	(0.09)	(0.09)
Individual CV	Y	Y	Y	Y	Y	Y
Household CV	Y	Y	Y	Y	Y	Y
Provincial CV	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y	Y
Constant	17.34*	15.99***	5.65**	5.98**		
	(3.02)	(3.49)	(1.94)	(2.35)		
Observations	29,223	31,802	29,223	31,802	15,067	18,807
R^2	0.03	0.04	0.01	0.01		

Note: This table reports the heterogeneous effects of exports on health. We divided the samples according to gender. The results for females are more significantly positive. In contrast, the results for males are insignificant. This evidence indicates the effects of exports on health are obvious for females. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively.

5. Mechanism analysis

5.1. Employment and income impact of exports

The analysis above shows that exports can improve the health of the population through increased employment opportunities and higher personal income. This section will verify these one by one. Columns (1) and (2) of Table 10 take whether the respondent has a job as the dependent variable (yes = 1, no = 0), and Columns (3) and (4) take the respondent's income as the dependent variable, taking the logarithm to facilitate the interpretation of the regression coefficients. The regressions include control variables and all control for individual and time-fixed effects.

The regression results show that exports show a significant positive effect on employment levels and income levels with or without the inclusion of control variables, thus confirming Hypotheses H1 and H2 that exports can improve the health of the population by promoting personal employment and raising personal income.

Table 10. The impact of exports on employment and income.

	work		ln *income*	
	(1)	(2)	(3)	(4)
ln *exp*	0.15*	0.08*	0.20***	0.20***
	(0.24)	(0.33)	(0.03)	(0.04)
Individual CV	N	Y	N	Y
Household CV	N	Y	N	Y
Provincial CV	N	Y	N	Y
Year FE	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y
Constant			5.58***	−3.13*
			(0.48)	(1.73)
Observations	17,162	16,747	52,830	52,344
R^2			0.27	0.28

Note: In this section, we investigate whether exports affect the health of the population. Columns (1) and (2) take whether the respondent has a job as the dependent variable (yes = 1, no = 0), and Columns (3) and (4) take the respondent's income as the dependent variable, taking the logarithm. The regression results display that exports show a significant positive effect on employment levels and income levels, so exports can improve the health of the population by promoting personal employment and raising personal income. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively.

5.2. Environmental impact of exports

From the analysis above, trade liberalization may reduce pollutant emissions by improving the productivity of enterprises, introducing cleaner production technologies, and promoting green R&D as a way to improve the health of the population. Therefore, this paper draws on Melén (2021) and Sly (2021) to measure air pollution in each province using sulfur dioxide (SO_2), nitrogen oxide (NO_2), dust (PM_{25}), solid waste (gufei), and hazardous waste emissions (weifei). We incorporated cross-multiplication terms of these pollution variables and export volumes in the model (1) to further examine the mechanisms of export impacts on health. Column (1) of Table 11 is a regression with BMI as the explanatory variable, and the explanatory variables include the region's sulfur dioxide emissions and a centralized cross-product of sulfur dioxide emissions and exports, controlling for individual, household, and province-level characteristic variables, as well as for time and individual fixed effects. Columns (2)–(5) are treated similarly and are not explained individually.

The regression results in Table 11 demonstrate that the regression coefficient on exports remains significantly negative after the inclusion of the cross-multiplier between pollutant emissions and exports, similar to the baseline regression results. All the cross-multipliers are significantly negative, except for the cross-multiplier ln exp × PM_{25}, which is not significant, but it also has a negative coefficient. This suggests that an increase in the exports of a region reduces the emissions of pollutants from the production processes in that region, which, in turn, has a positive impact on the health of the population, and H3 holds. Our empirical results confirm the "pollution halo" hypothesis, which implies that exporting is conducive to enterprises learning advanced low-carbon technologies and improving labor productivity. This, in turn, reduces pollution emissions and provides good environmental quality for the health of the population.

Table 11. Environmental impact of exports.

	BMI (1)	(2)	(3)	(4)	(5)
ln *exp*	−0.05**	−0.03***	−2,979*	−0.14**	−0.02***
	(0.06)	(1,729)	(1,549)	(0.08)	(0.07)
so2	0.003**				
	(0.007)				
ln *exp* × *so2*	−0.002**				
	(0.003)				
no2		0.003***			
		(0.009)			
ln *exp* × *no2*		−0.0004***			
		(0.003)			
PM_{25}			−0.005		
			(0.008)		
ln *exp* × PM_{25}			−0.002		
			(0.003)		
gufei				0.001	
				(0.001)	
ln *exp* × *gufei*				−0.0003**	
				(0.000)	
weifei					0.002***
					(0.003)
ln *exp* × *weifei*					−0.002**
					(0.002)
Individual CV	Y	Y	Y	Y	Y
Household CV	Y	Y	Y	Y	Y
Provincial CV	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y
Constant	15.51***	17.70***	16.68***	18.47***	17.05***
	(3.00)	(3.48)	(3.05)	(3.21)	(2.71)
Observations	53,143	50,677	52,219	49,605	52,632
R^2	0.03	0.03	0.03	0.02	0.02

Note: We also investigate whether the exports affect the health of the population via the environmental impact. Column (1) is a regression with BMI as the explanatory variable, and the explanatory variables include the region's sulfur dioxide emissions and a centralized cross-product of sulfur dioxide emissions and exports. Columns (2)–(5) are treated similarly and are not explained individually. The results suggest that an increase in the export of a region reduces the emissions of pollutants, which has a positive impact on the health of the population. Standard errors are clustered at the individual level, and significance levels are denoted by *, **, and ***, representing 10%, 5%, and 1%, respectively.

6. Conclusions

Currently, there is a gap in the literature studying the impact of exports on health, and most of the data selection is based on the regional level, with less literature comprehensively measuring the health status of individual residents. This paper utilizes the CFPS residents' database from 2012 to 2018, based on previous work, combined with macro-data such as the China Customs Database. It comprehensively examines the direction and path of influence of export trade on the health status of Chinese residents, based on theory and empirical evidence. It aimed to make some marginal contributions to the relative gaps in the field. In addition, the findings of the baseline regression and mechanism analysis in this paper also have some practical reference value. It may provide some reference for the formulation of China's foreign trade policy, public health and health service policy, and the strategic positioning of export enterprises.

The findings suggest that exports are conducive to improving the health of the population, both subjective and objective. This paper confirms the robustness of the baseline results by replacing the regression method, adding control variables, conducting a placebo test, and discussing endogeneity issues. One way that export trade might improve health is by increasing employment opportunities. Stable employment can give locals access to basic material security and medical treatment. Contrarily, export trade can raise income levels, and higher incomes can encourage household purchases of dietary supplements and access to medical care and preventive services, thus enhancing population health. In contrast to earlier research, we discovered that localized export operations can boost the health of the populace by lowering pollutant emissions and enhancing environmental quality. Finally, heterogeneity was investigated in this study. We found that exports have a stronger impact on the health of rural residents and women.

Given this, the following suggestions are made in this study. First of all, China has always been open to the outside world and actively participates in the creation and governance of global value chains in an era of "counter-globalization" and rising trade protectionism. China should therefore push for increasing export commerce while insisting on furthering its reform and opening. To increase the volume of China's exports, efforts should be made to identify new partners in terms of export destinations. Regarding the kinds of goods to be exported, we should intensify our exports in the health and digital sectors to establish China as a major player that actively supports globalization in global health governance.

Second, we actively encourage people to find work, particularly people in rural areas and women. On a larger scale, this will enhance rural residents' ability to produce and live comfortably, contribute to the revitalization of the countryside, and elevate the status of women in the workforce and the family. It can raise society's overall well-being level even further. At the microlevel, it will enhance households' economic foundation and maximize resource allocation in the factor market. Increasing rural employment options can aid in reducing the issue of the elderly and children being left behind, and outflows.

Besides, exporters should take active steps to increase company profitability and raise employees' pay. Chinese exporters can currently only access a limited portion of the global value chain, since they are still concentrated in the middle and lower regions of the chain. China should actively leverage the global market to increase exports in sectors like 5G and high-speed rail, where it has already achieved global technological superiority. It should actively assist labor-intensive industrial companies in technological innovation and boost their marketing skills.

Finally, the government should actively assume primary responsibility for environmental protection, realize the matching relationship between human and physical capital, increase factor productivity, and decrease the energy consumption of their products. The government should use the trade profits obtained from exports to fund environmental protection. Only in this way can we optimize the positive effects on the economy and the environment and offer a healthy environment for locals to live in.

Notwithstanding its contributions, this study presents several methodological limitations that necessitate further refinement in subsequent research endeavors. First of all, the identification of the endogeneity of exports is insufficient, so how to better construct the export shocks and export shock-induced pollution in different regions will be a direction for further research in the future. In addition, it is also of great practical significance to introduce health costs into trade welfare and analyze the impact of export expansion more comprehensively.

Author contributions

Runmin Deng: Data collection; data processing; methodology; writing and editing. Xinju He: Data collection; data processing; methodology; writing and editing. Yani Zhang: Data collection; data processing; methodology; writing and editing.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Acknowledgments

This research has been partially supported by the National Natural Science Foundation of China (under Grant No. 72001061). Views expressed in this article are solely those of the authors and should not be attributed to the funding body.

Conflict of interest

All authors declare no conflicts of interest in this paper.

References

Alam MS, Raza SA, Shahbaz M, et al. (2016) Accounting for Contribution of Trade Openness and Foreign Direct Investment in Life Expectancy: The Long-run and Short-run Analysis in Pakistan. *Soc Indic Res* 129: 1155–1170. http://doi.org/10.1007/s11205-015-1154-8

Alberini A, Cropper M, Fu TT, et al. (1997) Valuing Health Effects of Air Pollution in Developing Countries: The Case of Taiwan. *J Environ Econ Manage* 34: 107–126. http://doi.org/10.1006/jeem.1997.1007

Atkin D (2013) Trade, Tastes, and Nutrition in India. *Am Econ Rev* 103: 1629–1663.http://doi.org/10.2139/ssrn.1596827

Amiti M, Davis DR (2012) Trade, firms, and wages: Theory and evidence. *Rev Econ Stud* 79: 1–36. http://doi.org/10.1093/restud/rdr016

Autor DH, Dorn D, Hanson GH (2013) The China Syndrome: Local Labor Market Effects of Import Competition in the United States. *Am Econ Rev* 103: 2121–2168. http://doi.org/ 10.1257/aer.103.6.2121

Bombardini M, Li B (2020) Trade, Pollution and Mortality in China. *J Int Econ* 125: 103321. http://doi.org/10.1016/j.jinteco.2020.103321

Bernard A, Jensen J, Lawrence RZ (1995) Exporters, jobs, and wages in U.S. manufacturing: 1976–1987. *Brookings Pap Econ Act Microecon* 12: 67–119. https://doi.org/10.2307/2534772

Bond EW, Trask K, Wang P (2003) Factor Accumulation and Trade: Dynamic Comparative Advantage with Endogenous Physical and Human Capital. *Int Econ Rev* 44: 1041–1060. http://doi.org/10.1111/1468-2354.t01-1-00099

Byaro M, Nkonoki J, Mayaya H (2021) The Contribution of Trade Openness to Health Outcomes in Sub-Saharan African Countries: A Dynamic Panel Analysis. *Res Glob* 3: 100067. http://doi.org/10.1016/j.resglo.2021.100067

Baldwin JR, Brown WM (2004) Regional manufacturing employment volatility in Canada: the effects of specialization and trade. *Pap Reg Sci* 83: 519–541. http://doi.org/ 10.2139/ssrn.1403262

Bartik TJ (1991) Who Benefits from State and Local Economic Development Policies. Kalamazoo, MI: W.E. Upjohn Institute for Employment Research, 1991. http://doi.org/10.2307/144206

Birdsall N, Wheeler D (1993) Trade policy and industrial pollution in Latin America: Where are the pollution havens? *J Environ Dev* 2: 137–149. http://doi.org/ 10.1177/107049659300200107

Cesur R, Tekin E, Ulker A (2013) Air Pollution and Infant Mortality: Evidence from the Expansion of Natural Gas Infrastructure. *Econ J* 127: 330–362. http://doi.org/10.1111/ecoj.12285

Chay KY, Greenstone M (2003) The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession. *Q J Econ* 118: 1121–1167. http://doi.org/10.1162/00335530360698513

Chang S., Yang X. Zheng H., et al. (2020) Air quality and health co-benefits of China's national emission trading system. *Appl Energy* 261: 114226. http://doi.org/10.1016/j.apenergy.2019.114226

Chen M, Wang H (2024) Does import trade liberalization worsen residents' health? Evidence from China. *Front Public Health* 12: 1470338. http://doi.org/10.3389/fpubh.2024.1470338

Cole MA, Rayner AJ, Bates JM (1998) Trade Liberalisation and the Environment: The case of the Uruguay Round. *World Econ* 21: 337–347. http://doi.org/10.1111/1467-9701.00133

Copeland BR, Scott TM (1994) North-South Trade and the Environment. *Q J Econ* 3: 755–787. http://doi.org/10.2307/2118421

Cropper ML (1981) Measuring the Benefits from Reduced Morbidity. *Am Econ Rev* 71: 235–240. http://doi.org/10.1016/0309-586X(81)90042-X

Davis DR, Harrigan J (2007) Good Jobs, Bad Jobs, and Trade Liberalization. *Int Econ* 84: 26–36. http://doi.org/10.1016/j.jinteco.2011.03.005

Dean JM, Lovely ME, Wang H (2009) Are Foreign Investors Attracted to Weak Environmental Regulations? Evaluating the Evidence from China. *J Dev Econ* 90: 1–13. http://doi.org/10.1016/j.jdeveco.2008.11.007

Deb P, Gallo WT, Ayyagari P, et al. (2011) The effect of job loss on overweight and drinking. *J Health Econ* 30: 317–327. http://doi.org/10.1016/j.jhealeco.2010.12.009

Ebenstein A (2012) The Consequences of Industrialization: Evidence from Water Pollution and Digestive Cancers in China. *Rev Econ Stat* 94: 186–201. https://doi.org/10.1162/REST_a_00150

Eliason M, Storrie D (2006) Lasting or Latent Scars? Swedish Evidence on the Long-Term Effects of Job Displacement. *J Labor Econ* 24: 831–856. http://doi.org/10.1086/506487

Ettner SL (1996) New evidence on the relationship between income and health. *J Health Econ* 15: 67–85. http://doi.org/10.1016/0167-6296(95)00032-1

Fan H, Lin F, Lin S (2020) The Hidden Cost of Trade Liberalization: Input Tariff Shocks and Worker Health in China. *J Int Econ* 126: 103349. http://doi.org/10.1016/j.jinteco.2020.103349

Feenstra R, Hong C (2010) China's Exports and Employment, In: Feenstra, R.C., Wei, S.J., eds., *China's Growing Role in World Trade*, NBER and University of Chicago Press, 167–199. http://doi.org/10.7208/9780226239729-007

Feng J, Xie Q, Zhang X (2021) Trade Liberalization and the Health of Working-age Adults: Evidence from China. *World Dev* 139: 105344. https://doi.org/10.1016/j.worlddev.2020.105344

Franzini L, Ribble J, Spears W (2001) The Effects of Income Inequality and Income Level on Mortality Vary by Population Size in Texas Counties. *J Health Soc Behav* 42: 373–387. http://doi.org/10.2307/3090185

Gerking S, Stanley LR (1986) An Economic Analysis of Air Pollution and Health: The Case of St. Louis. *Rev Econ Stat* 68: 115–121.

Ghojagh HM, Agheli L, Faraji Dizaji S, et al. (2021) Economic development and health status in Iran: A panel data analysis. *Environ Sustain Indic* 17: 100221. http://doi.org/10.1016/j.indic.2022.100221

Grossman M (1972) On the Concept of Health Capital and the Demand for Health. *J Polit Econ* 80: 223–255. http://doi.org/10.1086/259880

Gruszczynski L (2020) The COVID-19 pandemic and international trade: Temporary turbulence or paradigm shift? *Eur J Risk Regul* 11: 337–342. http://doi.org/ 10.1017/err.2020.29

Guerrico SF (2021) The Effects of Trade-induced Worker Displacement on Health and Mortality in Mexico. *J Health Econ* 80: 102538. https://doi.org/10.1016/j.jhealeco.2021.102538

Hawkes C (2006) Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Global Health* 2: 1–18. http://doi.org/10.1186/1744-8603-2-4

Helpman E, Itskhoki O, Redding S (2010) Inequality and Unemployment in a Global Economy. *Econometrica* 78: 1239–1283. http://doi.org/10.3982/ECTA8640

Herzer D (2017) The Long-run relationship between trade and population health: Evidence from five decades. *World Econ* 40: 462–487. http://doi.org/10.1111/twec.12419

Hiyoshi A, Honjo K, Platts LG, et al. (2023) Trends in health and health inequality during the Japanese economic stagnation: Implications for a healthy planet. *SSM-Popul Health* 22: 101356. http://doi.org/10.1016/j.ssmph.2023.101356

Hummels D, Munch J, Xiang C (2016) No Pain, no Gain: The Effects of Exports on Effort, Injury, and Illness. Working Paper NBER, NO.3024. http://doi.org/10.2139/ssrn.2810427

Humphrey J, Mcculloch N, Ota M (2004) The impact of European market changes on employment in the Kenyan horticulture sector. *J Int Dev* 16: 63–80. http://doi.org/ 10.1002/jid.1063

Jawadi F, El Gouddi S, Ftiti Z, et al. (2018) Assessing the effect of trade openness on health in the MENA region: A panel data analysis. *Open Econ Rev* 29: 469–479. http://doi.org/ 10.1007/s11079-017-9450-3

Jensen HT, Marcus R, Brown K, et al. (2019) International Trade, Dietary Change, and Cardiovascular Disease Health Outcomes: Import Tariff Reform Using an Integrated Macroeconomic, Environmental and Health Modelling Framework for Thailand. *SSM-Popul Health* 9: 100435. https://doi.org/10.1016/j.ssmph.2019.100435

Kiran S (2021) Occupational health could be the new normal challenge in the trade and health cycle: Keywords analysis between 1990 and 2020. *Saf Health Work* 12: 272–276. https://doi.org/10.1016/j.shaw.2020.11.003

Kovak BK (2013) Regional Effects of Trade Reform: What is the Correct Measure of Liberalization. *Am Econ Rev* 103: 1960–1976. http://doi.org/10.1257/aer.103.5.1960

Krueger AO, Lary HB, Monson T, et al. (1983) *Trade and Employment in Developing Countries, Volume 3 Synthesis and Conclusions*. University of Chicago Press.

Kuhn A, Lalive R, Zweimüller J (2009) The Public Health Costs of Job Loss. *J Health Econ* 28: 1099–1115. http://doi.org/10.1016/j.jhealeco.2009.09.004

Lang M, McManus TC, Schaur G (2018) The Effects of Import Competition on Health in the Local Economy. *J Health Econ* 1: 1–13. http://doi.org/10.2139/ssrn.2668394

Levin A, Raut LK (1997) Complementarities Between Export and Human Capital in Economic Growth: Evidence from the Semi-industrialized Countries. *Econ Dev Cult Change* 46: 155–174. http://doi.org/10.1111/j.1467-9388.1994.tb00177.x

Levine DI, Rothman D (2006) Does Trade Affect Child Health. *J Health Econ* 25: 538–554. http://doi.org/10.1016/j.jhealeco.2005.10.001

Li M, Du W, Wang Z, et al. (2023) Export globalization and pollution localization: Multivariate heterogeneous data based on Chinese enterprises. *Energy Rep* 9: 472–483. http://doi.org/10.1016/j.egyr.2022.11.203

Li R, Luo Y, Zhu X, et al. (2025) Increasing health burdens driven by global trade induced air pollution. *Earth's Future* 13: 1–21. https://doi.org/10.1029/2024ef004814

Liang S, Katerina S, Stylianou JO, et al. (2017) Consumption-based Human Health Impacts of Primary PM2.5: The Hidden Burden of International Trade. *J Clean Prod* 167:133–139. https://doi.org/10.1016/j.jclepro.2017.08.139

Lindahl M (2005) Estimating the Effect of Income on Health and Mortality Using Lottery Prizes as an Exogenous Source of Variation in Income. *J Hum Resour* 40: 144–168. http://doi.org/10.2307/4129568

Mcmanus TC, Schaur G (2016) The Effects of Import Competition on Worker Health. *International Economics* 102: 160–172. https://doi.org/10.1016/j.jinteco.2016.06.003

Mcmichael AJ, Spirtas R, Kupper LL (1974) An Epidemiologic Study of Mortality within a Cohort of Rubber Workers,1964-72. *Occupational Medicine Official Publication of the Industrial Medical Association* 16: 458–464.

Melén E (2021) Air pollution and IgE sensitization in 4 European birth cohorts—the MeDALL project. *Journal of Allergy and Clinical Immunology* 147: 713–722. http://doi.org/10.1016/j.jaci.2020.08.030

Milner C, Wright P (1998) Modelling labour market adjustment to trade liberalization in an industrializing economy. *Economic Journal* 108: 509–528. http://doi.org/10.1111/1468-0297.00301

Morris J (1996) International Trade and the Environment. *Econ Affa* 16: 4–7. https://doi.org/10.1111/j.1468-0270.1996.tb00561.x

Nguyen V (2015) The Impact of Trade Facilitation on Poverty and Inequality: Evidence from Low- and Middle-income Countries. *J Int Trade Econ Dev* 24: 315–340. http://doi.org/10.1080/09638199.2014.898315

Owen AL, Wu S (2007) Is Trade Good for Your Health. *Rev Int Econ* 15: 660–682. http://doi.org/10.1111/j.1467-9396.2007.00677.x

Ou J, Zheng Z, Zhang N (2023) A study of the effect of trade openness on population health: Empirical evidence from China. *Sustainability* 15: 12571. https://doi.org/10.3390/su151612571

Pangallo M, Aleta A, del Rio-Chanona RM, et al. (2024) The unequal effects of the health–economy trade-off during the COVID-19 pandemic. *Nat Hum Behav* 8: 264–275. https://doi.org/10.1038/s41562-023-01747-x

Papageorgiou C, Perez-Sebastian F (2006) Dynamic in a Non-scale R&D Growth Model with Human Capital: Explaining the Japanese and South Korean Development Experiences. *J Econ Dyn Control* 30: 901–930. http://doi.org/10.1016/j.jedc.2005.03.005

Pierce JR, Schott PK (2016) The Surprisingly Swift Decline of US Manufacturing Employment. *Am Econ Rev* 106: 1632–1662. http://doi.org/10.1257/aer.20131578

Qadir N, Majeed MT (2018) The Impact of Trade Liberalization on Health: Evidence from Pakistan. *Am Econ Rev* 1: 71–108. http://doi.org/10.29145/eer/11/010104

Rogers RG, Hummer RA, Nam CB (2000) *Living and Dying in the USA: Behavioral, Health and Social Differentials of Adult Mortality*. https://doi.org/10.1016/B978-0-12-593130-4.X5000-1

Sakyi D, Villaverde J, Maza A (2015) Trade Openness, Income Levels, and Economic Growth: The Case of Developing Countries, 1970–2009. *J Int Trade Econ Dev* 24: 860–882. http://doi.org/10.1080/09638199.2014.971422

Schank T, Schnabel C, Wagner J (2007) Do exporters really pay higher wages? First evidence from german linked employer-employee data. *J Int Econ* 72: 52–74. http://doi.org/10.1016/j.jinteco.2006.08.004

Sly PD (2021) Adverse Environmental Exposure and Respiratory Health in Children. *Pediatr Clin N Am* 68: 277–291. https://doi.org/10.1016/j.pcl.2020.09.018

Strutt A, Anderson K (1999) Estimating Environmental Effects of Trade Agreements with Global CGE Models: A GTAP Application to Indonesia. CIES Discussion Paper No. 99/26, Centre for International Economic Studies, University of Adelaide. http://doi.org/10.1787/9789264180659-EN

Stevens P, Urbach J, Wills G (2013) Healthy trade: the relationship between open trade and health. *Foreign Trade Rev* 48: 125–135. http://doi.org/10.1177/001573251204800106

Sullivan D, Wachter TV (2009) Job Displacement and Mortality: an Analysis Using Administrative Data. *Quarterly J Econ* 124: 1265–1306. http://doi.org/10.1162/qjec.2009.124.3.1265

Tanaka S (2015) Environmental Regulations on Air Pollution in China and Their Impact on Infant Mortality. *J Health Econ* 42: 90–103. http://doi.org/10.1016/j.jhealeco.2015.02.004

Troesken W (2003) Lead Water Pipes and Infant Mortality in Turn-of-The-Century Massachusetts. http://doi.org/10.3386/w9549

Wang Z, Zhang B, Zeng H (2016) The Effect of Environmental Regulation on External Trade: Empirical Evidences from Chinese Economy. *J Clean Prod* 114: 55–61. https://doi.org/10.1016/j.jclepro.2015.07.148

Were M (2015) Differential Effects of Trade on Economic Growth and Investment: A Cross-country Empirical Investigation. *J Afr Trade* 2: 71–85. http://doi.org/10.1016/j.joat.2015.08.002

Xu X (2000) International trade and environmental regulation: Time series evidence and cross section test. *Environ Resour Econ* 17: 233–257.

Yang T, Zhou K, Ding T (2022) Air pollution impacts on public health: Evidence from 110 cities in Yangtze River Economic Belt of China. *Sci Total Environ* 851: 158125. http://doi.org/10.1016/j.scitotenv.2022.158125

Yasmeen R, Li Y, Hafeez M (2019) Tracing the trade–pollution nexus in global value chains: evidence from air pollution indicators. *Environ Sci Pollut Res* 26: 5221–5233. http://doi.org/10.1007/s11356-018-3956-0

Zhao H, Wu R, Liu Y, et al. (2023) Air pollution health burden embodied in China's supply chains. *Environ Sci Ecotechnol* 16: 100264. https://doi.org/10.1016/j.ese.2023.100264