Environmental Effects of Trade Liberalization: The China Shock and its Impact on U.S. Manufacturing Employment, Air Quality, and Infant Mortality

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Abstract

Economists have long debated the environmental impacts of trade liberalization: does foreign import competition cause a change in domestic environmental and health outcomes? In this study, I examine this question by looking at the effects of China's rising import competition on U.S. manufacturing employment, air quality, and infant mortality between 1990 and 2014. I find that local labor markets in the United States which experienced increased Chinese import penetration also saw a substantial decrease in the share of manufacturing employment relative to non-manufacturing industries. However, results indicate that air quality and infant mortality rates were not significantly impacted by increased exposure to Chinese imports.

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1 Introduction

Over the past 30 years, the world has been witness to China's meteoric rise as an economic superpower. Due to its large-scale production capabilities and low labor costs, China's emergence as a manufacturing powerhouse sent shockwaves through the sphere of international trade. While economists have long emphasized the benefits of international trade, foreign competition can result in detrimental domestic economic effects (Autor, Dorn, and Hanson 2016). Introductory trade theory establishes that "owners of a country's abundant factors gain from trade, but owners of a country's scarce factors lose" (Krugman and Obstfeld 2008). In the United States, we would expect that the impact of expanded international trade will have asymmetric effects: gains are likely to flow to capital and to high-skilled workers while costs are borne by low-skilled workers.

While the distributional effects of China's rise on the U.S. labor market, marriage market, and health outcomes have been well-studied, there is limited research studying the impact of increased import competition from China on air pollution in the U.S. If Chinese manufacturing adversely affects U.S. manufacturing employment, how will this affect pollution emissions from U.S. manufacturing activity, and in turn, health outcomes? The industrial sector contributes around 24% of greenhouse gas emissions in the United States (Environmental Protection Agency 2022). Exposure to poor air quality has been linked to key human capital indicators like worse schooling (Lavy, Ebenstein, and Roth 2014), poor labor market opportunities, and lower adult productivity (Chang et al. 2014). And with climate change at the forefront of public consciousness, it is timely and topical to study the relationship between foreign trade, employment, and air pollution.

In this paper, I assess how rising import competition from China affected manufacturing employment, air quality, and infant mortality in the U.S. First, I estimate the effect of Chinese-U.S. import penetration on U.S. labor markets. Second, I explore whether increased trade competition with China differentially influenced the environmental quality and infant mortality rates in different local labor markets depending on their degree of exposure to import competition. Following Autor, Dorn, and Hanson (2013), I use Chinese imports to eight high-income countries as an instrument for Chinese-U.S. import penetration in an instrumental variable (IV) model. My results show that while Chinese import competition considerably shrinks U.S. manufacturing employment, it does not significantly affect air quality or infant mortality.

The rest of this paper is organized as follows. Section 2 presents background information. Section 3 reviews the previous literature. Section 4 discusses the sources of data and lays out the empirical methodology. Section 5 presents and discusses the results of the empirical analyses. Section 6 concludes.

2 Background

The China Shock is a term that economists use to refer to the unprecedented surge in China's exports to the rest of the world, beginning in the early 1990s and plateauing around 2010. China's manufacturing surge can be attributed to the sweeping economic reforms implemented by Deng Xiaoping in the 1980s and 1990s, including the transition from central planning to a market economy and the creation of special economic zones that encouraged foreign firms to open factories in China (Autor 2016). It wasn't long before many high-income countries, including the United States, saw rising import competition from China. China's export boom was further augmented by its accession to the World Trade Organization in 2001. Trade relations between the U.S. and China were also notably impacted by the United States-China Relations Act of 2000, which authorized permanent normal trade relations (PNTR) with China. This act granted low tariff rates, without the need for annual renewal, to U.S. imports from China, thereby rendering exports from China to the U.S. more attractive. Liberalized trade between the two countries exposed local labor markets in the U.S. to increased import competition via their industry structure (Pierce and Schott 2020).

Given increased incentives for China to export goods to the U.S., as well as China's specialization and growth in manufacturing, China's share of U.S. manufacturing imports rapidly increased from 4.5% in 1991 to 10.9% in 2001 and to 23.1% in 2011 (Acemoglu et al. 2016). At the same time, U.S. manufacturing employment declined by 18.7% between 2000 and 2007. Panel A in Table 1 confirms these findings, indicating that the average commuting zone saw a 2.92 percentage point fall in manufacturing employment from 1990 to 2014.

The manufacturing sector consists of establishments that transform materials into new products, including the production of food, textiles, furniture, plastics, chemicals, petroleum, paper, metal products, electronics, vehicles, toys, and various other goods (Bureau of Labor Statistics 2022). A critical part of the manufacturing process is heating raw materials in order to produce new goods, which involves the burning of fossil fuels (to generate electricity to run the plant), carrying out chemical processes, smelting metal, or refining oil. All of these processes release harmful particles and pollutants into the atmosphere, such as carbon monoxide, sulfur dioxide, and nitrogen dioxide. The presence of these greenhouse gasses in the atmosphere contributes to climate change and raises global temperatures. Moreover, the particulate matter (a mixture of solid and liquid droplets in the air) released from factory emissions can be harmful to human health. Particles that are 10 μm or smaller (PM 10 or PM 2.5) pose the greatest problems because they are small enough to be inhaled, which affects the functioning of the lungs and other internal organs (Environmental Protection Agency 2021b).

Manufacturing also contributes to water pollution, as some manufacturing processes use large amounts of water and dump toxic wastewater into streams/rivers, polluting the water with toxic chemicals. In the U.S., the Clean Air Act of 1970, Clean Air Act of 1990, and Clean Water Act of 1972 have limited the amount of pollutants manufacturers can release. These Acts have encouraged manufacturers to take up abatement efforts such as the installation of cleaner technology like "scrubbers" to filter out harmful chemicals from exhaust fumes before they are released into the air (Environmental Protection Agency 2007). The EPA monitors factory emissions and fines manufacturers who violate the terms of the Clean Air and Water Acts. Although the Environmental Protection Agency sets federal pollution limits, environmental regulation can vary by state. Individual states may implement more stringent air quality laws, but they may not have weaker pollution limits than those set by EPA (Environmental Protection Agency 2007).

Table 2 displays the relationship between key outcome variables using simple OLS regressions. It is important to note that the only statistically significant relationship is between the change in manufacturing employment and the change in median air quality levels (Column (1)). These variables are positively correlated, indicating that in commuting zones with a higher share of the local labor force employed in manufacturing, there is higher median air pollution. That being said, these correlations do not imply causality,. For example, manufacturing employers may migrate to states with more lenient environmental regulations resulting in both higher manufacturing employment and higher air pollution.

Table 1: Summary Statistics

	Mean	S.D.	Min	Max	N
Panel A: Share of Manufacturing Employment					
Manufacturing Share, 1990	8.239264	5.705754	0	28.68073	722
Manufacturing Share, 2000	7.325231	5.045674	0	25.20627	722
Manufacturing Share, 2014	5.322191	3.753724	0	22.63275	722
Δ Manufacturing Share, 1990-2000	-0.914034	1.896504	-12.66141	23.27642	722
Δ Manufacturing Share, 2000-2014	-2.005544	2.275104	-12.32083	8.766564	722
Δ Manufacturing Share, 1990-2014	-2.919578	3.388822	-18.18666	21.76067	722
Panel B: Air Pollution (Air Quality Index)					
Maximum AQI, 1990	132.7586	55.12857	28	347	395
Maximum AQI, 2000	133.4867	43.66563	3	239.5	464
Maximum AQI, 2014	104.6124	35.91267	11	434	446
Δ Maximum AQI, 1990-2000	1.703561	42.23365	-137	148	348
Δ Maximum AQI, 2000-2014	-33.02034	47.5812	-134	279.667	402
Δ Maximum AQI, 1990-2014	-33.41999	51.83657	-174	234	327
Median AQI, 1990	35.23685	14.9101	3	103	396
Median AQI, 2000	38.04265	13.96637	0	111	465
Median AQI, 2014	35.78496	9.467672	3	97	447
ΔMedian AQI, 1990-2000	1.872609	13.70255	-73	42	349
ΔMedian AQI, 2000-2014	-2.617756	10.79709	-40.667	41.5	403
ΔMedian AQI, 1990-2014	-.4326689	13.3666	-65	31.5	328
Panel C: Infant Mortality Rate (number of deaths per 1000 live births)					
Infant Mortality Rate, 1990	10.51377	3.289791	4.95	30.58	300
Infant Mortality Rate, 2000	8.633761	2.961045	4.3	22.3	253
Infant Mortality Rate, 2014	7.305528	2.400952	3.5	18.8	230
Δ Infant Mortality Rate, 1990-2000	-1.777505	2.264509	-10.415	4.75	191
Δ Infant Mortality Rate, 2000-2014	-1.166736	2.024822	-10.25	3.4	173
Δ Infant Mortality Rate, 1990-2014	-2.789685	2.226507	-10.44933	6.6	168
Panel D: Import Penetration (IP)					
Δ U.S.-China IP, 1990-2000	0.808238	0.959025	-0.085778	9.982822	722
Δ U.S.-China IP, 2000-2014	1.121797	1.075995	-0.786199	6.408583	722
Δ U.S.-China IP, 1990-2014	0.965018	1.030836	-0.786199	9.982822	1,444
Δ Instrumented IP, 1990-2000	0.732447	0.79764	-0.557474	6.106096	722
Δ Instrumented IP, 2000-2014	1.190344	1.083228	-0.159849	6.630878	722
Δ Instrumented IP, 1990-2014	0.961396	-0.557474	-0.557474	6.630878	1,444

Notes: For calculations of Maximum AQI, CZ 37903 was excluded due to abnormalities in the data.

Table 2: Relationship Between Key Outcome Variables

	Δ Median AQI	Δ Max AQI	Δ Infant Mortality Rate
	(1)	(2)	(3)
Δ Manufacturing Employment	1.025** (0.000)	6.161 (0.564)	-0.01546 (0.869)
Δ Median AQI			0.008163 (0.465)
Δ Max AQI			-0.001497 (0.526)

**p<0.05

Notes: Simple OLS regressions of (1) the change in manufacturing employment on the change in median AQI; (2) the change in manufacturing employment on the change in maximum AQI; (3) the change in manufacturing employment on the change in infant mortality rates, the change in median AQI on the change in infant mortality rates, and the change in maximum AQI on the change in infant mortality rates. p-value indicating the statistical significance in parentheses.

3 Literature Review

This paper contributes to three strands of existing literature: the environmental consequences of trade liberalization, the relationship between trade and mortality, and finally, the impact of the China Shock.

First, over the past 30 years, one of the most widely debated issues in the realm of international trade has been the direction and channels through which international trade affects pollution. The pioneering work of Grossman and Krueger (1995) and Copeland and Taylor (2004) established the three major pathways through which liberalized trade affects industrial air pollution: 1) trade can lead to a greater scale of production, thereby increasing pollution (scale effect); 2) trade can cause a shift in production composition from clean to dirty industries (composition effect); 3) trade can stimulate a change in production techniques and advances in abatement processes as higher incomes drive demand for cleaner environment (technique effect). These effects can work in the opposite direction depending on what side of the trade flow a country is on. For example, if trade increases manufacturing employment, it may lead to greater production scale, and dirtier composition and manufacturing processes. On the other hand, if trade shrinks manufacturing employment, the effect will be the opposite: lower production scale, and cleaner composition and technology.

Building on this work, Levinson (2009) finds that, although declining air pollution from U.S. manufacturing in the 1990s is largely due to the technique effect, there is also a substantial composition effect wherein manufacturers have shifted to producing 'greener' products, partly due to increased international trade. More recently, Cherniwichan (2017), provides robust evidence that trade liberalization following NAFTA played a significant role in the clean-up of U.S. manufacturing during the 1990s via both composition and technique effects. He finds that reductions in plant emissions following NAFTA were due to sourcing of dirty intermediate inputs from Mexico instead of producing them domestically, and finds suggestive evidence of a trade-induced technological change. In contrast, Shapiro and Walker (2018) attribute the majority of the reduction in pollution emissions from manufacturing to tightened environmental regulations (as these encourage the adoption of abatement technologies) and show that trade has played a smaller role in explaining this pollution decline.

This paper also relates to the body of empirical work investigating whether international trade is linked to mortality. Previous research has found that U.S. counties more exposed to international trade exhibit increases in fatal drug overdoses as a result of decreased earnings and employment (Pierce and Schott 2020). However, a criticism of the outcome variable 'adult mortality' is that adults' health is likely to be affected by other factors accumulating over the course of a lifetime. Instead, infant mortality is a more relevant outcome variable as babies are more susceptible to poor air quality and their health outcomes can be more reliably explained by environmental conditions. Groundbreaking work by environmental economists has shown that air pollution is positively linked to infant mortality rates in both developed and developing nations (Chay and Greenstone 2003; Jayachandran 2009). Several studies have looked at how trade liberalization - particularly as it relates to China's export boom - affects infant mortality via air pollution. In Brazil, China's demand for commodities (iron ores) was correlated with increased pollution-related mortality of children in mining municipalities, but this effect is largely attributed to a municipality's specialization in mining activities rather than its trade exposure with China (Dornelas and Chimeli 2019). Most relevant to my study, Bombardini and Li (2019) explore whether the expansion of Chinese exports contributed to the country's worsening environmental quality and infant mortality rates. The authors find that Chinese regions more involved in export expansion faced higher infant mortality and pollution concentrations. They also find a negative, but insignificant "technique effect" whereby higher incomes increase demand for a cleaner environment.

The third area this paper contributes to is the expanding literature on the effects of the China Shock. In their seminal work, Autor, Dorn, and Hanson (2013) examine how local labor markets in U.S. Commuting Zones are impacted by Chinese import penetration. They demonstrate that rising imports cause greater unemployment, reduced labor force participation, and lower wages in labor markets that have import-competing manufacturing industries. The authors also find a steep drop in average household income and an increase in transfer payments through government welfare programs in local labor markets exposed to the China Shock. These results are also empirically supported by the works of Acemoglu et al. (2016) and Pierce and Schott (2016), who show that the sizable decrease in U.S. manufacturing employment since 2000 is linked to policy that liberalized U.S.-China trade relations. Autor, Dorn, and Hanson (2019) also find that increased Chinese import penetration negatively affects the marriage market by increasing male mortality and homicide, and deterring fertility, marriage, and joint child-rearing.

The large body of work on the China Shock has made it clear that Chinese exports adversely impacted the U.S. manufacturing industry. My paper seeks to extend the exploration of the China Shock by examining the environmental and health consequences. My main contribution to the literature is that I specifically investigate whether trade with China affected U.S. manufacturing pollution. This question is particularly relevant given China's economic superpower status, which was largely driven by its export boom. Additionally, the effects of the China Shock take place in the 2000s, whereas much of the existing literature on trade liberalization and the environment looks at the preceding time period (the 1990s). In my study, I also analyze the effects of Chinese import penetration on infant mortality rates in the United States. Given that our world is becoming increasingly globalized, it is vital to look at the health outcomes of changes in international trade, particularly as they affect the next generation of U.S. workers.

4 Data and Empirical Strategy

4.1 Data

The unit of analysis is at the Commuting-Zone (CZ) level, which is a geographic area that clusters U.S. counties with strong commuting ties. There are 722 Commuting Zones that cover the mainland United States, with an average population of 62635 in the year 1990. The information on manufacturing employment and wages, air quality, and infant mortality is available on a yearly basis at the county level. For the purpose of the analysis in the paper, I construct key outcome variables at the commuting zone level by collapsing the county-level data to the CZ level using the crosswalk files created by David Autor and David Dorn (2013).

The Bureau of Labor Statistics provides county-level data on total employment, manufacturing employment levels, and manufacturing wage levels on an annual basis for the years 1990-2014, recorded via the Quarterly Census of Employment and Wages. For all 722 CZs in the

U.S., we obtain the percentage of workers employed in manufacturing in a given commuting zone by dividing the number of employees in manufacturing by the total employees in a CZ.

Air quality levels for the years 1990-2014 are obtained from the Environmental Protection Agency. A county's air quality data is collected at outdoor monitors across the U.S. and is measured by the Air Quality Index (AQI). The AQI uses numbers from 0 to 500 to determine the quality of air, wherein an AQI less than 50 indicates good air quality, and an AQI greater than 300 is considered hazardous. The EPA tracks the emissions of five major pollutants regulated by the Clean Air Act of 1970: ground-level ozone, particulate matter (PM2.5 and PM10), carbon monoxide, sulfur dioxide, and nitrogen dioxide. However, the EPA only has outdoor air monitoring data for 1/3 of all U.S. counties (Environmental Protection Agency. 2021c). States are responsible for monitoring air quality in order to meet the minimum monitoring requirements - which are based on population size - set by the Clean Air Act. Oftentimes, states choose to locate monitors in areas with higher pollution concentrations or higher populations, and as a result, many small towns don't have monitors to report AQI data. When these data are collapsed to the CZ-level, I find that only 396 CZs have AQI data in the year 1990, albeit this number gets slightly larger by 2014 (Table 1). Table 3 shows that CZs with and without AQI data are statistically different - CZs without AQI data have less manufacturing employment and smaller population sizes. My analysis, therefore, captures the impact of the China Shock in larger places with higher levels of baseline manufacturing. These CZs are likely more affected by the growth in Chinese import penetration and changes in manufacturing employment, so my results can be interpreted as an upper bound on the effect of the China Shock on environmental outcomes.

Data on infant mortality rates come from the U.S National Vital Statistics System, from the National Center for Health Statistics. County-level data for the years 1990-2014 were downloaded from CDC Wonder's Linked Birth / Infant Death Records. This dataset contains county-level infant mortality data, which is calculated by dividing the number of deaths in the first year of life by the number of live births, multiplied by 1000. For public-use Vital Statistics data, the CDC doesn't report infant mortality for counties with populations fewer than 250,000 people, due to privacy and confidentiality concerns. As such, when these data are collapsed to the CZ-level, I find that only 300 CZs have infant mortality data in the year 1990, and this number gets smaller by 2014 (Table 1). Table 3 shows that CZs with and without infant mortality data are statistically different - CZs without infant mortality data have less manufacturing employment and smaller population sizes. If larger CZs are likely to be impacted by the growth in Chinese import penetration, and changes in manufacturing employment and air quality, it is important to look at the effect of the China Shock on infant mortality in these CZs.

Additional county-level data are obtained from IPUMS NHGIS (National Historical Geographic Information System). Data on total population for the years 1990, 2000, and 2010 are from the Decennial Census.

Finally, Chinese import penetration and CZ demographic data come from Autor, Dorn, and Hanson (2013). The explanatory and instrumental variables on Chinese import penetration are constructed using employment data from the Census County Business Patterns survey and trade data from the United Nations Comtrade Database.

Table 3: t-test Results Comparing CZs With and Without AQI Data and CZs With and Without Infant Mortality Data on Manufacturing Employment and Total Population

	Mean	S.D.	N	t-test
Panel A: Share of Manufacturing Employment				
With AQI Data	7.105542	4.630441	11,214	13.3973**
Without AQI Data	6.121648	5.037477	6,849	
With Infant Mortality Data	7.234525	4.136648	6,477	10.5150**
Without Infant Mortality Data	6.451812	5.130565	11,586	
Panel B: Total Population				
With AQI Data	69,963.76	486,791.2	11,214	10.7230**
Without AQI Data	6,830.682	26,907.66	6,849	
With Infant Mortality Data	113,155.9	636,193.3	6,477	17.6660**
Without Infant Mortality Data	8,497.006	32,700.08	11,586	

**p<0.05

4.2 Empirical Strategy

The empirical methodology in this paper follows the Autor, Dorn, and Hanson (2013) identification strategy. I exploit variation in differential exposure to Chinese import penetration faced by local labor markets (commuting zones) - based on CZs' local industry specialization - as an exogenous labor market shock. More specifically, I estimate the following specification:

$$\Delta Y_{it} = \beta_o + \beta_1 \Delta IP^{cu}_{it} + \beta_2 X_{it} + \alpha_t + \varepsilon_{it} \quad (1)$$

where ΔY_{it} is the decadal change in outcomes in commuting zone i during time interval t; ΔIP^{cu}_{it} is the change in CZ-level Chinese import penetration in commuting zone i during time interval t; X_{it} is the control vector that contains start-of-period CZ-level demographic and occupational controls; α_t is an indicator variable for the 2000-2014 period. The main outcome variables of interest are manufacturing employment, air pollution (measured by AQI), and infant mortality rate. The outcome variables are calculated by stacking ten-year or fourteen-year equivalent first differences for the two time periods, respectively: 1990 to 2000 and 2000 to 2014. These time periods are determined by China's trade expansion timeline: China's export boom began in the early 1990s, and crucial changes in U.S.-China trade policy occurred in 2000. Autor, Dorn, and Hanson (2018) show that Chinese import penetration rose by 0.95 percentage points from 1990 to 2000, with an additional 1.15 percent rise per decade from 2000 to 2014. Since ΔIP^{cu}_{it} is the key explanatory variable, β_1 is the coefficient of interest.

In this model, the regressor is the average change in Chinese import penetration experienced by the local labor markets, weighted by manufacturing's share in initial CZ employment:

$$\Delta IP^{cu}_{it} = \frac{L^{1990}_{i,manufacturing}}{L^{1990}_{i}} \frac{\Delta M^{cu}_{t,manufacturing}}{D^{1991}_{manufacturing}} \tag{2}$$

The first term $\frac{L^{1990}_{i,manufacturing}}{L^{1990}_{i}}$ is the share of commuting zone i's labor force employed in manufacturing the base year, as measured by the Quarterly Census of Employment and Wages.[1] Since my time periods of analysis are 1990-2000 and 2000-2014, I use 1990 employment levels as start-of-period measures. The second term $\frac{\Delta M^{cu}_{t,manufacturing}}{D^{1991}_{manufacturing}}$ is the growth of Chinese penetration in the U.S. that the manufacturing industry faced over time period t. It is calculated by dividing the growth in U.S. manufacturing imports from China, $\Delta M^{cu}_{t,manufacturing}$, by initial domestic demand in the base year 1991, $D^{1991}_{manufacturing}$ (where D is equivalent to U.S. manufacturing shipments plus net imports; $D_{manufacturing} = GDP_{manufacturing} + M_{manufacturing} - X_{manufacturing}$). Here, 1991 is the base year as it is

[1] The share of manufacturing employment is used as a proxy for the scale of manufacturing activity within a CZ, as it is the only comparable scale variable for different types of manufacturing sectors. A downside of using this variable as a proxy is that if different manufacturing industries with higher labor intensities are relatively environmentally friendly, we might assign more weight to cleaner sectors and less weight to dirtier sectors while composing our exposure measure.

near the start of China's export boom. This variable shows the magnitude of the trade shock relative to the employment structure in each commuting zone. Differences in ΔIP^{cu}_{it} across CZs arise from variation in local employment structure in 1990, with some CZs experiencing a greater trade shock due to a larger baseline concentration of employment within manufacturing as compared to non-manufacturing industries.

Appendix Figures A1, A2, A3, A4, and A5 plot CZ exposure to the China Shock ($\Delta IP^{cu}_{it,}$) against pre-shock population size, manufacturing employment, maximum AQI, median AQI, and infant mortality rate, respectively. These figures show that there is no clear relationship between China-U.S. import penetration and pre-shock (1990) levels of any variable. Appendix Figures A6, A7, A8, and A9 plot CZ exposure to Chinese import penetration against the change in manufacturing employment, the change in maximum AQI, the change in median AQI, and the change in infant mortality rate, respectively. Figure A6 shows that there is a clear negative correlation between import penetration and manufacturing employment, indicating that as a CZ's exposure to import competition increases, manufacturing employment decreases. Figures A7, A8, and A9 show a weak or no relationship between rising import penetration and air quality or infant mortality rate. This confirms the findings in Table 2.

4.2.1 Instrumenting for Chinese Import Penetration

The variable ΔIP^{cu}_{it} may potentially be endogenous, however, as the level of Chinese import penetration in the U.S. could be due to import demand shocks from within the U.S. In other words, both Chinese imports and CZ employment levels might be correlated with unobservable domestic shocks to manufacturing product demand in the U.S. For instance, stricter environmental regulations within the U.S. (driven by domestic pressure for cleaner air) may be causing offshoring and increased imports from China at the same time that Chinese imports are inducing offshoring and decreased manufacturing production - and thereby less air pollution emissions - in the U.S. If this is the case, the OLS results could be biased and give an incorrect estimate of the true effect of increased Chinese imports.

In order to mitigate this endogeneity bias and identify the causal impact of increasing Chinese import penetration on manufacturing employment, I follow the instrumentation strategy in Autor, Dorn, and Hanson (2013). I instrument growth in Chinese imports to the U.S. by using the growth of Chinese imports to eight other high-income countries.[2] This instrument satisfies both IV assumptions. First, Chinese imports to other high-income markets are correlated with Chinese imports to the U.S. through China's exports to all of these countries. This correlation is empirically proven via first-stage estimates in Table 5 Panel B. While the second IV assumption cannot be proven empirically, it is believable that Chinese imports to other high-income countries are not correlated with any outcome variables (like U.S. manufacturing, air quality, and infant mortality) other than through China-U.S. trade. This IV strategy essentially filters out much of the endogeneity, allowing me to capture the components of Chinese import growth that are derived from factors specific to China, such as its productivity and trade costs.

The instrument using imports from China to other high-income countries is calculated as follows:

$$\Delta \mathrm{IP}^{co}{}_{it} = \frac{L^{1980}_{i,\,manufacturing}}{L^{1980}_{i}} \; \frac{\Delta M^{co}_{t-1,\,manufacturing}}{D^{t-1}_{manufacturing}} \tag{3}$$

This is expression differs from (2) because China-U.S. import penetration $\Delta M^{cu}_{t,\,manufacturing}$ is replaced by Chinese imports to eight other high-income markets $\Delta M^{co}_{t-1,\,manufacturing}$. Additionally, other variables are replaced with lagged values in order to mitigate simultaneity bias (a demand

[2] The eight comparison countries (Australia, Denmark, Finland, Germany, Japan, New Zealand, Spain, and Switzerland) are determined by their similarities to the U.S. and the availability of comparable trade data at the detailed level needed to find manufacturing-specific shocks..

shock in the U.S. during time period t might affect demand in other high-income countries at that same time period, so the time period t-1, or pre-1990, values are used instead). The first term also uses lagged (1980) employment data from the County Business Patterns survey in order to control for confounding factors stemming from anticipated trade with China. While this instrument reduces endogeneity bias, it is important to note that this bias is not eliminated completely as demand shocks in these eight other high-income markets could still be somewhat correlated with demand shocks in the U.S.

5 Results

5.1 Main Results

Table 4 below presents the OLS estimates of the impact of Chinese import penetration on U.S. manufacturing employment, air quality index, and infant mortality. Table 5 shows the corresponding results from the IV regression. All regressions include the following start-of-period (1990) commuting zone level controls: the lagged share of the CZ population in manufacturing employment (which absorbs general shocks to the sector and isolates the variation in exposure to trade that comes from differences in industry mix), share of foreign-born population, share of college-educated population, racial composition, occupational controls for employment in jobs susceptible to offshoring and automation, and dummies for U.S. Census divisions. Robust standard errors are clustered at the state level to control for state-level variation in environmental regulations.

Table 5 Panel B provides the first-stage regression results. Across all specifications, I observe a strong, positive, and statistically significant correlation between the instrument and outcome variables, implying that the instrument ΔIP^{co}_{it} is correlated with the old explanatory variable of the change in China-U.S. import penetration ΔIP^{cu}_{it}. The F-statistics range from 72 to 80, implying that the underlying relationship is fairly strong.

Table 4: Estimated Impact of Manufacturing Trade Shock on Manufacturing Employment, Air Quality Index, and Infant Mortality Rate, 1990-2014 (OLS regression)

	Manufacturing Employment	Air Quality		Infant Mortality Rate
		Max AQI	Median AQI	
	(1)	(2)	(3)	(4)
Δ Import penetration	-0.408**	3.09	-1.507**	0.224
	(0.086)	(5.82)	(0.655)	(0.184)
Level in 1990	8.24	132.7	35.2	10.5
Observations	1,444	752	752	364

**p<0.05

Notes: Dependent variables: change in percentage of CZ population employed in manufacturing; change in maximum AQI levels, change in median AQI levels; change in infant mortality rate. All models include a dummy for the 2000–2014 period, occupational composition controls (start-of-period indices of employment in routine occupations and of employment in offshorable occupations as defined in Autor and Dorn 2013), start-of-period shares of commuting zone population that is Hispanic, black, Asian, other race, foreign-born, and college-educated. All regressions with the outcome variable infant mortality use an additional control for the share of women who are employed. Models are weighted by the product of period length and commuting zone share of the start-of-period U.S. mainland population. Robust standard errors in parentheses are clustered on state.

Table 5: Estimated Impact of Manufacturing Trade Shock on Manufacturing Employment, Air Quality Index, and Infant Mortality Rate, 1990-2014 (IV regression)

	Manufacturing Employment	Air Quality		Infant Mortality Rate
		Max AQI	Median AQI	
	(1)	(2)	(3)	(4)
		Panel A: 2SLS Estimates		
Δ Import penetration	-1.08**	5.53	-1.84	-0.0718
	(0.163)	(9.17)	(1.58)	(0.329)
		Panel B: First Stage Estimates		
Import penetration instrument	0.644**	0.657**	0.657**	0.661**
	(0.0558)	(0.0673)	(0.0673)	(0.0761)
F-statistic	78.73	80.93	80.93	72.99
Level in 1990	8.24	132.7	35.2	10.5
Observations	1,444	752	752	364

**p<0.05

Notes: Dependent variables: change in percentage of CZ population employed in manufacturing; change in maximum AQI levels, change in median AQI levels; change in infant mortality rate. All models include a dummy for the 2000–2014 period, occupational composition controls (start-of-period indices of employment in routine occupations and of employment in offshorable occupations as defined in Autor and Dorn 2013), start-of-period shares of commuting zone population that is Hispanic, black, Asian, other race, foreign-born, and college-educated. All regressions with the outcome variable infant mortality use an additional control for the share of women who are employed. Models are weighted by the product of period length and commuting zone share of the start-of-period U.S. mainland population. Robust standard errors in parentheses are clustered on state.

Manufacturing Employment

In both Table 4 Column (1) and Table 5 Column (1), the OLS and IV regressions respectively indicate that there is a negative and statistically significant relationship between the change in Chinese import penetration and the share of manufacturing employment. The OLS estimate in Table 4 Column (1) finds that a one standard-deviation increase in import penetration in commuting zone i (equal to the average decade-level CZ-level rise in trade exposure from the 1990 to 2014 period) leads to a decrease in the average share of manufacturing employment by 0.393 percentage points ($t = -4.75$). When the main variable of interest is replaced with the instrument, I find similar results in Table 5. Panel A Column (1) shows the 2SLS estimates, which find that a one-unit increase in import penetration in commuting zone i leads to a decrease in the average share of manufacturing employment by 1.08 percentage points ($z = 6.66$). These results are consistent with findings in previous studies (Autor, Dorn, and Hanson 2013; Acemoglu et al. 2016; Pierce and Schott 2016; Autor, Dorn, and Hanson 2019).

Air Quality

In both Table 4 Column (2) and Table 5 Column (2), the OLS and IV regressions respectively indicate that there is a positive but insignificant relationship between the change in Chinese import penetration and extreme AQI levels. This suggests that changes in manufacturing processes caused by Chinese import exposure do not affect the maximum levels of air quality in a time period - these maximum levels are likely explained by other pollution-causing factors or extreme weather events such as wildfires.

Table 4 Column (3) presents the OLS results for the impact of Chinese import competition on median AQI. The OLS estimate finds that a one standard-deviation increase in import penetration in commuting zone i leads to a decrease in the median AQI by 1.454 on average (t =

-2.30). However, once instrumented, Panel A in Table 5 Column (3) shows that there is still a negative, albeit insignificant, correlation between Chinese import penetration and median AQI (β_1 = -1.84, z = -1.17).

This result is consistent with certain studies that conclude that most pollution reductions from U.S. manufacturing are due to changes in the technology involved in the production of goods or changes in environmental regulation rather than increases in international trade (Levinson 2009; Pierce and Schott 2016). While both of these papers agree that international trade might be able to explain a small amount of pollution reductions from U.S. manufacturing, it is possible that this effect can be better explained by trade with some other countries, from where there have been increased imports of "dirty" intermediate inputs in recent years.

Infant Mortality

In both Table 4 Column (4) and Table 5 Column (4), the OLS and IV regressions respectively indicate that there is an insignificant relationship between the change in Chinese import penetration and infant mortality rate. In Table 4 Column (4), the OLS estimate is positive and insignificant (β_1 = 0.224, t = 1.22) while in Table 5 Column (4), the IV estimate is negative and insignificant (β_1 = -0.0718, z = -0.22). It is plausible that no statistically significant effect can be observed here because there was limited effect of Chinese import penetration on air pollution.

While my regression analyses do not show any significant relationship between Chinese import penetration and infant mortality, Ukil (2019) shows that there is a significant effect on other infant health outcomes. She finds that increased exposure to trade with China leads to increased economic anxiety and maternal stress from spousal employment losses in manufacturing industries, which in turn causes a decrease in average birth weight and an increase in the incidence of low birth weight. Although previous literature (Chay and Greenstone 2003) finds that cleaner air quality during pregnancy decreases infant mortality rates, potential improvements in air-quality-related positive infant health outcomes due to the China Shock may be canceled out by maternal-stress-related negative infant health outcomes.

5.2 Robustness Check

It is possible that Chinese import competition affected migration within the U.S. When jobs are lost, people are more likely to relocate to areas with greater job opportunities, which might cause high population density and contribute to air pollution (through the use of electricity/transportation). Appendix Table A1 summarizes average population growth rates for CZs from 1990 to 2014. Table 6 shows the results of a robustness check looking at the effect of Chinese import penetration on the change in a CZ's population size. I don't find any statistically significant effect, indicating that Chinese import penetration didn't affect air pollution via changes in migration. Appendix Figure A10 confirms this, showing that increased exposure to Chinese import competition doesn't affect population size in most CZs.

Table 6: Estimated Impact of Manufacturing Trade Shock on Migration, 1990-2014

	Total Population	
	OLS (1)	IV (2)
Δ Import penetration	-5,731.917 (30,132.23)	6,633.877 (41,514.49)
Observations	1,444	1,444

**p<0.05

Notes: Dependent variables: change in percentage of CZ population employed in manufacturing; change in maximum AQI levels, change in median AQI levels; change in infant mortality rate. All models include a dummy for the 2000–2014 period, occupational composition controls (start-of-period indices of employment in routine occupations and of employment in offshorable occupations as defined in Autor and Dorn 2013), start-of-period shares of commuting zone population that is Hispanic, black, Asian, other race, foreign-born, and college-educated. Models are weighted by the product of period length and commuting zone share of the start-of-period U.S. mainland population. Robust standard errors in parentheses are clustered on state.

6 Conclusion

This paper contributes to a long-standing debate over the environmental effects of trade liberalization. The effects of China's rapid export boom in the 1990s and 2000s were far-reaching and all-encompassing, impacting everything from mining communities in Brazil (Dornelas and Chimeli 2019) to marriage markets in the U.S. (Autor, Dorn, and Hanson 2019). My analysis examines how trade relations with China - a subject that remains politically contentious to date - affected manufacturing employment, air quality, and infant mortality in the United States. I identify these effects by exploiting U.S. local labor markets' exposure to Chinese import competition as an exogenous source of variation.

Results indicate that a one standard-deviation increase in import penetration from China in commuting zones within the United States led to a 0.393 percentage point decrease in the share of manufacturing employment. Using manufacturing employment as a proxy for the environmental effects of manufacturing activities, I then estimate the effects of increased Chinese penetration on air pollution and infant mortality. While this paper highlights the correlation between international trade and the environment, results do not find any statistically significant effect on either of these outcomes.

The scope for further research includes looking at how import competition from China affects the pollution emitted by individual manufacturing plants in the U.S. via within-plant compositional or technological adjustments. While research has primarily focused on the relationship between trade and aggregate pollution levels, recent studies suggest that within-plant responses to trade are an important determinant of how trade liberalization affects the environment (Cherniwichan 2017). Due to the hefty contributions of the industrial sector to U.S. greenhouse gas emissions, going forward, it is vital to examine how individual manufacturing plants alter their emissions in response to trade. These within-plant changes can help inform policy recommendations on how manufacturing plants - not just in the U.S. but worldwide - can reduce their emissions. Given the urgency of climate change, these further studies are critical and time-sensitive.

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Appendix

Figure A1: Commuting Zone Exposure to China Shock by Pre-Shock Population Size

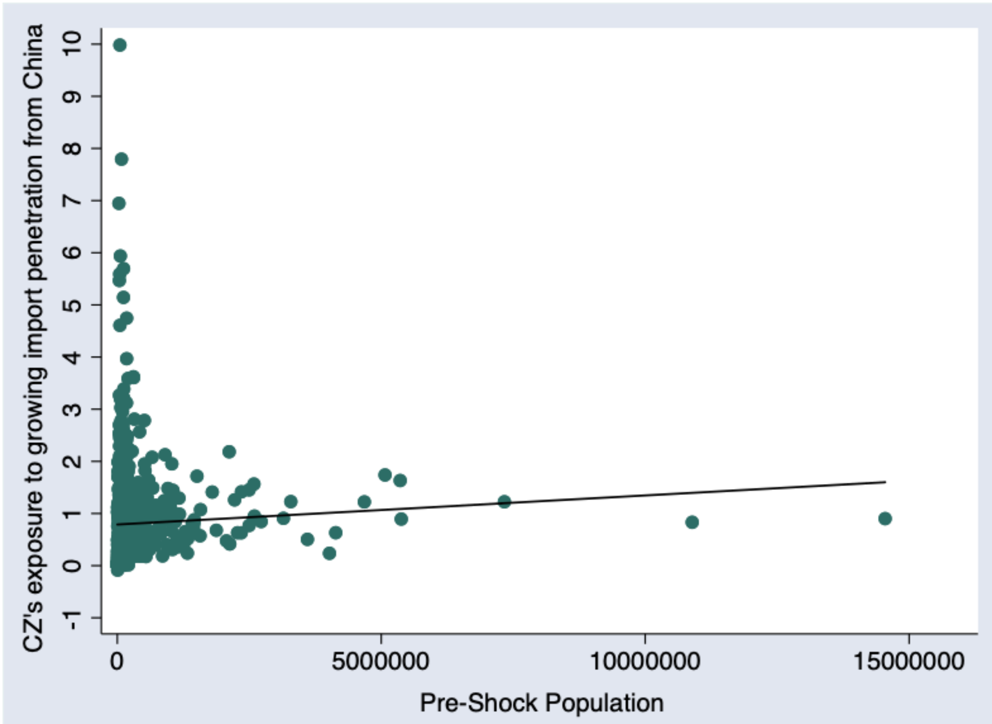


Figure A2: Commuting Zone Exposure to China Shock by Pre-Shock Manufacturing Employment

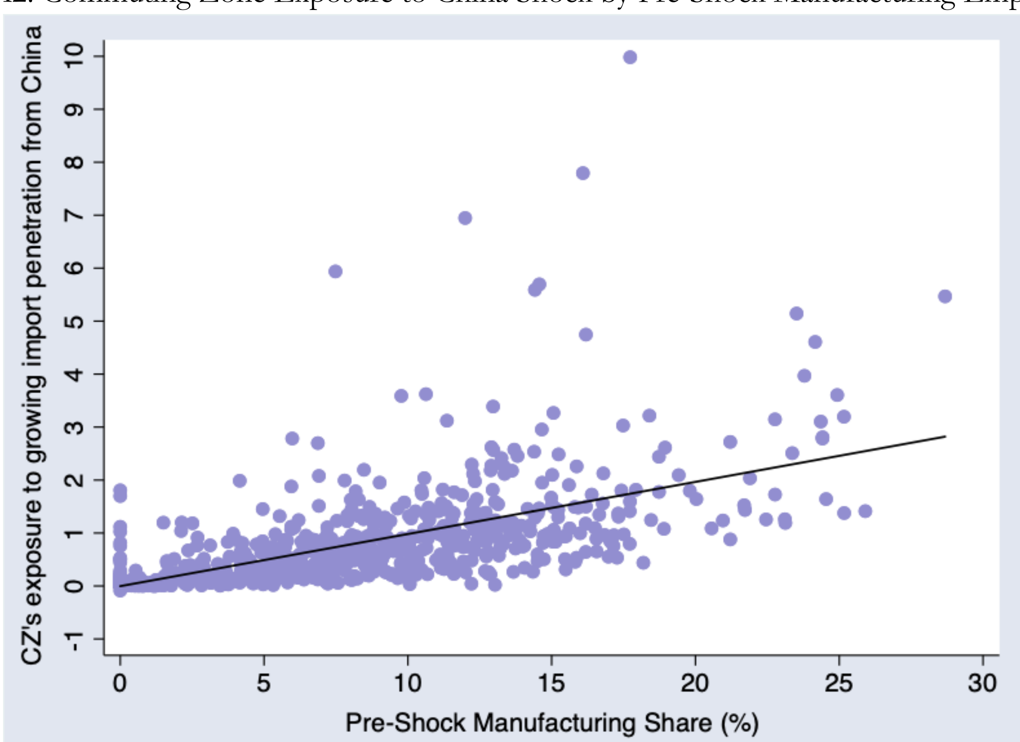


Figure A3: Commuting Zone Exposure to China Shock by Pre-Shock Maximum AQI

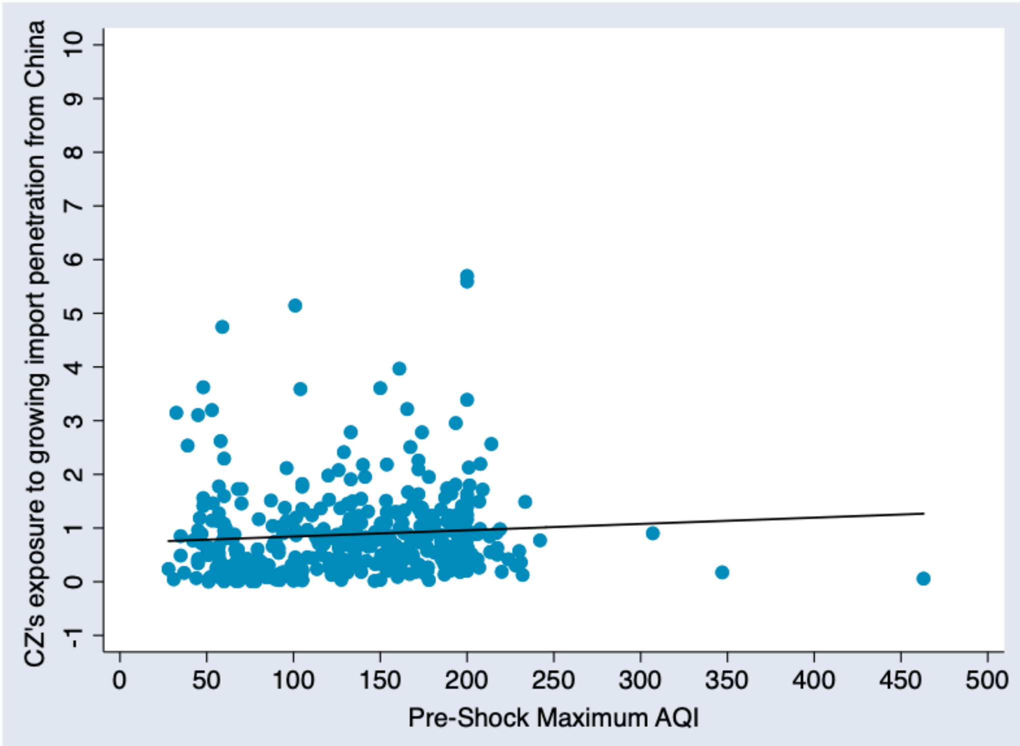


Figure A4: Commuting Zone Exposure to China Shock by Pre-Shock Median AQI

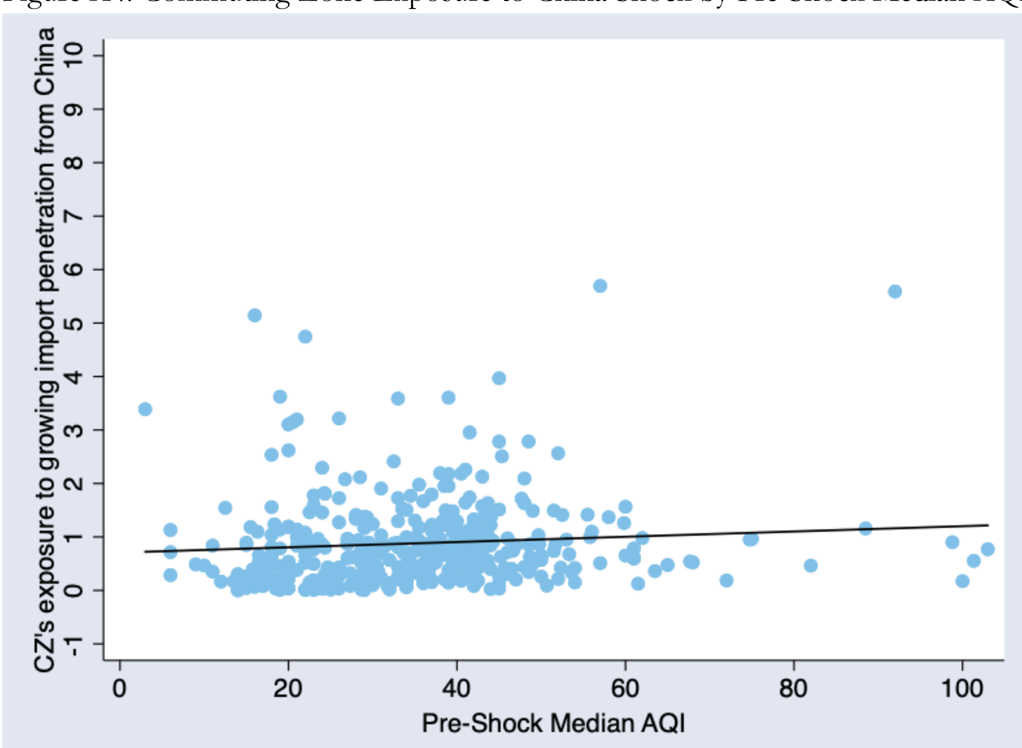


Figure A5: Commuting Zone Exposure to China Shock by Pre-Shock Infant Mortality Rate

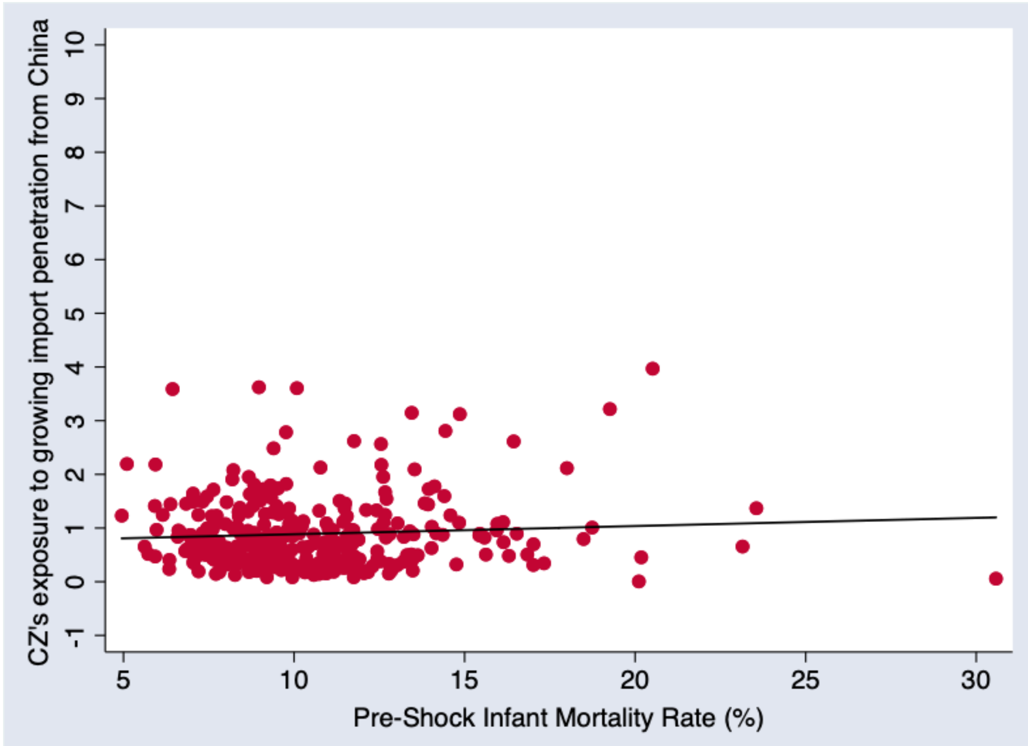


Figure A6: Commuting Zone Exposure to China Shock vs.
Changes in Manufacturing Employment, 1990-2014

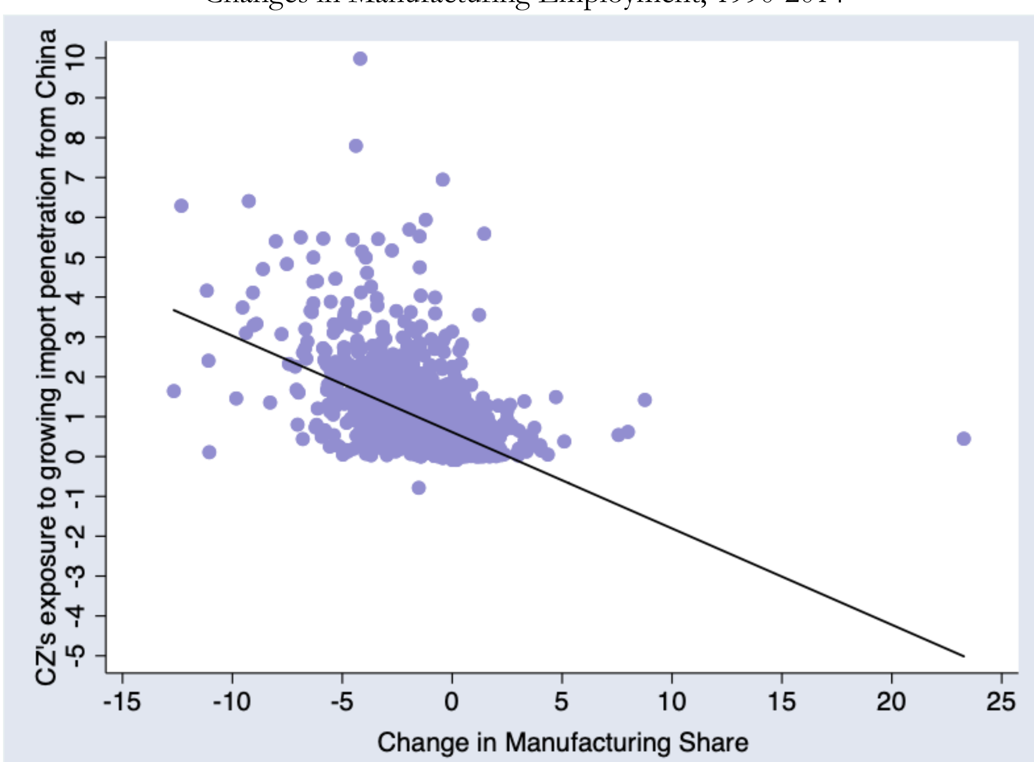
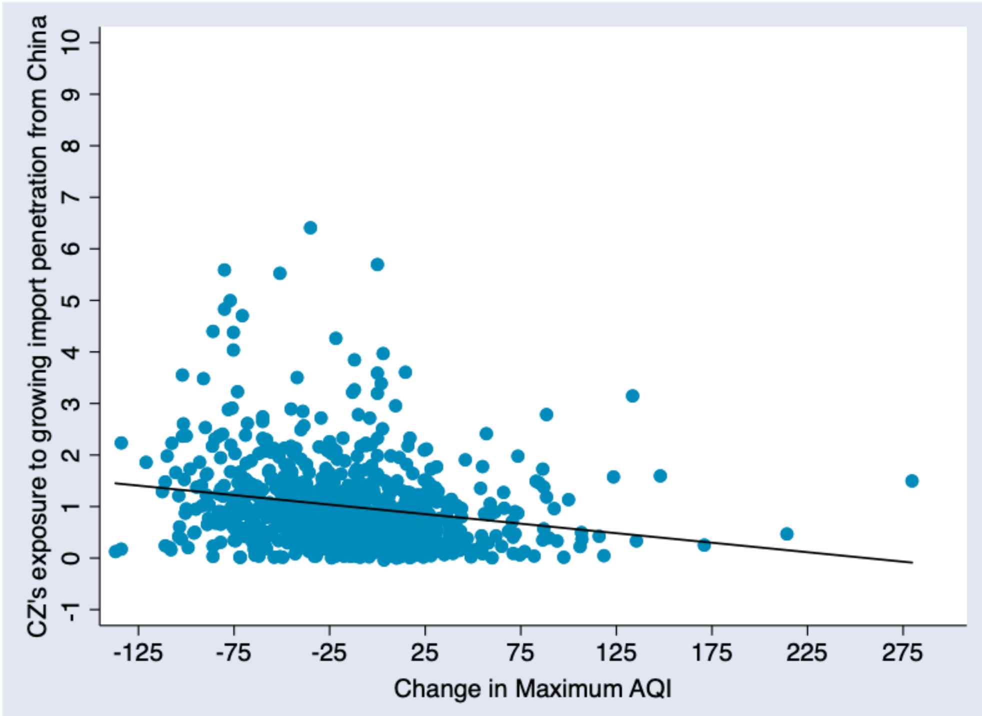


Figure A7: Commuting Zone Exposure to China Shock vs.
Changes in Maximum AQI, 1990-2014



Notes: CZ 37903 was excluded due to abnormalities in the data

Figure A8: Commuting Zone Exposure to China Shock vs.
Changes in Median AQI, 1990-2014

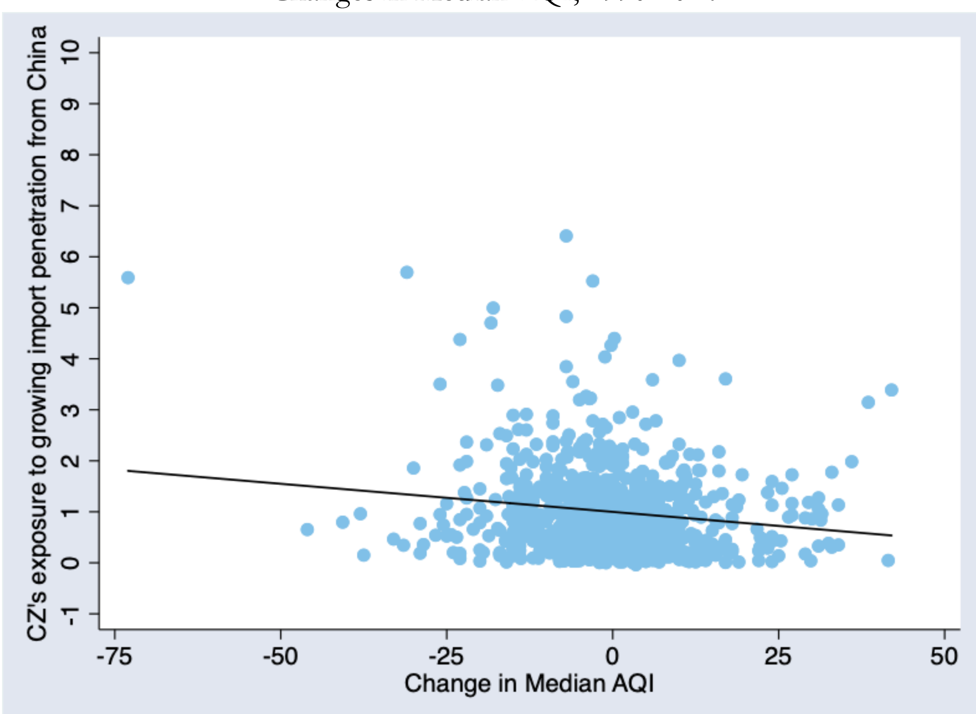


Figure A9: Commuting Zone Exposure to China Shock vs.
Changes in Infant Mortality Rate, 1990-2014

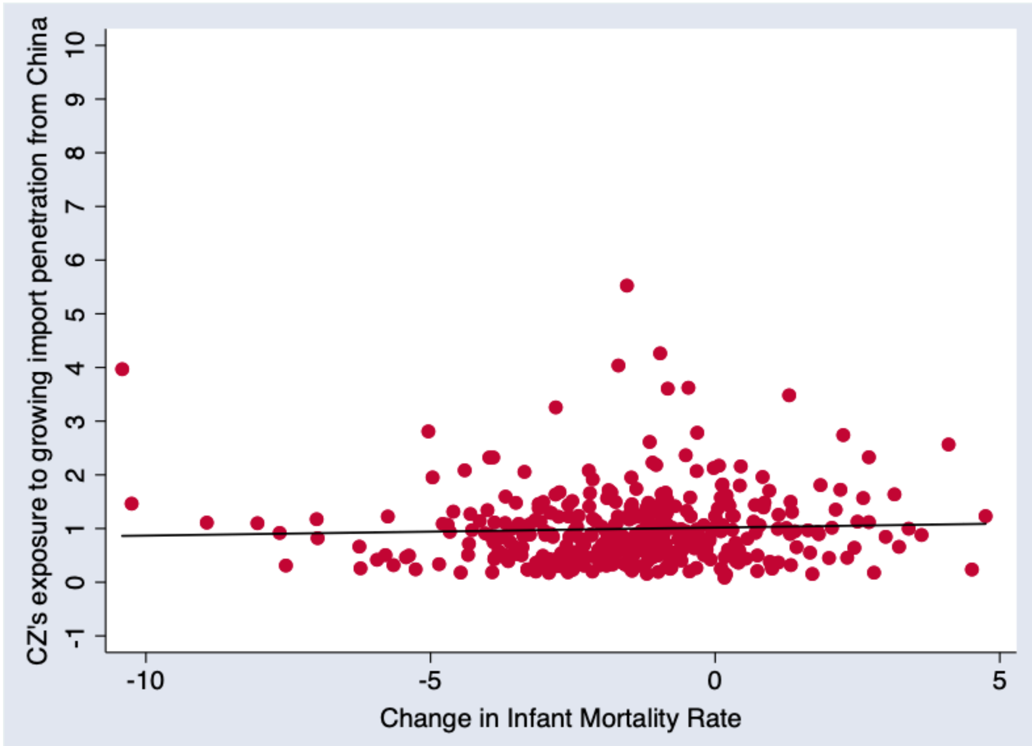


Figure A10: Commuting Zone Exposure to China Shock vs.
Changes in Population, 1990-2014

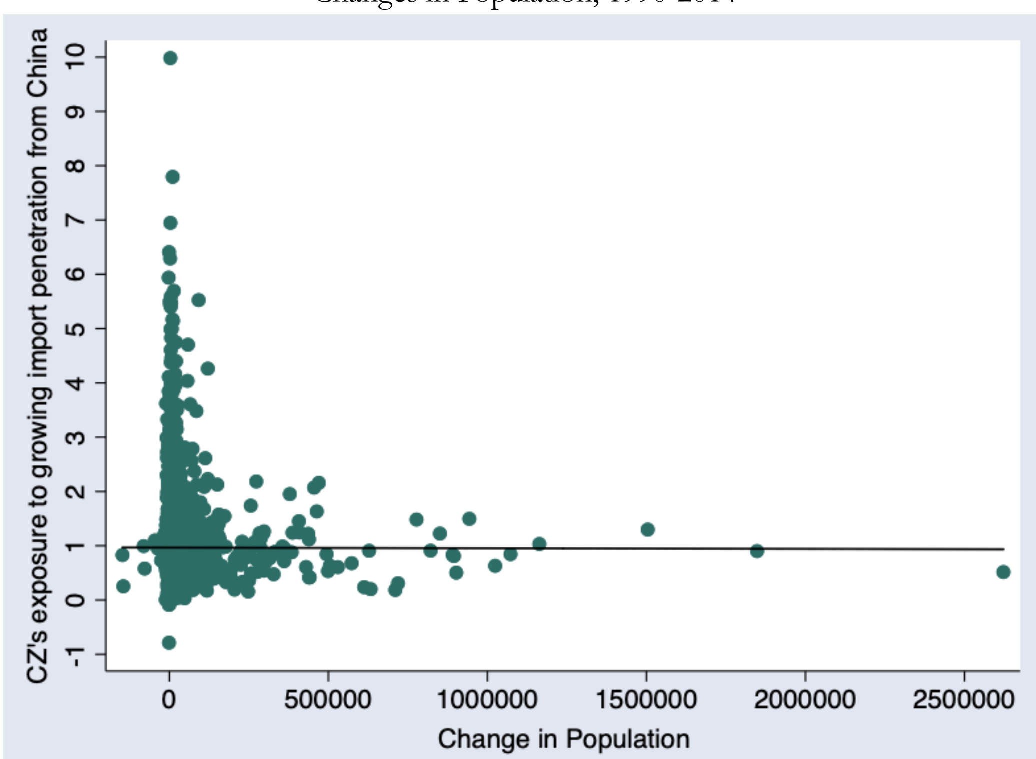


Table A1: Summary Statistics of Population Growth Rate

	Mean	**S.D.**	**Min**	**Max**	**N**
Population Growth Rate, 1990-2000	4.708743	9.804793	-19.39496	46.69582	722
Population Growth Rate, 2000-2010	9.62467	14.48321	-21.6834	196.6579	722
Population Growth Rate, 1990-2010	15.77652	24.93858	-32.54438	223.7759	722