Was Entry into the WTO Worth it: Environmental Consequences of Trade Liberalization

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Abstract

Despite the enormous economic benefit from accession to the WTO, overall welfare of trade liberalization might be compromised since pollution from production also increased. Using plausibly exogeneous tariff reduction on Chinese goods caused by the WTO accession, variation in industry composition across cities, and variation in pollution intensity across industries, I study the effect of trade liberalization on income, pollution and health in China during the period of 2000 to 2005. Using regional tariff shocks as instruments for change in income and pollution level, I show that cities that faced 10% larger GDP per capita increase experienced 6%-7% larger total mortality decline, and regions that faced 10% larger air pollution increase experienced 4%-13% larger total mortality increase. Overall, if all exports were generated from non-polluting industries, total mortality rate would have decline by 3.6% more. However, in terms of overall welfare, the gains from income growth overweight losses from pollution increase.

Keywords: Trade liberalization, tariff reduction, pollution, health, welfare evaluation.
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1 Introduction

China's accession into the World Trade Organization (WTO) in 2001 was one of the biggest events in international trade during the last two decades. Looking

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back in 2011, China achieved great economic growth over the 10 years with annual growth rate of around 10%. In terms of GDP, China grew from the 6th largest economy in the world in 2001 to the 2nd largest in 2011; it became the 1st largest merchandise exporter, 2nd largest merchandise importer, 1st investor and 1st destination for Foreign Direct Investment (FDI) among the developing countries. The growth in exports, imports and overall GDP benefited the life of Chinese citizens. Both urban disposable income and rural income per capita tripled from 2001 to 2011: urban from 7,000 RMB to 22,000 RMB, and rural from 1,800 RMB to 7,000 RMB.[1] In a speech given at a forum in Beijing commemorating the 10th anniversary, Director-General Pascal Lamy commented: "WTO membership has served as a stabilizer and accelerator in China's economic take-off."[2]

However, economic prosperity came along with environmental costs. During the period of 2001-2011, CO2 emission grew from 2.7 to 6.7 metric tons per capita; [3] total volume of industrial waste gas emission (in 100 million cubic meters) from 138,145 to 674,509. [4] Waste gas emission caused severe ambient air pollution problem. According to the World Bank, mean annual exposure of PM 2.5 in China was 44.2 $\mu g/m^3$ in 2000, and rose to 54.1 $\mu g/m^3$ in 2011,[5] while the WHO recommended threshold for healthy environment is 10 $\mu g/m^3$. [6] Starting from 2012, haze weather in Beijing stimulated heated discussion about environmental situations in China. News reports featuring the gloomy weather and environmental regulation issues of China appeared in both Chinese and international media[7]. Early 2015, a documentary movie called *Under the Dome* also promoted discussions all over China about the cause, the results and the possible solutions to the urgent environmental problem.

WTO's primary goal is to promote trade negotiation between economies, reduce trade barriers and create a competitive and transparent international trade environment. Thus, the focus of tariff negotiation is mainly economic concerns, not environmental ones. However, in the case of China, which was already a very polluted country before the WTO accession by the WHO standard, the effect of trade liberalization on the environment can not be overlooked. If the tariff regime incentivizes the production of goods with large environmental and health costs in China, what is the true gains from trade in terms of consumer welfare once the costs are accounted for?

On the other hand, when evaluating the effect of environment on health, most discussion does not pay much attention to the role of economic or income growth. There has been observation that people in developing countries have

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[1] `https://www.wto.org/english/thewto_e/acc_e/s7lu_e.pdf`

[2] `https://www.wto.org/english/news_e/sppl_e/sppl211_e.htm`

[3] `http://data.worldbank.org/country/china?view=chart`

[4] *Chinese Environmental Statistics Yearbook*, 2012, Bureau of Statistics of China.

[5] `http://databank.worldbank.org/data/reports.aspx?source=2&series=EN.ATM.PM25.MC.M3&country=`

[6] `http://apps.who.int/iris/bitstream/10665/69477/1/WHO_SDE_PHE_OEH_06.02_eng.pdf`

[7] *The Economist*: "The East is grey", August 10, 2013. *The Wall Street Journal*: "Beijing Choking on Air Pollution", Feb 24, 2014.

relatively low marginal willingness to pay for environmental protection, and one of the reasons is that the marginal utility of income or consumption is high in such cases. (Greenstone and Jack [2015]) Also, in terms of health outcomes, it is not that people in developing countries do not suffer from pollution, but that the health effect of income can be bigger. Thus, it is very important to understand the cost of environmental protection in the context of low income countries, and estimate the effect of income and pollution on health jointly.

This paper aims at evaluating China's gains from the WTO accession taking into account both the income growth benefits and the pollution and health cost. By comparing cities with differential income and pollution changes, I will investigate how the costs and benefits are ultimately distributed across areas, and thus assessing the extent to which inequality in welfare changed as a result of trade liberalization. Although China experienced the trade liberalization as a whole, the income and environmental effects differed across cities depending on city's initial industrial composition. Cities grew differentially in terms of export based on which industries they specialized in, and which industries grew most due to the overall trade shock. For cities with similar overall export value growth, the one specializing in more polluting industries might suffer more from increased pollution.

However, there are several challenges when studying the environmental consequences of trade liberalization. The first challenge is that in developing countries like China, reliable environmental data is not available. In 2000, only 41 major Chinese cities (among total of 340 cities) had reports of air quality index on the website of Chinese Environment Protection Bureau; 85 cities in 2010, and only in 2014 the number increased to 289. In addition, it is an open secret that local Chinese government manipulates the reading of monitors for career concerns (see GhanemGhanem and Zhang [2014]). Thus, for the period that I am studying, 2000 as pre-WTO and 2005 as post-WTO, there is no good city-level air quality data available. As an alternative, I use the satellite data by NASA on aerosol optical depth to infer ground air pollution concentration level by city, which is a commonly accepted method in the literature. (Foster et al. [2009], Gutierrez [2010], Jia [2012])

The second challenge is that export growth of cities can be correlated with many other city characteristics, especially local government policy. For example, richer cities might both discourage the development of dirty industries, and invest more in public health system. Thus, the effect of increased export on health may be confounded by other non-trade-related factors. In order to solve this problem, I will use regional tariff shock to instrument for export growth. After China entered the WTO, other WTO countries had to offer most-favorable-nation (MFN) tariff to Chinese export goods, and this overall tariff cut is not likely to be correlated with local economic conditions and government policies.

Overall, I will use plausibly exogeneous tariff reduction caused by WTO accession, variation in industrial composition across cities and variation in pollution intensity across industries to measure income shock and pollution shock by city. In order to generate overall and pollution-related regional tariff shocks, I will use a simple specific-factor trade model to guide the empirical measure.

To address quality concerns on Chinese government-reported data, I will use satellite data to measure economic activity and pollution intensity by city. In the end, I will do a back-in-the-envelope calculation to have an overall welfare measures of trade liberalization by account for both the overall health effects and consumption effect.

This paper contributes to several strands of literature related to trade and health. First, there has been a huge literature about the effect of international trade on environment. Antweiler et al. [2001] decomposes the trade effect on pollution into scale, technique, and composition effects and then tests the theory using cross-country data on sulfur dioxide concentrations. Copeland and Taylor [2004] builds a unified framework of economic growth, international trade and environmental consequences. However, both theoretical and empirical work in this literature remain in cross-country analysis without overall welfare evaluation. Second, the paper is closely related to the literature on distributional effect of trade liberalization. Topalova [2010] studies the regional effect of trade liberalization in terms of poverty alleviation in India. Kovak [2013] is the first paper to construct a theoretically consistent regional trade shock measure, and studies the effect of trade liberalization on local wages. Autor et al. [2013] studies how the shock of Chinese exports affects local labor markets of the U.S. However, most papers in this literature focus solely on economic outcomes. In addition, my paper is closely related to Becker et al. [2005] about welfare measure with quantity and quality of life. Instead of cross country comparison, I will do the analysis on city level, eliminating more uncontrolled region heterogeneity, and also incorporate dynamics in the model. Finally, my research contributes to the literature studying the effect of pollution on health. Chay and Greenstone [2003] uses the economic downturn in the U.S. at the beginning of 1980s to get exogenous changes of pollution levels, and studies the effect of total particulate matters on infant mortality rate. Arceo et al. [2015] uses daily data of pollution and infant mortality in the Mexico City to provide evidence of health cost of pollution in a developing country context. Chen et al. [2013] uses the regression discontinuity generated by collective winter heating system in China to study the effect of sustained air pollution on life expectancy. In the literature, by omitting the income effect of industrial activities, the effect of pollution on health may not be corrected measured.

The paper will be organized as follows. Section 2 is a description of data and measurement and summary of statistics. Section 3 will introduce background information about China's WTO accession and provide preliminary evidence about the trade induced income, pollution and health effect. Section 4 presents a theoretical model to show how tariff cuts will translate into production increases, and how different industries and cities benefit. Section 5 will be main empirical estimations, while Section 6 includes additional discussions and various robustness checks. The last section concludes.

2 Data and Measurement

2.1 Data

2.1.1 Health data

The major health measure used in the paper is mortality rate. I use city-level population and number of death by age group from the 2000 China Population Census, and 2005 1% Population Survey. The 2000 Census covers the whole population in mainland China in 340 cities of 31 provinces, surveyed during the period of 1999.11.1-2000.10.31. The 2005 Survey was conduction using stratified multistage clustered probability sampling methods during the period of 2004.11.1-2005.10.31. The survey also covered all cities in mainland China, but the city-level data is not available for all provinces. I could only get city-level measures for 136 cities in 16 provinces. Infant mortality rate (mortality rate in age 0) is used in the robustness check instead of the main regression, since on the one hand side, I would like to conduct the welfare analysis on the whole population, and on the other hand, there are more reporting errors (under-reporting) for infant deaths than overall deaths in the census.

I also use the aggregate mortality rate by cause from Disease Surveillance Point (DSP) on city level in 1999-2000, to check for mortality trends before the WTO accession. The DSP system started in 1989 as a basic health monitoring system by the Chinese Center of Disease Control (CDC), with 145 surveillance points in 31 provinces, chosen by multi-stage cluster population probability sampling to form a representative national population sample. Each surveillance point monitors about 30 to 100 thousand population, and in total records 50 thousand death cases, 100 thousand birth cases and many contagious disease epidemic cases every year. For death cases, basic demographic information and cause of death in ICD-9 code is recorded. [8]

2.1.2 Trade and production data

The tariff information by 2-digit Harmonized System Code is from World Integrated Trade Solution (WITS). Weighted effectively applied import tariffs on 96 Chinese products are reported by the importing countries, from 2000 to 2010. In the next subsection I will talk in details about how I construct the tariff by product, industry and city.

Firm-level data in 2000 and 2005 is from the Database of Chinese Industrial Enterprises Survey (IES) collected by the National Bureau of Statistics of China. The database contains the information of all state-owned industrial enterprises and the privately-owned ones whose sales revenues are above 5 million RMB annually. The information includes the basic information (address, legal entity, capital ownership, industry code, etc.), financial information (total sales, export, assets, tax, etc.) and product information(primary product, secondary product,etc.). In this paper, the information used includes city code, industry

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[8] `http://www.phsciencedata.cn/Share/en/data.jsp?id=7253a104-63ac-40f7-a0ac-b04c1096ae52a&show=1`

code, total sales revenue, total export value, total cost of sales, total capital, fixed capital and wage paid. There are 162,883 firms in 2000 and 268,330 in 2005.

2.1.3 Pollution data by industry and by city

One important element in this paper is pollution intensity for each industry. First, I will use a simple rule to classify industries into two categories: polluting v.s. non-polluting industry. Second, there is national industry pollution intensity by pollutant type (soot, water, waste gas, SO_2) from the 2003 (which is the earliest available report on this measure) Chinese Environmental Yearbook.

Ambient air pollution level for each city is calculated from NASA's MODIS data set. "The MODIS Aerosol Product monitors the ambient aerosol optical thickness over the ocean globally and over a portion of continents."[9] Aerosols are tiny solid and liquid particles suspended in the atmosphere, and can either come from natural sources like windblown dust, sea salts and volcanic ash, or from human activities like smoke from fire and pollution from factories. In terms of ambient air pollutants, aerosol level is most closely related to particulates. Wang and Christopher [2003] shows that the correlation between aerosol optical thickness and $PM_{2.5}$ is 0.7 in Alabama, U.S. The data used in this paper is NASA MODIS Daily Level 2 data with a spatial resolution of 10 by 10 kilometers pixel.[10] Due to lack of credible measure of ambient air pollution level from ground monitoring stations in China, this satellite data has been used to proxy for air pollution in several papers (Jia [2012], Long et al. [2014]).

Figure 1 plots the distribution of AOT levels across 106 Chinese cities used later in the regression. Blue line is the distribution in 2000, and red one in 2005. We can see that distribution shifted to the right over the time period, indicating that air pollution measures in AOT level got worse, consistent with the World Bank report mentioned previously.

[Figure 1 about here.]

2.1.4 Other city level data

For city characteristics, variables including GDP, population, total employment, and population density are from City Statistics Yearbook of 2000 and 2005.

I also use night light intensity data from NASA [11] to proxy for economic activities following Henderson et al. [2012], to address quality concerns about government-reported GDP.

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[9] `http://modis-atmos.gsfc.nasa.gov/MOD04_L2/index.html`

[10] `http://neo.sci.gsfc.nasa.gov/view.php?datasetId=MODAL2_M_AER_OD&year=2000`

[11] `http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html`

2.2 Measurement

2.2.1 Mortality rate

The major outcome variable used is the standardized total mortality. The formula for calculating the age-standardized total mortality rate in city i is as follows:

$$MR_i^{std} = \sum_{g=1}^{G} MR_{gi} PS_g$$

where MR_{gi} is the mortality rate in age group g in county i and PS_g is the share of population in age group g in the whole country. This measure has been used in Hanlon and Tian [2015] and Hanlon [2015]. Chen et al. [2013] uses life expectancy, which is a similar measure. In order to have comparable mortality rates over time and eliminate the age structure variation, I use age structure in 2000 to standardize the mortality rates in 2005.

Infant mortality is the most common health measure in the environmental and health literature (Chay and Greenstone [2003], Almond and Currie [2011]), because infant's exposure to detrimental environmental conditions are relatively short and not confounded with factors that contribute to health conditions. However, the infant mortality in population census in China is relatively poorly measured, especially in rural areas. Thus, the effect of trade on infant mortality rate will be postponed to the robustness check part.

2.2.2 Tariff

The second important problem is how to construct weighted tariff by product, by industry and by city.

The tariff is reported by WITS, with 96 product categories, and by partner countries. For example, in 2000, China exported to 68 countries, and in 2005, the number of partner countries increased to 106. For each product, I generate the average tariff faced by Chinese exporters by weighting the tariff of each importing country by the share of export out of the total export value of the product.

For example, for aluminum, the total export value of China in 2005 is 100 units, and Country A imports 40 units and Country B imports 60 units. The import tariff of Country A of aluminum from China is 2.3 (%) and that of Country B is 1.3 (%). Then the tariff faced by Chinese aluminum exporters is 2.3*40%+1.3*60%.

However, the import value and import tariff are not independent. For example, it is very likely that countries that imports a lot will impose lower import tariff. Because later I will argue that reduced tariff will induce higher export volumes on the supply side without affecting the demand side, this correlation is troublesome. Thus I will use the trade volumes in the baseline year (2000) as weights. Using the same example, if out of the 100 units, if Country A imports

40 units and Country B 60 units in 2005, and 20 and 80 units in 2000, I will calculate the tariff in 2005 as 2.3*20%+1.3*80% instead of 2.3*40%+1.3*60%.

After constructing the weighted average of tariff faced by Chinese exporters by product category, I construct the weighted average of tariff by industry. The problem here is that trade product category is classified using 2-digit HS code, focusing on product characteristics mainly, while industry classification is done using 4-digit U.S. Standardized Industrial Classification (SIC) code, which takes into account the production procedure. I use the data and code provided in Pierce and Schott [2009] to match HS code with SIC code. The second problem is that the Chinese Industrial Enterprise Survey uses a Chinese version of SIC code, which is slightly different from the U.S. SIC code. Thus I will do a manual matching between the two sets of industry code. Details about the matching is shown in Appendix A. After doing the matching between product and industry classification, I construct the tariff faced by an industry in the following way: Suppose that Industry 1 has 3 HS categories, then the tariff faced by Industry 1 is the mean of the tariffs in the 3 HS categories.

After constructing the weighted average of tariff faced by Chinese exporters by product category, I construct the weighted average of tariff by city. Tariff cuts can have two effects on the production: price effect and cost effect. On the one hand side, since the tariff faced by exports are reduced, the effective price of the good increases. In other words, in order to sell products to other countries at the same price as before, now Chinese exporters can charge higher prices and pay less tariff. On the other hand, without perfect factor mobility across regions, and in the short-run, if we assume that the total amount of production factors are constant in a region, then the price increase of goods will lead to higher prices of input factors. In order to highlight these channels, in Section 4 I will use a specific-factor model to show how to construct the regional tariff shocks properly.

2.2.3 Division of polluting v.s. non-polluting industries

Following Hanlon and Tian [2015], I classify the industries into polluting and non-polluting ones. This classification is according to an official document of Chinese government. In the document issued by Chinese Environment Protection Bureau ([2003] No.10) named *About Inspection of Environmental Qualification of Companies that are Applying for Listing and Refinancing*, the heavy-polluting industries are: metallurgical, chemical, petrochemical, coal, thermal power, building materials, paper, brewing, pharmaceutical, fermentation, textile, leather and mining.

2.2.4 National level industry pollution density

Using industry level pollutant emission and industrial output (values from IES), I calculated pollution intensity of each industry, in terms of waste gas, SO_2, soot and water emission per dollar of output. We can see in Table 1, most of industries ranking high on the pollution intensity list are also defined as polluting industry in my classification. Electric, gas and sanitary services ranks the top in the pollution intensity list, but it is not a exporting industry. I will use both the division of polluting v.s. non-polluting industry and the industry pollution intensity measures in the empirical part.

[Table 1 about here.]

3 Background

The World Trade Organization (WTO) is an international organization that promotes and runs trade negotiations between countries, intending to create a competitive, transparent and predictable international trade environment. The WTO was created in January 1, 1995, in the Uruguay Round negotiations, following its predecessor, General Agreement on Tariffs and Trade (GATT). GATT was originally signed by 23 nations in Geneva on October 30, 1947, and the WTO has 161 member countries on 26 April 2015.

China was among the 23 original signatories of the GATT in 1948, but was out of the agreement after 1949 due to domestic political and economical situations. China notified the GATT in 1986 of its wish of resuming its status as a GATT contracting party, and started to work on a series of economic reforms to transform the economy into a more market-oriented one. On November 10, 2001, China's accession was approved in the 4th Ministerial Conference in Doha, and China became the 143rd member of the WTO.

Upon accession, China committed to undertake a series of important commitments to open and liberalize its regime to better integrate into the word economy, providing a more predictable environment for trade and foreign investment according to the WTO rules. Specifically, China would eliminate dual pricing practices, differences in treatment on goods produced for sale in China and the goods for exports; reduce price controls intended to protect domestic producers; eliminate import quota and bound import tariffs; not maintain or introduce any export subsidies on agricultural products.

At the same time, China would have Most-Favorable-Nation (MFN) status with all other member countries, which meant that there would be upper bounds on the import tariff that other countries imposed on Chinese goods, and those tariffs should be equalized among all MFN countries. Also, other WTO member countries needed to gradually phase out import quota on Chinese goods. During the phase-in period of WTO entry of 2001 to 2005, the average tariff faced by Chinese exporters decreased from 4.9% in 2000 to 4.1% in 2005, with annual decrease rate of 0.15 percentage point. In response, China experienced substantial export growth from 0.25 billion dollars in 2000 to 0.75 billion dollars in 2005. (Figure 2).

[Figure 2 about here.]

Export growth and tariff cuts vary across industries and products. As shown in Figure 2, on average, import tariff was higher in non-polluting industries than in polluting industries, and export value level is also higher for non-polluting industry than for polluting ones. In terms of percentage changes, if we take a look at distribution of log tariffs, we can see that actually the distribution of log tariff on polluting goods shifts further to the left than the one for non-polluting goods. (Figure 3). When interacting the tariff reductions with city initial industrial compositions, cities would experience differential sizes of regional tariff shock, both in the polluting and the non-polluting industries.

[Figure 3 about here.]

Making use of differential regional tariff shocks and industry pollution intensity, I will try to disentangle the income effect and pollution effect of trade liberalization, and see how the welfare gains of trade distribute across cities. In order to highlight the intuition of the empirical work, let's take a look at two pairs of cities in China. In Figure 4, in City Pair I, *Ganzhou* and *Huainan* experienced similar GDP growth, while pollution in *Ganzhou* increased much more. As a result, *Huainan* was able to decrease mortality rate more. If we take a closer look at the industrial composition, we can see that *Ganzhou* experience much higher growth in polluting industries than in non-polluting industries, while *Huainan* had the opposite trends. For the second pair of cities, *Bengbu* and *Chuzhou*, the cities had similar industrial growths of polluting and non-polluting industries, and similar pollution decreases, while *Bengbu* grew more in terms of GDP. As a result, *Bengbu* experienced higher decrease in mortality rate.

[Figure 4 about here.]

These two examples highlights the importance of working with both the income and the pollution effect it comes to the discussion of trade liberalization effect on health, and how industrial composition maps to differential income and pollution growth. Combined with exogeneous shock of tariff reduction after WTO accession, I will try to identify the environmental and health consequences of trade liberalization.

4 Theoretical model

4.1 Motivating theoretical trade model

When import tariff (which is a sales tax) on Chinese goods decreases, for the same price that consumers pay, Chinese exporter will receive higher prices. Increase in price of goods will affect the allocation of production factors across industries within a city, thus affect industry output levels. To formalize the idea, I will use a specific-factor model as in Jones [1975], Kovak [2013] and Hanlon and Miscio [2016].

The economy is a Ricardo-Viner economy with r regions. All regions have the same technology in production; the only different between regions is endowment of factors. In each region, there are N industries, each producing a homogeneous good. The production of each industry i requires a common input, capital, and a industry specific factor. K is the endowment of capital and T_i is the endowment of industry-i specific factor. Due to the specific factor here, the model allows for a spatial distribution of production in different industries, even with perfect competition.

First, from the industry-specific cost minimization problem, we can get a_{K_i} and a_{T_i}, the capital and industry specific factor needed for production of one unit of output. Both of them are functions of factor prices. Suppose that Y_i is the output in industry i, then by factor market clearing condition, we have

$$a_{T_i} Y_i = T_i \quad \forall i \tag{1}$$

$$\sum_i a_{K_i} Y_i = K \tag{2}$$

Under perfect competition, profit is zero. Let P_i be price of good i, r be interest rate for capital, and R_i be price of industry-i specific factor, then we have

$$a_{T_i} R_i + a_{K_i} r = P_i \quad \forall i \tag{3}$$

Log-linearizing (3) , and let hat variables represent proportional changes, we will have

$$(1-\theta_i)\hat{r} + \theta_i \hat{R}_i + (1-\theta_i)\hat{a}_{K_i} + \theta_i \hat{a}_{T_i} = \hat{P}_i \tag{4}$$

where $\theta_i = \frac{a_{T_i} R_i}{a_{t_i} R_i + a_{K_i} r}$ as the cost share of the specific factor in industry i.

Cost minimization implies that a_{T_i} and a_{K_i} will adjust such that small changes of factor prices will not affect cost. Using this envelop condition, we have

$$(1-\theta_i)\hat{a}_{K_i} + \theta_i \hat{a}_{T_i} = 0 \tag{5}$$

and thus

$$(1-\theta_i)\hat{r} + \theta_i \hat{R}_i = \hat{P}_i \quad \forall i \tag{6}$$

Suppose that T_i is fixed in all industries, and K might change. Log-linearizing (1) will give us

$$\hat{Y}_i = -\hat{a}_{T_i} \quad \forall i \tag{7}$$

Log-linearizing (2) and substituting (7) into it will result in

$$\sum_i \lambda_i (\hat{a}_{K_i} - \hat{a}_{T_i}) = \hat{K} \tag{8}$$

where $\lambda_i = \frac{K_i}{K}$ is the fraction of region capital used in industry i. Let σ_i be the elasticity of substitution between T_i and K_i in production,

$$\sigma_i = \frac{dln(a_{T_i}/a_{K_i})}{dln(r/R_i)} \tag{9}$$

we have

$$\hat{a}_{T_i} - \hat{a}_{K_i} = \sigma_i(\hat{r} - \hat{R}_i) \quad \forall i \tag{10}$$

Substituting (10) into (8), we will have

$$\sum_i \lambda_i \sigma_i (\hat{R}_i - \hat{r}) = \hat{K} \tag{11}$$

Solving the system of equations of (6) and (11) with $N+1$ equations of $N+1$ unknowns ($\hat{R}_i$ and $\hat{r}$), taking $\hat{P}_i$ and $\hat{K}$ as given, we will have

$$\hat{r} = \frac{-\hat{K}}{\sum_{i'} \lambda_{i'} \sigma_{i'}/\theta_{i'}} + \sum_i \beta_i \hat{P}_i \tag{12}$$

where

$$\beta_i = \frac{\lambda_i \sigma_i/\theta_i}{\sum_{i'} \lambda_{i'} \sigma_{i'}/\theta_{i'}} \tag{13}$$

and

$$\hat{R}_i = \frac{\hat{P}_i - (1-\theta_i)\hat{r}}{\theta_i} \tag{14}$$

Moreover, we can solve for the output level in industry i using (7) (5) and (10).

$$\hat{Y}_i = \frac{1-\theta_i}{\theta_i} \sigma_i (\hat{P}_i - \hat{r}) \tag{15}$$

$$\begin{aligned}
\widehat{GDP}/Export\widehat{V}alue &= (\widehat{\sum_i P_i Y_i}) \\
&= \sum_i \frac{P_i Y_i}{\sum_{i'} P_{i'} Y_{i'}} (\hat{P}_i + \hat{Y}_i) \\
&= \sum_i \frac{P_i Y_i}{\sum_{i'} P_{i'} Y_{i'}} (\frac{1-\theta_i}{\theta_i}\sigma_i + 1)\hat{P}_i - \hat{r} \sum_i \frac{P_i Y_i}{\sum_{i'} P_{i'} Y_{i'}} \frac{1-\theta_i}{\theta_i}\sigma_i \\
&= Price^t - Cost^t \qquad (16)
\end{aligned}$$

where

$$Price^t = \sum_i \frac{P_i Y_i}{\sum_{i'} P_{i'} Y_{i'}} (\frac{1-\theta_i}{\theta_i}\sigma_i + 1)\hat{P}_i$$

$$Cost^t = \hat{r} \sum_i \frac{P_i Y_i}{\sum_{i'} P_{i'} Y_{i'}} \frac{1-\theta_i}{\theta_i}\sigma_i$$

$Price^t$ represents the direct effect of price changes: industries that experience bigger price increase will increase more in production, and regional price shock is a weighted average of industry shocks. $Cost^t$ represents the indirect effect of price changes: with all industries wanting to produce more, price of capital will increase.

In the empirical regression, I will construct both price and cost using industry information and tariff changes. For simplicity, I will assume Cobb-Douglas production function, where σ_i is equal to 1. θ_i is cost share of the specific factor, and is measured using share of wage bill out of total cost from the IES firm data. K_i is measured using total capital in the industry. $P_i Y_i$ is total sales revenue in industry i. Most importantly, $\hat{P}_i$ will be measured as $-\Delta \ln(1 + tariff_i/100)$.[12]

Also, Equation 17 generates a testable hypothesis: if I regress total export value on price and cost, the coefficients should be 1 on price and -1 on cost. Later in the empirical part, I will test this hypothesis.

4.1.1 Constant pollution intensity across industries, and constant pollution intensity over time.

Suppose that among the industries $1, ..., N$, the first k industries are more capital intensive, and generates a unit of pollution for each dollar of output. Also, pollution intensity of industries do not change over time.

$$Plln_i = aP_iY_i$$

Then the total volume of pollution in region r is

$$\begin{aligned}
\widehat{Plln} &= a\sum_{i=1}^{k} \frac{P_iY_i}{\sum_{i'=1}^{k} P_{i'}Y_{i'}}(\hat{P}_i + \hat{Y}_i) \\
&= a\sum_{i=1}^{k} \frac{P_iY_i}{\sum_{i'=1}^{k} P_{i'}Y_{i'}}(\frac{1-\theta_i}{\theta_i}\sigma_i + 1)\hat{P}_i - a\hat{r}\sum_{i=1}^{k} \frac{P_iY_i}{\sum_{i'=1}^{k} P_{i'}Y_{i'}}\frac{1-\theta_i}{\theta_i}\sigma_i \\
&= aPrice^{p,I} - aCost^{p,I} \qquad (17)
\end{aligned}$$

Similar as in the export value part, I will have a price factor ($Price^{p,I}$, first block) and a cost factor ($Cost^{p,I}$, second block), with equal coefficients (but opposite signs). I use superscript I to indicate that I use an indicator variable to define pollution v.s. non-polluting industries.

4.1.2 Different pollution intensity across industries, and constant pollution intensity over time.

Suppose that Industry i generates a_i unit of pollution for each dollar of output. Then

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[12] Let the price paid by consumer be P_i^c, and price charge by exporters be P_i. Then $P_i = P_i^c/(1 + tariff_i/100)$, and $\hat{P}_i = \hat{P}_i^c - \Delta \ln(1 + tariff_i/100)$. Suppose that price paid by consumer does not change, then we get $\hat{P}_i = -\Delta \ln(1 + tariff_i/100)$.

$$Plln_i = a_i P_i Y_i$$

Then the total volume of pollution in region r is

$$\begin{aligned}
\widehat{Plln} &= \sum_{i=1}^{n} \frac{a_i P_i Y_i}{\sum_{i'=1}^{n} a_{i'} P_{i'} Y_{i'}} (\hat{P}_i + \hat{Y}_i) \\
&= \sum_{i=1}^{n} \frac{a_i P_i Y_i}{\sum_{i'=1}^{n} a_{i'} P_{i'} Y_{i'}} (\frac{1-\theta_i}{\theta_i}\sigma_i + 1)\hat{P}_i - \hat{r} \sum_{i=1}^{n} \frac{a_i P_i Y_i}{\sum_{i'=1}^{n} a_{i'} P_{i'} Y_{i'}} \frac{1-\theta_i}{\theta_i}\sigma_i \\
&= Price^{p,A} - Cost^{p,A} \qquad (18)
\end{aligned}$$

In this specification, a_i is the pollution intensity of industry i. In the empirical part, it will be measured using pollutant emission/output form national level data. I use superscript A to indicate that this is an alternative measure, and a_i can represent the pollution intensity in terms of SO_2 or soot. I will use both the polluting-non-polluting division method and the pollution intensity method in the main regression.

5 Empirical model

5.1 Model setup

First, to study the effect of trade liberalization on city air pollution, I would like to run the following regression:

$$\triangle \ln(AOT)_c = \alpha_0 + \alpha_1 \triangle \ln(export^p)_c + \Gamma X_c + \epsilon_c$$

where $\triangle \ln(AOT)_c$ is proportional change of aerosol optical thickness in city c from 2000 to 2005, and $\triangle \ln(export^p)_c$ is the proportional change of export in polluting industries. X_c is a vector of other city characteristics including proportional change of population density and baseline air pollution level. However, if cities that grow a lot in polluting industries are also the ones that have substantial increase in vehicle use, then the effect of export on air pollution will be overestimated. To solve the potential omitted variable bias problem, I will use the price factor and cost factor generated by exogeneous tariff reductions to instrument for $\Delta \ln export^p$.

Similarly, to study the effect of trade liberalization on city income level, I will run the following regression:

$$\triangle \ln(GDP)_c = \beta_0 + \beta_1 \triangle \ln(export^t)_c + \Gamma X_c + \epsilon_c$$

where $\triangle \ln(GDP)_c$ is the change of log GDP in city c, and $\triangle \ln(export^t)_c$ is the change in log export in all industries. However, if cities that grow a lot in exports are also the ones that grow a lot in non-export goods, then the effect of export on city income level will be overestimated. Thus, I will use regional tariff changes to instrument for total export growth.

Finally, I would like to see how the pollution effect and income effect show up in people's health. The main regression is

$$\triangle \ln MR_c = \gamma_0 + \gamma_1 \triangle \ln(GDP)_c + \gamma_2 \triangle \ln(AOT)_c + \Gamma X_c + \epsilon_c$$

where $\triangle \ln MR_c$ is change in total mortality rate in city c. There can be extra confounding factors include government investment in medical system. If places with higher economic growth also invest more in health system, and discourage growth of polluting industries, then estimates of γ_1 and γ_2 will be biased. Regional tariff changes will help to disentangle the income and pollution effect after trade liberalization.

5.2 Pre-trend of mortality rate

One threat to identification in the main regression on mortality rate is whether pre-trend of mortality rate by city is correlated with tariff changes in later periods. In other words, if the cities that experienced higher regional tariff shock (either price factor or cost factor) had had a declining (or increasing) trend of mortality rate even before the WTO accession, then we cannot take tariff shocks as exogeneous.

In order to check pre-trend of mortality rate, I will use the mortality information from the DSP system. The regression is as follows:

$$MR_{2000,c} = \alpha_0 + \alpha_1 Price_c^p + \alpha_2 Cost_c^p + \alpha_3 Price_c^t + \alpha_4 Cost_c^t + \alpha_5 MR_{t,c} + \epsilon_c$$

where $MR_{2000,c}$ is the total mortality rate in city c and year 2000, $MR_{t,c}$ is the total mortality rate in city c and baseline year t, where t can be any year between 1991 and 1999. $Price_c^t, Cost_c^t, Price_c^p, Cost_c^p$, are regional tariff shocks that affect the price and cost of production in city c that happened between 2000 and 2005. If there is pre-trend of mortality rate (before 2000) that correlates with the tariff shocks in the later period (after 2000), then we would expect some of α_1 to α_4 to be significant. Thus, After running the regression, I will test the joint hypothesis:

$$H_0 : \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$$

If I fail to reject the joint hypothesis, then I will conclude that there is no evidence of existence of pre-trend.

[Table 2 about here.]

As shown in Table 2, no matter which baseline year I use, there is no evidence that regional tariff shocks after 2000 are correlated with change of mortality rate before 2000 (F statistics for joint test range from 0.3 to 0.9). In terms of baseline year mortality rate, we can see that indeed mortality rates in years closer to 2000 predicts mortality rate in 2000 better ($\hat{\alpha}_5$ is 0.4 in early years and 0.8 in later years). To conclude, I find that tariff shocks are exogeneous to local health condition trends.

5.3 Main specification

5.3.1 Export and GDP, first stage, reduced form.

First I will check the relationship between regional tariff shocks, production and income. The regression is

$$\Delta Y_c = \beta_0 + \beta_1 Price_c + \beta_2 Cost_c + \Gamma X_c + \epsilon_c$$

where Y_c is log of per capita GDP or log of total export values in city c, and $Price_c$ is price factor $Price_c^t$ and $Cost_c$ is cost factor $Cost_c^t$. When Y_c is log of export values in polluting industries, then $Price_c = Price_c^{p,I}$ and $Cost_c = Cost_c^{p,I}$. I also control for other factors like proportional change in population density and proportional change in export share of total sales revenue.

The model also generates testable hypothesis that $\beta_1 = -\beta_2 = 1$. The regression results are as in Table 3. We indeed see positive price effect and negative cost effect, and joint test failed to reject the null hypothesis. In the GDP regression, both price and cost factors have significant effects, while in the export regressions, we can only observe significant cost effect.

[Table 3 about here.]

5.3.2 Export and pollution, first stage, reduced form.

From the theoretical model, we have the relationship between city air pollution level and regional tariff shocks as follows:

$$\Delta \ln(AOT)_c = \beta_0 + \beta_1 Price_c^p + \beta_2 Cost_c^p + \Gamma X_c + \epsilon_c$$

Also, depending on my assumption of industrial pollution intensity, I have 4 specifications in Table 4: Column (1) and Column (2) with $Price^{p,I}$ and $Cost^{p,I}$, Column (3) and Column (4) with $Price^{p,A}$ and $Cost^{p,A}$. Column (3) uses SO_2 emission intensity as measure of a_i and Column (4) use soot intensity. Column (1) has no additional controls while the later three columns have proportional change in population density and initial air pollution levels.

In Table 4, we can see that in all specification where we have extra controls (Column (2)-(4)), we have significantly positive price effect, and not significant cost effect. In the joint test of $H_o : \beta_1 = -\beta_2$, 2 out of 4 specifications fail to reject the null hypothesis.

[Table 4 about here.]

5.3.3 Mortality regression: OLS and 2SLS

Finally, I will combine the income regression and pollution regression to see how trade liberalization affect people's health.

$$\triangle \ln MR_c = \gamma_0 + \gamma_1 \triangle \ln(GDP)_c + \gamma_2 \triangle \ln(AOT)_c + \Gamma X_c + \epsilon_c$$

Due to possible endogeneity concerns discussion previously, I will use regional tariff shocks to instrument for change in GDP and change in pollution level. In Table 5, Column (1) is OLS regression with change in GDP and change in AOT only, with no other controls, and Column (2) adds controls like proportional change in population density, proportional change in export share of output, proportional change in employment, and baseline GDP and AOT levels. In Column (3) to (5), I instrument change in GDP and change in AOT as shown in the previous first-stage analysis, with different specifications. From the OLS regression with controls, regions that faced 10 percent larger GDP per capita increase will experience 2.5 percent larger mortality decline, and 10 percent large air pollution increase will lead to 2.9 percentage larger mortality increase. In the 2SLS regressions, the effect of GDP ranges from 0.55 to 0.65, and the effect of air pollution ranges from 0.43 to 1.34. Overall, in the 2SLS, both the beneficial effect of GDP and the harmful effect of air pollution become larger. At the sample mean of $\triangle \ln(GDP_{pc})$ (0.6) and the mean of $\Delta(AOT)$ (0.12), in the absence of GDP growth, $ln(MR)$ will increase by 0.4, and in the absence of air pollution increase, $ln(MR)$ will decrease by 0.14. Both factors are important determinants of total mortality rate and should be accounted for when analyzing the health consequences of trade liberalization.

[Table 5 about here.]

6 Discussion and robustness checks

6.1 Discussion of government's role

One concern about identification using tariff shock is the potential role of government. If local governments use different policy instruments to either offset or reinforce the regional tariff shocks, then the effect that we identify is trade shock confounded with policy reactions. Possible policies that local governments use to promote exports include providing value-added tax rebate, low interest rate loans, and low cost land to exporting firms. Although it would be good to test all possible policy effects, due to data constraint, I will only check if value-added tax rebate is correlated with tariff shocks.

Value-added tax (VAT) rebate is allowed by the WTO rule to avoid tax multiplicity. In China, VAT rebate is part of the export related fiscal policies ever since the 1985. Since 1994, VAT has been set to 17% for most manufacturing goods, and official rebate rate was set to be either full rebate (17%) or partial rebate (5%, 13% 15%) for export goods. However, the real rebate rates vary a lot by region and firm's ability to claim the rebate, especially after the 2004 reform when the central government stopped to be the only payer for the rebate, and started to have 25% payment by local government and 75% by central government conditional on local payment.[13]

Using real VAT rebate rate calculated from firm-level data, Chandra and Long [2013] shows that each percentage point increase in the VAT rebate rate will lead to increase of the export amount by 13%. The formula to calculate the firm-level rebate rate is as follows:

$$RebateRate_{VAT} = (0.17 * revenue - VAT_{throughput} - VAT_{payable})/export$$

The downside of this approach is the firm level VAT information can have much noise due to reporting errors or lag of payment for rebates. Thus, I calculate the real rebate by firm, and take means by industry-city to construct averages in 2000 and 2005. Also, I drop top and bottom 1% firm level rebate rates, and either top and bottom 1% or 5% city-industry level rebate rates. From Equation (15), the relationship between industry output and prices is

$$\hat{Y}_i = \frac{1-\theta_i}{\theta_i}\sigma_i(\hat{P}_i - \hat{r}) = \frac{1-\theta_i}{\theta_i}\sigma_i\hat{P}_i - \frac{1-\theta_i}{\theta_i}\sigma_i\hat{r}$$

where $\hat{P}_i$ can be decomposed into $-\Delta\ln(1+tariff_i/100)$ and $-\Delta\ln(1+17\%-rebate_i)$, where the first refers to the tariff reduction and second refers to the tax rebate. Thus, I will have

$$\hat{Y}_i = -\frac{1-\theta_i}{\theta_i}\sigma_i\Delta\ln(1+tariff_i/100) - \frac{1-\theta_i}{\theta_i}\sigma_i\Delta\ln(117\%-rebate_i) - \frac{1-\theta_i}{\theta_i}\sigma_i\hat{r}$$

I call the first $Price_i$, second $Rebate_i$ and the third $Cost_i$. Stacking all cities and industries together, I run the following regression:

$$\Delta\ln(export)_{ic} = \theta_0 + \theta_1 Price_{ic} + \theta_2 Cost_{ic} + \theta_3 Rebate_{ic} + \Gamma X_{ic} + \epsilon_{ic}$$

where i represent industry and c represents city. I will assume that $\theta_3 = 0$ first, and then add $Rebate_{ic}$ into the regression. If the estimates for $\theta_1$and θ_2 do not change a lot after adding $Rebate_{ic}$, and I fail to reject $H_o : \theta_3 = 0$, then I will conclude that there is no evidence that local government VAT rebate is correlated with regional tariff shocks.

The regression results are shown in Table 6. In first three columns, I drop the city-industries pairs that falls in top or bottom 1% in terms of rebate rates. Column (1) controls for *Price*, *Cost* and indicator variable for whether the industry is polluting industry or not. Column (2) controls for *Rebate*, and Column (3) adds interaction of *Rebate* and polluting industry dummy.We can see that the coefficients for *Price* and *Cost* do not change much over specifications, and coefficient for *Rebate* is not significant. Column (4)-(6) are the same as Column (1)-(3) except that I drop the top and bottom 5%, and the results are similar.

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[13] For details about VAT rebate system and the 2004 reform in China, see Chandra and Long [2013].

Overall, I find no evidence that local governments are trying to reinforce or offset the regional tariff shocks using export VAT rebate. It might be true that they are trying to promote export growth using different kinds of policies, but as long as these policies are not correlated with tariff shocks, the identification strategy still works.

[Table 6 about here.]

6.2 Robustness check

6.2.1 Infant mortality

One concern for using total mortality is that adult mortality is life-time accumulated effects, and infant mortality would be a cleaner measure since infants have limited time exposure to outside factors. However, due to possible reporting errors in census data for infants, I only use infant mortality as one robustness check.

As shown in Table 7, when using change in log of infant mortality as outcome, the beneficial effect of income is not significant and has mixed signs across specification. There is still some evidence about harmful effect of pollution, and the magnitude is much larger than in the total mortality regression. This confirms that infants are more sensitive to air pollution. On the income side, one hypothesis is that the infant mortality that is affected on the margin by income growth might be for the low-income group only (who cannot afford to deliver babies in hospitals for example), while for the higher-income group, the infant mortality rate is already quite low and is not sensitive to income growth. However, without detailed individual-level data, I am not able to test this hypothesis.

[Table 7 about here.]

6.3 Adjust calculation of return to capital

From Equation (12), to calculate the return to capital $\hat{r}$ (which is an input in the calculation of $Cost^t$ and $Cost^p$), I need information of $\hat{K}$ and $\lambda_i = K_i/K$ since

$$\hat{r} = \frac{-\hat{K}}{\sum_{i'} \lambda_{i'}\sigma_{i'}/\theta_{i'}} + \sum_i \beta_i \hat{P}_i$$

where

$$\beta_i = \frac{\lambda_i \sigma_i/\theta_i}{\sum_{i'} \lambda_{i'}\sigma_{i'}/\theta_{i'}}$$

In the main regression (Table 5), I choose $\hat{K} = 0$ and capital (K_i) as total capital in industry i reported by firms. In order to check the robustness of previous results, I will try with different sets of assumptions about capital mobility and definition of capital.

In Table 8, Column (1) is OLS regression as in Column (2), Table 5. Column (2) uses $\hat{K} = K_{2005} - K_{2000}$, and K is total capital in a certain city. Column (3)-(5) maintains the assumption of $\hat{K} = 0$, but changes the definition of capital. Column (3) uses $K_i^{new} = export_i/sales_i * K_i$, adjusting for export intensity of the industry. Column (4) uses fixed capital instead of total capital. Column (5) uses $K_i^{new} = export_i/sales_i * K_i^{fixed}$. In all 2SLS results, for simplicity I use the same instruments as in Column (5), Table 5, where the pollutant intensity is by soot emission rates.

The results are quite robust across different specifications, thus there is no evidence that the choice of parameters in calculation of return to capital is driving the results.

[Table 8 about here.]

6.4 Night light intensity instead of GDP

Another concern that might affect the result is that GDP data might subject to errors in reporting and manipulation by the local government. Night light intensity has been proven to provide an alternative measure of economic activity intensity, and the data quality is not subject to political conditions. Thus, in Table 9, I replace GDP per capita with night light intensity, and the effect of air pollution still remains.

[Table 9 about here.]

6.5 Non-polluting as placebo

I also conduct a placebo test by replace $Price^{p,I}$ and $Cost^{p,I}$ with $Price^{np}$ and $Cost^{np}$[14], and use them in both the first-stage for trade shock and air pollution, and the final mortality regression.

In Table 10, the first two columns are the same as in Table 4, while in Column (3) and (4), I use $Price^{np}$ and $Cost^{np}$ instead of $Price^{p}$ and $Cost^{p}$. We can see that regional tariff shocks in polluting and non-polluting industries have exactly the opposite effects on change in pollution level. This results reiterate the intuition of the model: production factors are allocation among polluting and non-polluting industries, and good shock in one sector is an indirect bad shock to the other sector.

In Table 11, Column (1) and (2) are OLS regression as in Table 5, Column (3) is the 2SLS regression when pollution change is instrumented with polluting industry shocks, and Column (4) is the 2SLS regression when instrumented with non-polluting industry shock. Coefficient estimates are very close to each other in Column (3) and (4), and both first-stage in Table 10 and 2SLS in Table 11 confirm that the model intuition carries through in the empirical regressions.

[Table 10 about here.]

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[14] $Price^{np}$ and $Cost^{np}$ can be calculated using the two blocks in Equation (17), by replace the index of $i = 1, ..., k$ with $i = k + 1, ..., n$.

[Table 11 about here.]

6.6 Back-in-the-envelope calculation

I the analysis before, pollution is a natural output of more production in the polluting sector. Only consumption enters into consumer's utility function, and the cost of pollution in terms of worsen health is not taken into account. However, suppose we put the health cost of the pollution into the welfare calculation, what would be the net welfare gain from trade? Following Becker et al. [2005], I will do a simply welfare analysis. Suppose that overall welfare

$$V(y, MR) = (1 - MR)u(y)/r$$

where $1 - MR$ is probability of survival, $u(y)$ is utility from consumption and r is the interest rate. The utility function takes the form of

$$u(y) = \frac{y^{1-1/\gamma}}{1 - 1/\gamma}$$

Log-linearizing the function $V(y, MR)$

$$\hat{V}(y, MR) = (\widehat{1 - MR}) + (1 - 1/\gamma)\hat{y} \approx -(MR_{2005} - MR_{2000}) + (1 - 1/\gamma)\hat{y}$$

$$\begin{aligned} \hat{V}(y, MR) &= (\widehat{1 - MR}) + (1 - 1/\gamma)\hat{y} \\ &\approx -(MR_{2005} - MR_{2000}) + (1 - 1/\gamma)\hat{y} \\ &\approx -(e^{\hat{MR}} - 1) * MR_{2000} + (1 - 1/\gamma)\hat{y} \end{aligned}$$

I will use regression result in Section 5 to generate predicted values of GDP per capita, air pollution, and mortality rates, and then calculate welfare gains, under three sets of assumptions. Income will be predicted using Table 3, Column (2); air pollution will be predicted using Table 4, Column (2); Mortality rate will be predicted using Table 5, Column (3). In the first case, I will predict income with $Price^t = Cost^t = 0$, and air pollution using $Price^{p,I} = Cost^{p,I} = 0$. In the second case, I will predict income with current $Price^t$ and $Cost^t$ levels, and predict air pollution using $Price^{p,I} = Cost^{p,I} = 0$. In the last case, I will use income and air pollution predicted at current price and cost factor levels. Using the same parameter values as in Becker et al. [2005], I will take $\gamma = 1.25$.

Results are summarized in Table 12. Case 1 assumes that there is no tariff shocks, thus, income and pollution are not affected by trade. Case 2 allows tariff shocks to affect income, but assumes that tariff shocks will not affect pollution level, as if all production were clean. Case 3 is the real-life case where tariff shocks affect both income and pollution. Comparing the three cases, we can see that growth rate in GDP per capita is about 1% larger with trade, and growth rate in air pollution level is 3.6% larger with trade. In term of decline rate of total mortality rate, Case 2 is the highest since people enjoy the income benefit and don't suffer from pollution increase, and the real-life case with income growth and pollution increase rate is even worse than Case 1, meaning that people are better off in terms of health without trade. However, if we look at overall welfare measure, overall welfare is higher in Case 3 than in Case 1, meaning that overall people are still better off with trade, although ideally we would like to have Case 2.

In Case 3, total mortality rate declines by 17.2%[15], while in Case 2, it declines by 20.8%[16]. Thus, in the absence of pollution, total mortality would have decline by 3.6% more. The different of welfare in Case 2 and Case 3 is small, and one reason is that the cost of air pollution only enters the utility function through survival rate, while in real life, increase in medical costs, loss in property value and other avoidance costs can also be significant.

[Table 12 about here.]

7 Conclusion

This paper examines the evidence of how China's accession into the WTO in 2001 affected income, air pollution level and mortality rates across 106 Chinese cities. Using regional tariff shocks as instruments for change in income and pollution level, I show that cities that faced 10% larger GDP per capita increase experienced 6%-7% larger total mortality decline, and regions that faced 10% larger air pollution increase experienced 4%-13% larger total mortality increase. Overall, if all exports were generated from non-polluting industries, total mortality rate would have decline by 3.6% more. The results are robust across different specifications, and there is no evidence that local governments are trying to reinforce or cancel out the tariff shocks using export policies. However, in terms of overall welfare, the gains from income growth overweight losses from pollution increase.

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[15] Calculated using exp(-0.187)-1

[16] Calculated using exp(-0.234)-1

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Table 1: Industry rank of pollutant production per dollar of output, 2003.

Industry name	SO2	Soot	Waste gas	Water	Polluting industry?
Electric, Gas and Sanitary Services	1	1	4	5	No
Stone, Clay, Glass, and Concrete Products	2	2	21	10	Yes
Paper and Allied Products	3	5	16	1	Yes
Petroleum Refining and Related Industries	4	3	23	9	Yes
Coal Mining	5	7	7	3	Yes
Primary Metal Industries	6	4	9	11	Yes
Mining and Quarrying of Nonmetallic Minerals	7	16	3	8	Yes
Metal Mining	8	13	2	4	Yes
Lumber and Wood Products, Except Furniture	9	11	6	12	No
Textile Mill Products	10	9	14	6	Yes
Chemicals and Allied Products	11	6	15	7	Yes
Food and Kindred Products	12	8	20	15	No
Industrial and Commercial Mach. and Computer Equip.	13	12	19	19	No
Oil and Gas Extraction	14	17	12	18	Yes
Tobacco Products	15	19	13	20	No
Communications	16	25	10	2	No
Transportation Equipment	17	10	22	17	No
Fabricated Metal Products	18	14	5	16	No
Leather and Leather Products	19	20	17	13	Yes
Instruments	20	22	8	14	No
Rubber and Miscellaneous Plastic Products	21	18	11	23	Yes
Furniture and Fixtures	22	23	25	24	No
Printing, Publishing and Allied Industries	23	24	1	22	No
Apparel, Finished Products from Fabrics	24	21	18	21	No
Electronic, Electrical Equip. & Comp.	25	15	24	25	No

Note: Pollutant emission by industry is from Chinese Environmental Statistics Yearbook. Sales revenues are from Chinese Industrial Enterprise Survey (IES). The list here is by 2-digit Standardized Industrial Classification (SIC) code. The rank is calculated using 2003 data, since this is the earliest year available with detailed pollutant information and industry classification.

Table 2: Is the past trend in mortality rate correlated with tariff shocks?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Baseline year	1991	1992	1993	1994	1995	1996	1997	1998	1999
$\text{Price}^{p,I}$	27.6	12.8	3.5	15.0	-14.1	-39.5	1.3	7.4	9.1
	(32.3)	(32.2)	(39.1)	(33.0)	(30.2)	(27.1)	(20.3)	(17.3)	(16.9)
$\text{Cost}^{p,I}$	11.6	32.6	34.5	11.9	2.8	42.9	-11.0	10.7	-9.2
	(29.9)	(34.8)	(32.7)	(29.7)	(35.7)	(31.0)	(27.0)	(16.9)	(15.3)
Price^{t}	1.5	11.9	44.7	1.6	24.7	47.2	17.4	6.8	11.9
	(41.2)	(31.9)	(44.3)	(40.0)	(36.9)	(31.8)	(25.1)	(19.5)	(14.7)
Cost^{t}	1.6	-17.5	-48.3	7.0	-11.7	-46.9	26.6	-2.3	0.8
	(42.1)	(36.8)	(49.0)	(42.7)	(44.4)	(37.7)	(35.2)	(23.3)	(15.8)
MR baseline	0.4***	0.4***	0.4***	0.4***	0.6***	0.6***	0.6***	0.8***	0.8***
	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Constant	29.0***	29.4***	27.1***	29.7***	20.6***	19.3***	17.3***	8.6*	8.0
	(5.7)	(6.9)	(5.6)	(6.0)	(6.0)	(4.6)	(5.3)	(5.0)	(5.7)
Observations	113	109	107	111	109	114	114	112	111
R-squared	0.2	0.2	0.3	0.2	0.5	0.4	0.4	0.6	0.7
F-stat for H_0	0.6	0.6	0.4	0.6	0.9	0.5	0.3	0.8	0.3

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Errors clustered at province level. Different columns use different baseline year (1991-1999).

Table 3: How tariff shocks affect export and income

	$\triangle \ln(GDP_{pc})$		$\triangle \ln(Export^t)$		$\triangle \ln(Export^p)$	
Mean(Y)	0.63		1.10		0.99	
	(1)	(2)	(3)	(4)	(5)	(6)
Price	0.84***	0.93***	1.11	0.34	1.54	0.47
	(0.26)	(0.26)	(1.78)	(0.65)	(2.08)	(0.80)
Cost	-0.53**	-0.67**	-1.56	-2.27*	-4.77*	-3.22**
	(0.22)	(0.24)	(3.22)	(1.25)	(2.31)	(1.24)
Observations	106	106	106	106	105	105
R-squared	0.06	0.08	0.01	0.78	0.04	0.84
Other controls	No	Yes	No	Yes	No	Yes
Test: $\beta_1 = -\beta_2 = 1$	0.13	0.33	0.98	0.21	0.29	0.17

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Errors clustered at province level. Compared with Column (1)(3)(5), Column (2)(4)(6) are controlled with change in log of population density and change in export share of output. Regressions weighted by 2000 city population size.

Table 4: How tariff shocks affect pollution

$\triangle \ln(AOT)$	I(Polluting)		SO2	Soot
	(1)	(2)	(3)	(4)
$Price^p$	0.66	0.70*	1.61***	0.04***
	(0.50)	(0.35)	(0.39)	(0.01)
$Cost^p$	-0.73	-0.26	0.15	0.00
	(0.52)	(0.43)	(0.29)	(0.01)
Observations	106	106	106	106
R-squared	0.06	0.15	0.22	0.23
Controls	No	Yes	Yes	Yes
Test: $\beta_1 = -\beta_2$	0.90	0.24	0.00	0.00

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Errors clustered at province level. Compared with Column (1), Column (2)(3) (4) are controlled with change in log of population density and initial air pollution level ($\log(\mathrm{AOT})_{2000}$). Regressions weighted by 2000 city population.

Table 5: Total mortality and trade shock, main result

$\triangle \ln(MR)$	OLS		2SLS		
Mean: -0.19			I_p	SO2	Soot
	(1)	(2)	(3)	(4)	(5)
$\triangle \ln(GDP_{pc})$	-0.16*	-0.25**	-0.65	-0.55**	-0.56**
	(0.09)	(0.11)	(0.38)	(0.24)	(0.21)
$\triangle \ln(AOT)$	0.15	0.29**	1.34*	0.43*	0.58**
	(0.12)	(0.11)	(0.70)	(0.22)	(0.23)
$\triangle \ln(PopDen)$		-0.49*	-0.67*	-0.55*	-0.57**
		(0.23)	(0.36)	(0.28)	(0.26)
$\triangle \ln(E\%)$		-0.07**	-0.09***	-0.07**	-0.07**
		(0.03)	(0.02)	(0.03)	(0.03)
$\triangle \ln(Emp)$		-0.06	-0.33	-0.13	-0.16
		(0.14)	(0.23)	(0.16)	(0.16)
$\ln(GDP_{pc})_{2000}$		-0.04	-0.05	-0.05	-0.05
		(0.04)	(0.05)	(0.04)	(0.04)
$\ln(AOT)_{2000}$		0.14**	0.31**	0.18**	0.20**
		(0.06)	(0.14)	(0.08)	(0.07)
Observations	106	106	106	106	106
R-square	0.06	0.29		0.18	0.12
F-stat for GDP	-	-	2.53	2.40	2.51
F-stat for AOT	-	-	2.68	3.63	3.96

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Errors clustered at province level. Column (1) (2) are OLS regressions. Column (3)-(5) are IV regressions where both GDP and AOT are instrumented using price factors and cost factors. Column (3) uses $Price^{p,I}$ and $Cost^{p,I}$, and Column (4)-(5) use different pollutant emission intensities. F-stat for GDP and F-stat for AOT are F-statistics for first stage regressions. Regressions weighted by 2000 city population.

Table 6: Are local VAT rebate rates correlated with tariff shocks?

	Dropped top and bottom 1%			Dropped top and bottom 5%		
$\Delta \ln(export)$	(1)	(2)	(3)	(4)	(5)	(6)
Price	1.14***	1.14***	1.15***	0.94***	0.94***	0.94***
	(0.25)	(0.25)	(0.25)	(0.30)	(0.30)	(0.30)
Cost	-0.13	-0.12	-0.10	-0.50	-0.50	-0.50
	(0.42)	(0.42)	(0.42)	(0.59)	(0.59)	(0.59)
Polluting industry	-0.23***	-0.23***	-0.24***	-0.28***	-0.28***	-0.28***
(=1)	(0.06)	(0.06)	(0.06)	(0.06)	0.01	0.01
Rebate		0.00	-0.01		(0.01)	(0.02)
		(0.01)	(0.01)			-0.00
Interaction			0.02*			(0.02)
			(0.01)			(0.0222)
Log(export$_{2000}$)	-0.20***	-0.20***	-0.20***	-0.17***	-0.17***	-0.17***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Constant	3.29***	3.29***	3.29***	2.93***	2.92***	2.92***
	(0.26)	(0.26)	(0.26)	(0.26)	(0.26)	(0.26)
Observations	2,118	2,118	2,118	1,863	1,863	1,863
R-squared	0.10	0.10	0.11	0.08	0.08	0.08

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Errors clustered at city level.

Column (1)-(3) dropped city-industry pairs that fall in top or bottom 1% of rebate rates. Column (4)-(6) dropped the ones that fall in top or bottom 5%. Interaction is interaction of rebate rate and polluting industry dummy.

Table 7: Infant Mortality and trade shock

$\triangle \ln(IMR)$	OLS		2SLS		
Mean: -0.78			I_p	SO2	Soot
$\triangle \ln(GDP_{pc})$	-0.43	-0.31	0.63	0.41	0.00
	(0.42)	(0.51)	(2.24)	(1.80)	(1.49)
$\triangle \ln(AOT)$	-0.05	0.23	3.69*	2.58	1.83*
	(0.32)	(0.43)	(2.03)	(1.45)	(0.92)
$\triangle \ln(PopDen)$		-3.07	-5.18	-4.54	-4.00
		(2.37)	(3.20)	(2.60)	(2.48)
$\triangle \ln(E\%)$		-0.13	-0.19	-0.17*	-0.16*
		(0.08)	(0.11)	(0.09)	(0.09)
$\triangle \ln(Emp)$		0.07	-0.42	-0.25	-0.17
		(0.68)	(0.72)	(0.62)	(0.59)
$\ln(GDP_{pc})_{2000}$		0.25	0.27	0.26	0.26
		(0.20)	(0.23)	(0.22)	(0.21)
$\ln(AOT)_{2000}$		0.17	0.55	0.42	0.36
		(0.24)	(0.51)	(0.49)	(0.40)
Observations	93	93	93	93	93
R-squared	0.01	0.12			0.00

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Errors clustered at province level. Column (1) (2) are OLS regressions. Column (3)-(5) are IV regressions where both GDP and AOT are instrumented using price factors and cost factors. Column (3) uses polluting v.s. non-polluting division, and Column (4)-(5) use different pollutant emission intensities. Regressions weighted by 2000 city population.

Table 8: Total mortality and trade shock, different $\hat{r}$

$\triangle \ln(MR)$	OLS	2SLS			
Mean: -0.19	(1)	(2)	(3)	(4)	(5)
$\triangle \ln(GDP_{pc})$	-0.25**	-0.39	-0.67*	-0.61**	-0.67
	(0.11)	(0.27)	(0.33)	(0.26)	(0.39)
$\triangle \ln(AOT)$	0.29**	0.58**	0.68*	0.56**	0.72**
	(0.11)	(0.24)	(0.31)	(0.22)	(0.31)
$\triangle \ln(PopDen)$	-0.49*	-0.55**	-0.59*	-0.57*	-0.60*
	(0.23)	(0.22)	(0.29)	(0.27)	(0.28)
$\triangle \ln(E\%)$	-0.07**	-0.07**	-0.07**	-0.07**	-0.07**
	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)
$\triangle \ln(Emp)$	-0.06	-0.14	-0.20	-0.17	-0.21
	(0.14)	(0.16)	(0.16)	(0.16)	(0.18)
$\ln(GDP_{pc})_{2000}$	-0.04	-0.05	-0.05	-0.05	-0.05
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
$\ln(AOT)_{2000}$	0.14**	0.19**	0.23**	0.21**	0.23***
	(0.06)	(0.08)	(0.07)	(0.08)	(0.08)
Observations	106	106	106	106	106
R-squared	0.29	0.19		0.10	

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Errors clustered at province level. Column (1) is OLS regressions. Column (2)-(5) are IV regressions where both GDP and AOT are instrumented using price factors and cost factors. Column (2) allows for across-region capital mobility. Column (2)-(5) use different ways to calculate return to capita. Column (3) uses capital adjusted by export intensity. Column (4) uses fixed capital. Column (5) uses fixed capital adjusted by export intensity. All 2SLS regressions assume soot as the main pollutant. Regressions weighted by 2000 city population.

Table 9: Total mortality and trade shock

$\triangle \ln(MR)$	OLS		2SLS		
Mean: -0.19			I_p	SO2	Soot
$\triangle \ln(light)$	-0.08	-0.11	-0.48	-0.47*	-0.44**
	(0.07)	(0.07)	(0.36)	(0.22)	(0.20)
$\triangle \ln(AOT)$	0.16	0.31**	1.52*	0.63	0.75**
	(0.11)	(0.13)	(0.75)	(0.39)	(0.34)
$\triangle \ln(PopDen)$		-0.39*	-0.25	-0.17	-0.20
		(0.21)	(0.42)	(0.23)	(0.24)
$\triangle \ln(E\%)$		-0.07**	-0.10***	-0.08***	-0.08***
		(0.03)	(0.02)	(0.02)	(0.02)
$\triangle \ln(Emp)$		-0.04	-0.24	-0.08	-0.10
		(0.12)	(0.23)	(0.16)	(0.16)
$\ln(Light)_{2000}$		-0.02	-0.07	-0.06	-0.06
		(0.03)	(0.04)	(0.03)	(0.03)
$\ln(AOT)_{2000}$		0.15*	0.41**	0.28**	0.29**
		(0.07)	(0.17)	(0.11)	(0.11)
Observations	106	106	106	106	106
R-squared	0.04	0.24			

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Errors clustered at province level. Column (1) (2) are OLS regressions. Column (3)-(5) are IV regressions where both light and AOT are instrumented using price factors and cost factors. Column (3) uses polluting v.s. non-polluting division, and Column (4)-(5) use different pollutant emission intensities. Regressions weighted by 2000 city population.

Table 10: How tariff shocks affect pollution, placebo test

$\triangle\ln(AOT)$	I(Polluting)		I(Non-polluting)	
Mean: 0.12	(1)	(2)	(3)	(4)
Price	0.66	0.70*	-0.36**	-0.42**
	(0.50)	(0.35)	(0.16)	(0.18)
Cost	-0.73	-0.26	0.30	0.62**
	(0.52)	(0.43)	(0.27)	(0.24)
Observations	106	106	106	106
R-squared	0.06	0.15	0.03	0.15
Test: $-\beta_1 = \beta_2$	0.90	0.24	0.80	0.32
Controls	No	Yes	No	Yes

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Errors clustered at province level. Column (1) and (2) use $Price^{p,I}$ and $Cost^{p,I}$ as regressors, and Column (3) and (4) use $Price^{np}$ and $Cost^{np}$ as regressors. Column (2) and (4) control for change in log of population density and initial air pollution level ($\log(\text{AOT})_{2000}$). Regression weighted by 2000 city population.

Table 11: Total mortality and trade shock, placebo test

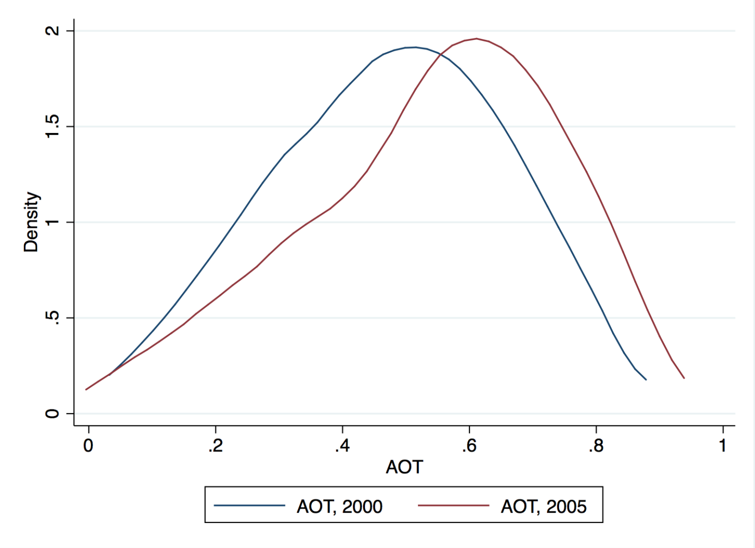
$\triangle \ln(MR)$	OLS		2SLS	
Mean: -0.19			I_p	I_{np}
$\triangle \ln(GDP_{pc})$	-0.16*	-0.25**	-0.65	-0.61*
	(0.09)	(0.11)	(0.38)	(0.30)
$\triangle \ln(AOT)$	0.15	0.29**	1.34*	1.06**
	(0.12)	(0.11)	(0.70)	(0.39)
$\triangle \ln(PopDen)$		-0.49*	-0.67*	-0.63*
		(0.23)	(0.36)	(0.32)
$\triangle \ln(E\%)$		-0.07**	-0.09***	-0.08***
		(0.03)	(0.02)	(0.02)
$\triangle \ln(Emp)$		-0.06	-0.33	-0.27
		(0.14)	(0.23)	(0.16)
$\ln(GDP_{pc})_{2000}$		-0.04	-0.05	-0.05
		(0.04)	(0.05)	(0.05)
$\ln(AOT)_{2000}$		0.14**	0.31**	0.27**
		(0.06)	(0.14)	(0.10)
Observations	106	106	106	106
R-squared	0.06	0.29		

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Errors clustered at province level. Column (1) (2) are OLS regressions. Column (3)-(4) are IV regressions where both GDP and AOT are instrumented using price factors and cost factors. Column (3) uses $Price^{p,I}$ and $Cost^{p,I}$ to instrument for pollution, and Column (4) uses $Price^{np}$ and $Cost^{np}$. Regressions weighted by 2000 city population.

Table 12: Welfare analysis

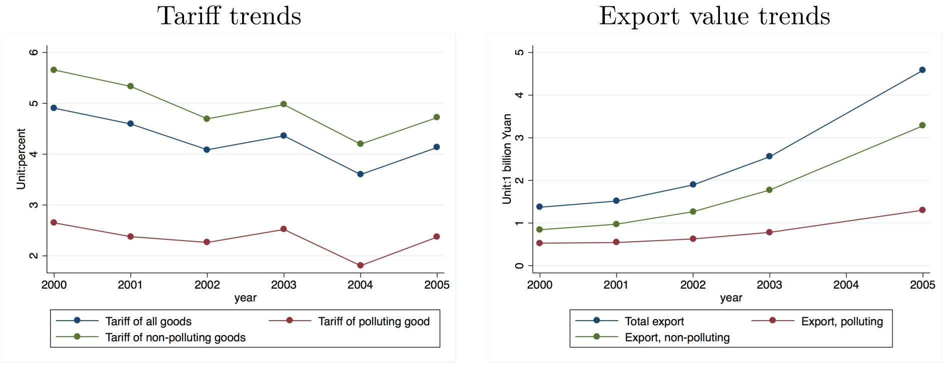
		Case 1	Case 2	Case 3
		Trade=0, Pollution=0	Trade=1, Pollution=0	Trade=1, Pollution=1
$\hat{y}$	Mean	0.608	0.617	0.617
	Std.	0.046	0.054	0.054
$\widehat{AOT}$	Mean	0.109	0.109	0.145
	Std.	0.064	0.064	0.069
$\widehat{MR}$	Mean	-0.225	-0.234	-0.187
	Std.	0.109	0.116	0.113
$\hat{V}$	Mean	0.123	0.126	0.125
	Std.	0.009	0.011	0.011

Figure 1: Pollution level distribution across cities, 2000 and 2005



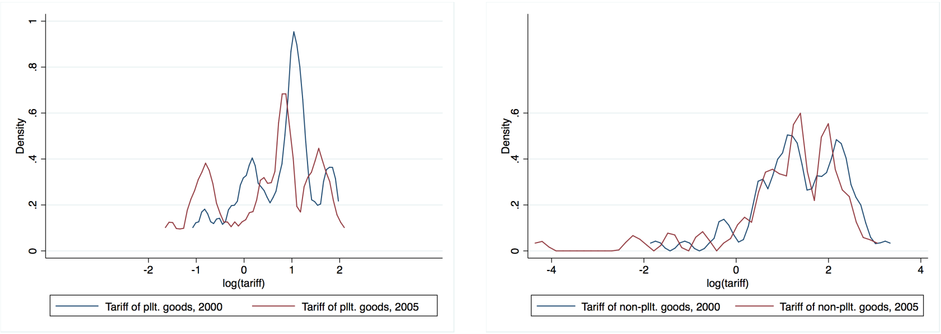
Note: Data for aerosol optical thickness (AOT) is from NASA satellite information. Distributions are across 106 cities used in the final regressions. Kernel density is estimated with bandwidth 0.11.

Figure 2: Total Chinese export value and average tariff, 2000-2005



Note: Data for tariff and export values is from World Integrated Trade Solution (WITS). Each data point on the left graph is average tariff faced by Chinese exporters in a year. For a year, tariff of all goods is simple mean across 96 product categories. Tariff for polluting (non-polluting) goods is simple mean across 24 (72) non-polluting goods. Polluting and non-polluting goods are defined according to their corresponding industry characteristics. Each data point on the right graph is total export value in a year. For division of pollution v.s. non-polluting industries, see data section.

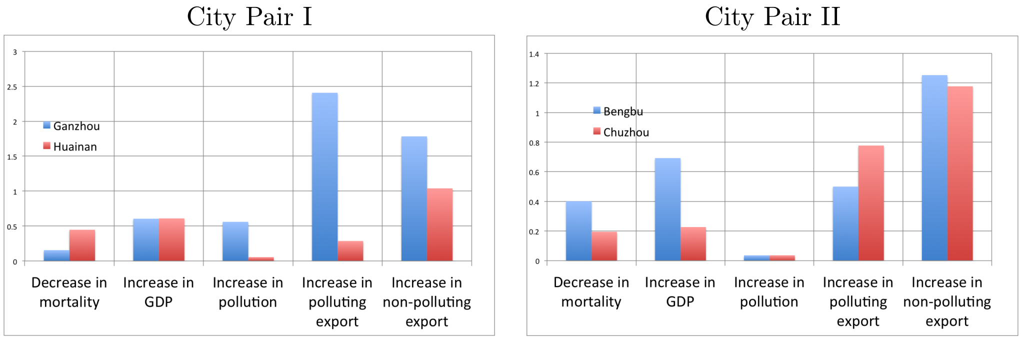
Figure 3: Density of log of import tariff on Chinese goods, 2000 and 2005, polluting and non-polluting goods


Polluting goods

Non-polluting goods

Note: Data for tariff is from World Integrated Trade Solution (WITS). The figure on the left is the density of log of tariff for polluting goods, and the figure on the right is the density of non-polluting goods. There are 96 product categories in total, and 24 are defined as polluting goods. Kernel density is estimated with bandwidth 0.11.

Figure 4: Export, GDP, pollution and mortality rate: two pairs of cities, 2000 to 2005 changes



City Pair I

City Pair II

Note: Export information is from Chinese Industrial Enterprise Survey (IES). Pollution data is from NASA aerosol optical thickness satellite images. GDP is from city statistics yearbooks, and mortality rates are from population census. All changes are changes in log terms. Ganzhou is a city in Jiangxi province, and Huainan, Bengbu and Chuzhou are cities in Anhui province.

A Matching U.S. Industry with Chinese Industry

[Table 13 about here.]

[Table 14 about here.]

[Table 15 about here.]

B Summary of statistics

In this section I will present summary of statistics for the variable that will be used in the main regressions.

[Table 16 about here.]

Table A.1: List of relevant U.S. industry, by 2-digit SIC code

Industry Code	Industry Name
1	Agricultural Production - Crops
2	Agricultural Production - Livestock and Animal Specialties
7	Agricultural Services
8	Forestry
9	Fishing, Hunting and Trapping
10	Metal Mining
12	Coal Mining
13	Oil and Gas Extraction
14	Mining and Quarrying of Nonmetallic Minerals, Except Fuels
15	Building Cnstrctn - General Contractors & Operative Builders
16	Heavy Cnstrctn, Except Building Construction - Contractors
17	Construction - Special Trade Contractors
20	Food and Kindred Products
21	Tobacco Products
22	Textile Mill Products
23	Apparel, Finished Prdcts from Fabrics & Similar Materials
24	Lumber and Wood Products, Except Furniture
25	Furniture and Fixtures
26	Paper and Allied Products
27	Printing, Publishing and Allied Industries
28	Chemicals and Allied Products
29	Petroleum Refining and Related Industries
30	Rubber and Miscellaneous Plastic Products
31	Leather and Leather Products
32	Stone, Clay, Glass, and Concrete Products
33	Primary Metal Industries
34	Fabricated Metal Prdcts, Except Machinery & Transport Eqpmnt
35	Industrial and Commercial Machinery and Computer Equipment
36	Electronic, Elctrcl Eqpmnt & Cmpnts, Excpt Computer Eqpmnt
37	Transportation Equipment
38	Mesr/Anlyz/Cntrl Instrmnts; Photo/Med/Opt Gds; Watchs/Clocks
39	Miscellaneous Manufacturing Industries

Note: Data from `https://www.osha.gov/pls/imis/sic_manual.html`

Table A.2: List of Relevant Chinese Industries by 2-digit GB code

Industry Code	Industry name
6	Agriculture
7	Mining and Washing of Coal
8	Extraction of Petroleum and Natural Gas
9	Mining and Processing of Ferrous Metal Ores
10	Mining and Processing of Non-ferrous Metal Ores
11	Mining and Processing of Nonmetal Ores
13	Mining of Other Ores
14	Processing of Food from Agricultural Products
15	Manufacture of Foods
16	Manufacture of Beverages
17	Manufacture of Tobacco
18	Manufacture of Textile
19	Manufacture of Textile Wearing Apparel, Footware, and Caps
20	Manufacture of Leather, Fur,Feather and Related Products Feather and Related Products
21	Processing of Timber, Manufacture of Wood, Bamboo,Rattan, Palm, and Straw Products
22	Manufacture of Furniture
23	Manufacture of Paper and Paper Products
24	Printing,Reproduction of Recording Media
25	Manufacture of Articles for Culture, Education and Sport Activity
26	Processing of Petroleum, Coking, Processing of Nuclear Fuel
27	Manufacture of Raw Chemical Materials and Chemical Products
28	Manufacture of Medicines
29	Manufacture of Chemical Fibers
30	Manufacture of Rubber
31	Manufacture of Plastics
32	Manufacture of Non-metallic Mineral Products
33	Smelting and Pressing of Ferrous Metals
34	Smelting and Pressing of Non-ferrous Metals
35	Manufacture of Metal Products
36	Manufacture of General Purpose Machinery
37	Manufacture of Special Purpose Machinery
39	Manufacture of Transport Equipment
40	Manufacture of Electrical Machinery and Equipment
41	Manufacture of Communication Equipment, Computers and Other Electronic Equipment
42	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work
43	Manufacture of Artwork and Other Manufacturing

Note: Data from `http://www.stats.gov.cn/tjsj/tjbz/201301/t20130114_8675.html`

Table A.3: Matching U.S. and Chinese industries

Chinese Ind. Code	U.S. Ind. Code	Chinese Ind. Code	U.S. Ind. Code
6	1, 2, 7, 8, 9	25	39
7	12	26	29
8	13	27	28
9	10	28	28
10	10	29	28
11	14	30	30
13	14	31	30
14	20	32	32
15	20	33	33
16	20	34	33
17	21	35	34
18	22	36	35
19	23	37	36
20	31	39	37
21	24	40	36
22	25	41	36
23	26	42	38
24	27	43	39

Note: Matched by author.

Table A.4: Summary of statistics

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	Mean	S.D.	Min	Max
$\Delta \ln(MR)$	106	-0.19	0.15	-0.73	0.14
$\Delta \ln(GDP_{p.c.})$	106	0.63	0.15	-0.29	1.38
$\Delta \ln(AOT)$	106	0.13	0.15	-0.76	0.66
$\Delta \ln(Employment)$	106	-0.08	0.14	-0.74	0.43
$\Delta \ln(PopulationDensity)$	106	0.03	0.05	-0.44	0.94
$\ln(MR)_{2000}$	106	1.76	0.14	1.38	2.18
$\ln(GDP_{p.c.})_{2000}$	106	8.72	0.59	7.73	10.55
$\ln(AOT)_{2000}$	106	-0.73	0.33	-1.95	-0.26
$\Delta \ln(Export^t)$	106	1.24	0.85	-1.69	4.38
$\Delta \ln(Export^p)$	105	1.06	0.97	-1.69	5.65
$\Delta \ln(Export^t/Sales^t) = \Delta \ln(E\%)^t$	106	0.15	0.67	-2.19	2.52
$\Delta \ln(Export^p/Sales^p) = \Delta \ln(E\%)^p$	105	-0.08	0.91	-2.28	5.32
$Price^t$	106	0.10	0.06	-0.02	0.31
$Price^{p,I}$	106	0.09	0.05	-0.02	0.24
$Cost^t$	106	0.09	0.04	-0.01	0.30
$Cost^{p,I}$	106	0.10	0.05	-0.00	0.34
$Price^{p,so2}$	106.00	1.80	1.17	0.07	9.40
$Price^{p,soot}$	106.00	0.04	0.03	0.00	0.22
$Cost^{p,so2}$	106.00	0.07	0.06	-0.00	0.35
$Cost^{p,soot}$	106.00	3.23	2.41	-0.06	12.32