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Essays on the link between pollution and local financial Products

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Covid Impact Statement

The covid lockdown greatly impacted the progress of this research. During the length of the lockdown, we were locked out of the office with our entire database and research tools locked within. During the initial lockdown, the university did not provide remote access, bringing any type of progress to a standstill. Throughout the entire Covid-period, progress was intermittently interrupted by connection or technical issues. It was only around April 2021 that I was able to take all my affairs out of the office and to continue my research uninterrupted.

This delay meant that my funding ran out well before this research reached fruition. Due to the living cost crisis and living challenges of the last year or so, I had to acquire a full-time job while also pursuing this research full time. A challenge that would have had its own implications for this research.

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الحمد لله أولا وآخرا وظاهرا وباطنا

و

من لا يشكر الناس لا يشكر الله

This thesis would not have been possible without the support of my supervisors: Dr Alfonso Dufour and Dr Andreas Hoepner. I would also like to acknowledge all my co-authors with whom I worked on my final research chapter. I would also like to extend my gratitude to the doctoral scholarship programme of the ICMA centre, and all the support and guidance the institution has provided.

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هذا ما عندي، فإن أحسنت فمن الله، وإن أسأت أو أخطأت فمن نفسي والشيطان

To my family and friends

Abstract

Our thesis consists of three studies. Our first study focused on the impact of water pollution and municipal bonds issued by county authorities in the United States. Using the Toxic Release Inventory database, we used a measurement of toxicity and environmental impact to quantify the yearly level of pollution and found a correlation between the quantity, impact and toxicity of the chemicals and the yield of the bond issuances. To demonstrate causality, we used difference in difference around local green chemistry laws.

Our second study focused on chemical accidents. To our knowledge, this is the first study investigating the impact of chemical accidents and leaks on cities. Using the toxicity and environmental impact figures developed earlier, we studied how accidents in industrial facilities could increase the yield of city-level municipal bonds issuances. We also analysed the impact of medical monitoring laws on the distribution of risk between the public and private sectors and found that cities within medical monitoring states tend to suffer a smaller impact to their yield when accidents occur. We also found that these medical monitoring laws transfer the risk of accidents to the corporate bond issues of the owners and operators of the facilities where the accidents occur.

Our third study focused on what entrepreneurs can do to reduce pollution. We investigated the relationship between green start-ups and air pollution, by creating a global dataset of start-ups and cities. We then examined how these start-ups impacted air quality and found that the cumulative number of green start-ups drove down the number of PM2.5. We

also performed a sub-sectoral analysis to identify which start-ups had the greatest impact on reducing air pollution. We found that green start-ups do reduce the level of air-pollution in urban centres, especially those related to material science and green energy.

Table of Contents

List of Figures

List of Tables

1. Introduction

"Evil has appeared on land and sea because of what the hands of men have earned, that Allah may make them taste a part of that which they have done, in order that they may return" (30:41 Quran) (Al-Hilali & Khan, 1998).

1.1. Introduction

Environmental sustainability is a pressing topic. In Europe, two record breaking heat waves, a historic drought, and war in Ukraine have revealed that dependence on polluting energy sources is no longer viable. From the war, Europe has lost its access to cheap fossil fuels, while the heatwaves and drought may be linked to the release of pollutants.

The financial sector provides four key functions for society: providing payment systems, matching capital with demand, managing personal and intergenerational finances, and providing risk management services to individual and corporate investors. Over the twentieth century, the sector evolved from a simple lubricant for the economy to one of the main pillars of a developed economy. However, one of the main shortcomings in the fourth key function was not accounting for the externalisation of costs from businesses to society (Fatemi & Fooladi, 2013). With climate change and pollution in general, the costs of clean-up or remediation are never limited to culpable businesses (Andrew, 2008). The externalisation of these costs was driven by capitalism and profits; however, in as early as the 1970s, people – especially those in large American cities – started to realise that they were paying the pollution costs.

Driven by popular demand – specifically, in California – the federal government introduced stricter environmental policies. This governmental effort was aimed at removing these costs from consumers, who pay through health problems or quality-of-life sacrifices and transferring them back to the businesses responsible for the pollution. During this period, the Nixon administration established the Environmental Protection Agency (EPA), approved the Clean Air Act and the National Environmental Policy Act, established the National Oceanic and Atmospheric Administration, and approved the Federal Water Pollution Control Act. This period of US history is now known as the environmental decade.

Despite these efforts, the financial sector continued to price only legal liability risk in its financial products offered to polluters. Also, many firms continued to fight well into the 2010s to lower the liability risk and externalise even more costs. Since the environmental decade, a crucial political shift took place in one of the two main political parties in the United States. With the right-wing shift of the Republican Party, the party that produced the EPA and accomplished many other environmental milestones, became the Mecca for advocates of relaxed environmental regulation. The culmination of this movement was Donald Trump leaving the Paris Agreement and the US Supreme Court diminishing the power of the EPA to control CO_2 emissions.

Since the second half of the 1990s, these pollution externalities have been included in asset pricing. This began with the introduction of legal liabilities and ad-hoc state legislation and continued with large efforts developed by the EPA to build programs for monitoring pollution. The most famous of these programs is the toxic release inventory (TRI), which was established in 1985 and started reporting about toxic releases in 1987. However, due to a lack of expertise within the EPA itself, much of the toxicity information was founded on the goodwill of the industry to share such information. Clearly, this issue may hamper the reliability of the information collected and it has already led to many adjustments to the programme, with major changes implemented principally in 1998. Despite its many limitations, including the number of chemicals it tracks, the TRI programme remains one of the longest-running and most consistent pollution-tracking programmes available.

This thesis is split into two parts. The first part, Chapters 4 and 5, focuses on how non-polluting, publicly funded institutions must pay for the externality cost of pollution in their areas – specifically, counties and other places. In the US, places – such as urban areas, including villages, towns or even major cities – are designated by the Census Bureau. Often, public institutions find themselves forced to pay for pollution caused by private manufacturers in their areas; in fact, the institutions' positions are sometimes precarious regarding emitters, especially in small, rural towns and villages dependent on specific industries for jobs and taxation. We call this concept *the municipal dilemma*, in which local governments must choose between jobs and income when planning about their natural resources and the wellbeing of their citizens.

The second part of this thesis, Chapter 6, focuses on how entrepreneurs and the private sector can alleviate many of the pollution problems faced by local authorities. The major differences between this part of the thesis and the previous part are in the scope and range of the datasets used; whereas the first part focuses solely on the United States due to the availability of data and the length of the sample period, the second part uses a global sample and takes a global approach to tackling the emissions problem.

To build the datasets used in our analysis for each of the chapters, tools such as geographic information systems (GIS) were used to geolocate, map and identify emitters and the boundaries of local authorities and, in some cases, conglomerations of urban areas.

The goal of this thesis is to tell a story about how the private sector has externalised pollution costs to other institutions, usually those funded by taxpayers. These institutions have had to compensate for this pollution through higher cost of capital at the expense of their local populations, which populations often suffer the health consequences of the pollution. Finally, we conclude in Chapter 6 by analysing how, with purpose-driven, place-based entrepreneurship, the private sector could meaningfully reduce pollution.

Over the last few decades, the conversation about pollution and toxicity in the US has been loud and growing louder. Many cases of serious water pollution have galvanised the national conversation on the effects of pollution. A similar conversation occurred in the 1970s, which led to the foundation of the EPA and the environmental decade. However, what is coming to light today is of much more serious consequence to the public. For example, the deliberate mismanagement of Perfluoroalkyl (PFAs) and the Perfluorooctanoic Acids (PFOAs) without the awareness of the EPA or any authorities showed the true limitations of the oversight structures. This issue was first raised in the environmental and legal communities with the case of Parkersburg, West Virginia, before being brought to the general public's attention by Marc Ruffalo in *Dark Waters*. Unfortunately, this case was followed by many other serious pollution cases related to chemical releases.

In the 2010s, several other US water and environmental pollution cases made international headlines, such as the Flint, Michigan water crisis and the water justice movement for native tribes, among others.

Even when dealt with and stored correctly, pollutants still pose a serious risk on the economy and the survival of local areas. For example, when a toxic waste reservoir built to house Phosphogypsum was found leaking in Manatee County, the army corps of engineers asked the residents of many Tampa Bay counties to evacuate. With serious potential for its walls to fail, many towns and urban areas had to be evacuated under threat of an impending chemical flood. Thus, even after polluting ceases and the release of chemicals halts, their long storage poses a serious risk to local communities, and its maintenance risks and costs often fall directly onto local authorities.

1.2. Theoretical framework

Local authorities and populations are in a peculiar place when it comes to managing their local economies. We call their position 'the municipal dilemma', a concept we coined to represent what many see as a choice between environmental regulations and economic stimulus.

Many Americans, especially those on the political Right, believe that lower regulation favours economic growth. With a lower regulatory burden more projects and activities become economically feasible and these lead to higher employment, greater revenues, and wealth creation for local economies. This logic is particularly relevant is in small, rural economies dominated by a single industrial sector.

Many towns whose main activities take tolls on the environment, such as mining towns, have found themselves at the forefront of this type of thinking. As they have suffered in recent decades due to technological development and transition to alternative sources of energy, many have found it easier to simply blame regulations. Even some of the CEOs of mining companies blame politicians for excessive regulations, which may be a simple scapegoating method to divert responsibility.

The best argument against this logic is the oil boom seen in the US over the last decade. Fracking, the main technology behind the latest oil production boom in the US, is a polluting technology and has resulted in serious and sometime irreparable damage to the environment. Indeed, when and where the technology has been profitable, regulations have been either mostly relaxed to allow work to continue or simply incapable of stopping it.

Some states, however, have chosen to forbid fracking, thus choosing to forgo profit in favour of preserving the environment. In contrast, the other side of this debate argues that protecting the environment should take precedence and that any revenue earned from environmentally damaging activities is unsustainable, as the revenue is simply corporations externalising the costs of operation to local communities, who would continue to pay well after the polluting activity has ceased. Those making this argument would point to examples such as Flint, Michigan, which is dealing with serious environmental issues despite most of the original polluters having either closed or moved out (Carmody, 2016).

The environmental issues have led to movements, such as the Lake Erie basic rights charter, passed by referendum by the residents of Toledo, Ohio. The people in the city were dealing with toxic drinking water caused by algae blooms in the lake. Thus, they gave the lake basic rights, which was the first time in US history that nature was given legal rights. The law was quickly struck down in court when one of the main polluters of the lake, Drewes Farm, was joined by Ohio to sue Toledo. The judge argued that the vagueness of the law could result in endless liability and economic damage for multiple groups. This case is a perfect embodiment of the ongoing debate in the US between local activist groups and local authorities on one side and polluters and the general interest of sometimes larger governmental institutions on the other. It is in the context of this debate that our research takes place.

1.3. Research objectives

Our general research aims are to understand how chemical and air pollution impacts local authorities, and to assess whether ad-hoc legislation or local entrepreneurs can effectively control pollution. We start with chemical pollution, as this is the most dangerous. We focus on the US, where the long history of the EPA datasets provides an ideal starting point.

We then analyse whether green start-ups can help reducing air pollution. The general objectives are summarised as follows:

- Provide a better understanding of the municipal bond market's reactions to chemical emissions and air pollution.
- Understand how legislations and litigations can change the emissions risk landscape.
- Provide clarity on who is affected by emission risks, the emitters, or the local authorities where the emissions occur.
- Analyse how effective green start-ups and green enterprises are in decreasing pollution and climate issues.

To obtain an unbiased reflection of the market in this research, we limit ourselves to using primary market data untainted by trades. We understand that, especially with the start-up analysis, there will be a speculation bias; however, by excluding any finances raised outside initial public offerings, we hope to specifically capture the start-up culture.

1.3.1. Chapter 2 objectives

Chapter 2 provides the literature context in which this thesis takes place. We begin by introducing the main concepts and providing their histories before discussing the recent literature on the concepts, which include the following:

- Municipalities and the finances of local authorities in the US. We explain municipal bonds and their history and importance.
- The history of the TRI and how it has changed over time, relative to other toxicity and emission databases released by the EPA. We

discuss some of the serious health risks associated with chemicals across the United States.

- Legal and political milieu in which these emissions and regulation changes occur.
- The role of start-ups as local grassroots movements in making positive changes in their environments.

1.3.2. Chapter 3 objectives

Chapter 3 explains the research methodologies used in this thesis. We explain most of our data manipulation and how we constructed our variables. The objectives are as follows:

- Provide a clear methodology on how we mapped bond issuances.
- Provide step-by-step instructions for how we mapped the sources of pollution and the start-ups.
- Explain how we managed toxicity and created environmental impact factors.

1.3.3. Chapter 4 objectives

Chapter 4 provides empirical evidence to show the link between water pollution and municipal finances. We hypothesised that pollution introduced into water tables result in a direct increase in water management and clean-up costs to local authorities. We performed this analysis on a county level since water systems are managed by county governments. The objectives are as follows:

- Provide an empirical analysis between pollution and municipal bonds issuance yield.

- Establish causality using state laws that introduce significance restrictions on large groups of chemicals deemed risks to the population.
- Establish the importance of chemical toxicity metrics in understanding the impact of chemical releases.

1.3.4. Chapter 5 objectives

To our knowledge, this is the first financial study investigating the impact of medical monitoring laws in mitigating the impact of chemical accidents on local authorities. Instead of focusing on large areas that could have more resource independence, we focused on places, or any urban area recorded by the Census Bureau. Our objectives were as follows:

- Provide an empirical link between the finance of places and cities and any accidental release of chemicals within their boundaries.
- Limit ourselves to the EPA datasets, which show the identities of polluters.
- Conduct a two-sided analysis covering the risk for municipal bonds and the corporate debt market.
- Study how medical monitoring laws shift future medical liability from local populations and authorities to polluters.

1.3.5. Chapter 6 objectives

In this chapter, we aim to show that by enabling and hosting green initiatives, cities and localities may improve their environments. We focused on urban centres that have hosted green start-ups since the early 2000s and how this green funding impacted air quality. We aimed to accomplish the following:

- Study the impact of venture capital on air pollution by comparing cities with venture capital to cities without it.
- Determine whether cities with green start-ups are more capable of addressing air pollution.
- Identify the green start-up sector with the greatest impact on reducing air pollution.

1.4. Methodologies

The methodology of this research was built in layers, each of which required a different approach and skillset. These layers had to include an understanding of the physical and scientific realities before expanding into financial services and products.

The first layer was mapping. Everything we analysed had to be coded into useful geographic information systems (GIS) maps. This included local authorities, chemical release points, start-ups, and municipal products. The last of these had to be mapped through issuance contracts, which we obtained through the Municipal Securities Rulemaking Board (MSRB) database. We processed nearly 2.5 million bonds. These securities were then linked to the areas on the Census Bureau maps that best matched their services. This methodology will be explained in more detail in the next chapter.

As for the chemicals, we use methods to estimate their toxicity and potential impact on the environment and then standardised these values. Then we used EPA metrics to estimate the impact of the chemicals with a factor we constructed. Air pollution was provided by one of our partners in the OECD.

For financial modelling, we used many tools. Because we had a large dataset with many issuers over different time periods, each of which had different issuances, we ended up with an unbalanced panel dataset. Thus, we estimated our results using panel regression. We also used logit regressions, placebo tests, and difference in differences among other tests for robustness.

1.5. Limitation of research

The first general limitation in our research was the data itself. Most of our data had to be mapped and geolocated, which introduced inaccuracy. For example, factories are areas identified on maps by simple points. Further, whether mapping cities, counties, or urban areas, there is a level of uncertainty introduced by the original mappers. Thus, we used only official maps. Adding to this inaccuracy is the fact that local authorities are fluid environments; they change, expand, merge, or simply cease to exist. Due to the lack of availability of all the historic maps of all the local authorities, we used official maps from 2017.

Aside from the mapping, we also encountered other data inaccuracies. These included demographic controls, which were limited to official estimates and censuses, which are carried out only once per decade in the US.

The last major uncertainty of our analysis was caused by the issuers. Unlike similar research, we built our dataset from the ground up. We read the issuance contract of every bond issued in our dataset and allocated them to the areas that best corresponded to their jurisdiction. This introduced a potential for human error, even though we detected mismatches within the MSRB database itself. The geolocation of the start-ups was automated using available databases. However, despite being reliable with a Latin alphabet, the geography was more challenging when the addresses were in different alphabets.

1.6. Conclusion

The challenges brought on by pollution and the long-term impacts of emissions are serious and growing. The externalities of these emissions, which have long been thought to not affect the long-term growth of an economy, are now coming back to bite. It is therefore reasonable for them to be priced into the financial risks of securities issued by the biggest polluters. In our research, the questions we tried to answer can be broken down into multiple layers.

First, public finances are one of the main players impacted by pollution and climate change. Until recently, it was assumed that the cost of releasing toxic substances was born mainly by the company responsible for the chemicals, especially in the developed world; after all, governments establish and fund institutions like the EPA as well as environmental ministers, secretaries, and specialists (Matsumura, Prakash, & Vera-Munoz, 2013; Hsu, Li, & Tsou, The Pollution Premium, 2022). However, the real impact of such institutions is limited to tracking and controlling. When firms work within the established rules, they still externalise the cost of their legal pollution to outside environments.

Second, we aim to show that despite being a victim of these emissions, local authorities have power to enact legislation that protects them. To illustrate this, for the first two chapters we examine only state regulations. But we also wanted to understand the general impact of legislations on emission responsibility. So instead of focusing on one type of legislation, we try to understand three: local emission-limiting laws, responsibility-shifting laws, and national regulations setting new standards. The first type corresponds to a state wanting to limit emissions by banning specific chemicals or processes, the second corresponds to states deciding to introduce rules that force polluters to assume more of the costs of the pollution, and the third analyses new laws that set new air quality standards in different countries and how these laws can catalyse ground-level entrepreneurial activities. Thirdly, we sought to understand how venture capital has the power to change realities and how local populations can do so.

2. Literature review

2.1. Introduction

A major American issue is the intersection of and interaction between pollution, activists, and governments. Climate change is felt across the globe; however, this intersection is American in origin and will continue to be a defining debate of American politics for the near future.

Historically, the US has been responsible for the most emissions and chemical releases in the world. The country was responsible for four hundred billion metric tons of carbon dioxide since the beginning of the Industrial Revolution. Historically, the US has produced double the amount that China has produced to this day (Ritchie, 2019).

Greenhouse gas (GHG) emissions are only a fraction of all the emissions and chemical releases that would have occurred over this period. Much of the chemical pollution produced a century ago still has a tangible impact on the lives of the people who experienced it. Flint, Michigan, is a great example of this. In the last decade, the city has undergone a humanitarian crisis caused by the quality of its water and pipes, which has culminated to nearly 12000 children diagnosed with lead poisoning and 12 direct fatalities (Chapman & Keller, 2016). The event led to a grassroots mobilisation and outrage that compelled a visit by the US president himself.

This event led many journalists to question the origin of the chemical pollution. Many journalists and activists started searching for the source of the pollution in Flint, Michigan, and the Flint River and found historical evidence that the first chemicals were released in the 1830s by the first lumber mills in the area. This problem was exacerbated between the 1900s and 1930s, when the city switched from lumber and paper-based industries to two carriages on automobiles. At that time, the city had been taking its drinking water and industrial water from the Flint River and dumping its wastewater back into it. Thus, pollution from over a century ago prevented the development and prosperity of a city today.

Despite not polluting as much as the US, many other countries have experienced contamination scandals. Especially since decolonisation, this type of news has been more prevalent in developing countries, such as Nigeria. The difference between these countries and the US, however, is the American federal system.

The United States provides a transparent, democratic form of government with strong judicial and scientific oversight that enable its citizens to become full participants in the system. The country also benefits from a high literacy rate, allowing its population to understand their rights and participate in their civic responsibilities. Further, unlike other federal countries such as Russia or Nigeria, the population still trusts and believes in the democratic system.

The geographic nature of the impact of pollution in general and the power of the local governments in the US create a unique interaction between pollution and developments funded by local authorities. These authorities usually use debts from municipal bond markets to fund such developments.

2.2. Forms of government in the United States

2.2.1. State Government vs Federal Government

The writers of the US Constitution compiled a large body of documents called The Federalist Papers. These papers represent the original intentions of the Founding Fathers when they drafted the Constitution. Thus, a large section of the American legal community, known as originalists, regard the papers with reverence. This is relevant, as the initial relationship between the local and state governments and the federal institutions was originally defined in these papers (specifically, Federalist No. 45).

James Madison, the author of the American Constitution, was also the writer of Federalist No. 45, which he titled 'The Alleged Danger from the Powers of the Union to the State Governments Considered'. In this paper, he focuses on quelling the fears of the local populations from an overarching federal bureaucracy. (To better understand the context, the American public had just fought a bloody war of independence to remove a distant tyrant, and there was no room to replace this tyrant with a tyrannical system.) Madison articulated that the states would dominate the union, with power to litigate all ordinary aspects of their citizens' lives, including property rights, internal order, and extensive control over local economies. The federal government's duties and involvement in internal affairs would only be felt during times of danger and war. In application, this meant that the internal affairs of the nation were determined by the states whereas the national and foreign policies were decided in Washington, DC.

This relationship, as defined by Madison, would change significantly after the American Civil War. Before the Civil War, in 1861, the federal government had only 5,837 employees, excluding postal workers. This number tripled by 1871, growing to 15,344 (Rein, 2011), and meant that the federal government would now have a say in property rights, among many other aspects of local life. However, the role of the federal government remained limited for another century.

After the Great Depression, the balance of power shifted further towards the federal government. Before the Great Depression, federal spending accounted for only one sixth of the domestic government; the federal government provided few services directly to people outside the US Postal Service. This conservative approach continued in finances, as the federal government provided meagre financial assistance to the states (Aronson & Hilley, 1986).

After the Great Depression, World War II, the Cold War, and the emergence of the US as the only world superpower, a major shift in the role of the US federal government had to occur. Today, the US federal government plays an increasing role in the lives of Americans (Briffault, The central place of States and Local Governments in American Federalism, 2008). This phenomenon is compounded by the US being involved in wars for most of the second half of the 20th century and all the 21st century thus far. The federal government today employs 2.1 million civilian workers (Congressional Research Service, 2022).

Despite this change in the role of the federal government, the role of the local states is still central to American federalism. As James Madison stated, 'the ordinary course of affairs' should be determined at the state level (Madison, 1788). The rules that structure civil society, including property and land-use, criminal and family law, and waste management and water use are also determined at the state level. Even running for office in the federal government requires abiding by voting rules and regulations determined at the state level (Briffault, The central place of States and Local Governments in American Federalism, 2008). For example, US presidential elections are a series of fifty-one local elections taking place across the country, with each state deciding whom to vote for locally and then sending their delegates to Washington (Cornell Law School, 2022).

Federal law	State Law	Local Laws
• Immigration Law • Bankruptcy law • Social Security and Supplemental Security Income • Patent and Copyright laws • Federal criminal laws: Tax evasion and financial crimes mostly.	• Criminal Matters • Divorce and Family matters • Welfare, public assistance, or Medicaid matters • Real estate and properties • Business Contracts • Personal injuries, accidents and medical malpractice and workers' compensation	• Rent Laws • Zoning • Local Safety

Table 2.1: General legal authority of the different authorities (Legal Aid Society of Northeastern New York, 2022)

2.2.2. The Role of the State

The foundation of the US legal system is built on the idea that there are 50 equal states in the Union; however, not all US territories and jurisdictions are parts of states. States can range from states to commonwealths, to incorporated or unincorporated territories, or any combination of these arrangements (The Green Papers, 2020). Each state has a constitution, which is much more detailed and thus longer than its federal counterpart; the federal constitution enumerates only the powers of the federal government whereas the state equivalent addresses all other constitutional topics (Briffault, The central place of States and Local Governments in American Federalism, 2008). Many Americans are proud that their constitution has been mostly unchanged since 1787. However, as of 2003, only 19 states have operated under the same constitution since their inception. In total, the 50 states have had 150 constitutions, with 6,800 amendments, averaging 136 amendments per state (Briffault, The central place of States and Local Governments in American Federalism, 2008).

One focus of any state constitution is the principles and the methodologies of applying fiscal policies. This is mainly because the federal constitution pays little attention to the federal government's taxation, borrowing, and money-spending (U.S. Constitution art. I, 1787). However, the federal constitution contains no constraints or guidance on how the states should tax or spend their revenue. Thus, the state constitutions must fill this gap (Briffault, The central place of States and Local Governments in American Federalism, 2008).

The overwhelming majority of state constitutions introduce boundaries on how the state can raise and spend money, by introducing concepts like ‘public purpose’, which are designed to minimise the actions taken by the government, especially regarding support for the private sector (Rubin, 1993). However, the lax judicial interpretation of these concepts renders these constraints more conceptual than realistic, used mostly as opposition talking points instead of as policy by the party in government (Briffault, The central place of States and Local Governments in American Federalism, 2008).

However, the fiscal parts of the constitution that continue to impact the functions of government are those related to state and local borrowing. Many constitutions forbid states from being indebted and or impose exceptionally low debt limits. To change these principles, a supermajority or referendum is required (Briffault, The Disfavored Constitution: State Fiscal Limits and State Constitutional Law, 2003).

There are also limitations on how states can acquire revenue, through caps and prohibitions on specific tax types, such as income and property taxes. These caps are exceedingly difficult to change upwards because they would also require either a supermajority or a referendum. More detailed caps also exist on valuation-based taxes, like property taxes, that cap the annual increases in those valuations (Briffault, The Disfavored Constitution: State Fiscal Limits and State Constitutional Law, 2003).

Despite states being central players in the US’s internal finances, they are simply outnumbered by local players who play an even larger role in the lives of their citizens. These players constitute municipal governments, which include counties, cities, and townships and their different forms of government.

2.2.3. Below the state level

Of the 50 states in the Union, only five were admitted in the 20th century, the last two being Hawaii and Alaska in 1959 (United States Census Bureau, 2013). However, the number of local governments has changed dramatically since the beginning of World War II; starting at around 150,000 in 1942, the number decreased dramatically, to slightly under 80,000, until the beginning of 1970, when it increased slowly. It has now stagnated at around 90,000 (United States Census Bureau, 2019).

Local governments tend to overlap in area and scope, and most Americans find themselves as citizens of at least two local forms of government aside from their states.

Counties

Counties exist under multiple forms in the US, being called ‘boroughs’ in Alaska and ‘parishes’ in Louisiana. These are direct decedents of their English counterparts, known as ‘shires’, and most states are entirely divided into counties (United States Census Bureau, 1990). Most of the role of local government falls to counties, who are responsible for prosecutions, records, births, deaths, property assessment for tax purposes, and voting registers, among other more tangible responsibilities, such as road maintenance, social welfare, and healthcare to the less fortunate (Briffault, The central place of States and Local Governments in American Federalism, 2008).

There are a few exceptions to this general system. For example, in Virginia, all cities exist outside the authority of the counties, and in Connecticut and Rhode Island, despite having geographic counties, there are no county governmental structures. Finally, some counties exist within large cities. Most large cities have merged their county and city governments into one, such as in San Francisco, Philadelphia, New York, Boston, Honolulu, and Denver (Briffault, The central place of States and Local Governments in American Federalism, 2008).

After the number of states, the number of counties also tends to remain stable in the US, only slightly increasing since the 1950s (United States Census Bureau, 2012). However, our research also included US territories. Thus, we counted more than 3,250 counties rather than the 3,150 indicated by the Census Bureau (United States Census Bureau, 2019).

Initially, most counties had service and regulatory roles, embodied in multiple civil servants, such as assessors, coroners, sheriffs, and district attorneys (United States Census Bureau, 1990). Most of these officials were locally elected, giving them local oversight; however, their roles were mostly limited to executing the policies and services of the states (United States Census Bureau, 2012). Nonetheless, in limited circumstances, the role of some counties has changed since the 1950s. These counties tended to include larger cities and used the power and influence of these cities to expand their mandate even into policymaking. This change was welcomed by the states, as they saw it as a form of delegation to manage peculiar metropolitan geographies. This trend continued, with most states empowering counties with elected officials and expanding their control to mass transit, housing, airports, and water supplies (United States Census Bureau, 2012; Briffault, The central place of States and Local Governments in American Federalism, 2008).

Cities

The level below the county is the city. However, ‘city’ is their colloquial denomination; the official nomenclature determined in the late 1980s refers to cities as ‘places’ (United States Census Bureau, 1990). This official naming convention has not been standardised across the entire nation. In some states, cities are called ‘boroughs’ (not to be confused with the Alaskan ‘borough’, which stands for ‘county’), ‘town’ (not to be confused with towns in New England, which will be explained later), and ‘village’ (Briffault, The central place of States and Local Governments in American Federalism, 2008).

The Census Bureau defines a ‘place’ as any concentration of populations, without them needing to have defined limits, power, or governmental functions, thus centring places around urbanisation (Briffault, The central place of States and Local Governments in American Federalism, 2008).

Places can be one of two types: incorporated and unincorporated. Over 19,000 of the 24,000 places recorded across the US are incorporated (United States Census Bureau, 1990). However, unlike other forms of local authorities, incorporated places increased by 16% between the 1950s and the early 2000s (Briffault, The central place of States and Local Governments in American Federalism, 2008).

To be an incorporated place is like being a charity or company; it is the creation of a new organisation with objectives and powers. This usually occurs when the local population votes to incorporate a new form of government, which is an elected legislative body and an elected executive. This new local government is usually a direct consequence of demand for better services or simply a growth in population and density, requiring a greater support that the county simply cannot provide (Briffault, The central place of States and Local Governments in American Federalism, 2008).

The percentage of the population that lives in cities across the US has steadily increased over time. In 2002, this percentage was around 62%; in 2020, the percentage was 80.7% (United States Census Bureau, 2021; Briffault, The Disfavored Constitution: State Fiscal Limits and State Constitutional Law, 2003).

Special districts

Whereas all forms of counties, places, townships and so on are known as general-purpose districts, there is another form of government known as special districts. Special districts exist to fulfil a single mission. The number of these districts continues to grow as people find new specialisations and reasons to create them. The latest trend in creating special districts is that of ‘Municipal Broadband’, which improves and provides faster broadband connection to the local community (Cooper, 2022). As of 2002, there were 35,000 special districts in the US (Briffault, The central place of States and Local Governments in American Federalism, 2008). In 2012, this number increased to 51,000 (Maciag, 2012).

These special districts have been the target of a public polemic for many reasons, one of which is their increase. On 7 March 2016, a national award-winning TV show brought the problem to the spotlight (Perota, Werner, Hoskinson, Pennolino, & Leddy, 2016). After the show many have debated their importance and the necessity of such a convoluted system, however, to any student of the American system, they are the building block of managing public causes and infrastructures.

The largest portion of special-purpose districts are school districts. There are 17,000 public school districts in the US (Bouchrika, 2022). The other main jobs for specialised districts include fire protection, water supply, housing and community development, flood management, and health and hospitals (Briffault, The central place of States and Local Governments in American Federalism, 2008).

Special districts can be split into two main types: top-down and bottom-up. Top-down districts are usually created by the state or other governing bodies to solve or address a specific problem or need. They may be governed by a state-appointed board of directors. Bottom-up districts are elected by communities, within the constraints of the state's legislation (Briffault, The central place of States and Local Governments in American Federalism, 2008).

Metropolitan Government

As many Americans live in metropolitan areas, many citizens proposed creating metropolitan governments. Despite initial support, the proposal faced opposition at all levels, especially considering that some metropolitan areas cross county and state lines (Briffault, The Local Government Boundary Problem in Metropolitan Areas, 1996).

Overall, these efforts brought collaboration and even mergers between some local governments. These mergers were usually limited to both local governments being in the same state, as with Miami and Dade, and usually consolidated the central city's government with that of the county (Briffault, The central place of States and Local Governments in American Federalism, 2008). Other types of collaborations included issuing financial securities, as in the case of the Association of Bay Area Governments in California.

2.2.4. Protections of the local governments.

Initially, the role of local governments was defined by the Dillon Rule, named after Judge John F. Dillon of the Iowa Supreme Court. The Dillon rule emerged from the judge's commentaries on the Law of Municipal Corporations published shortly after the American Civil War (Briffault, The central place of States and Local Governments in American Federalism, 2008). The rule simply states that the local government is a delegate of the state government and is allowed to act only in matters that the state has explicitly delegated (Briffault, Our Localism: Part I: The Structure of Local Government Law, 1990). However, such an approach never gained appeal among politicians for being too restrictive.

Many states quickly began to introduce protections for their local governments, in the form of three main constraints. The first prohibits states from establishing special commissions aimed at taking control of important local functions, the second prohibits states from introducing laws that would target specific local governments, and the third prohibits states from imposing unfunded mandates on local authorities (Reynolds & Briffault, 2022).

The most recent and important protection given to local governments is the principle of 'home rule', which protects the initiative and immunity of local governments. The power of initiative was designed to allow local governments to act on important issues without awaiting approval from superior jurisdictions whereas the immunity rule prevents superior jurisdictions from displacing and jeopardising the authority of local governments (Clark, 1985).

All these protections came with a caveat: that the local government is a creature of the state, which holds the power to change their boundaries or structure or even eliminate them. Thus, most structures and protections are general rules; however, there is considerable variation between states (Briffault, The central place of States and Local Governments in American Federalism, 2008; Reynolds & Briffault, 2022).

2.3. Municipal Finances

Unlike states and the federal government, municipalities have a limited capacity to levy taxes within their jurisdiction. Thus, they are dependent on limited types of taxes and require debt to address problems that emerge outside their day-to-day operations.

2.3.1. Municipal Fiscal Policies

There are two main sources of funding for municipal governments: local and intragovernmental sources. These sources apply to all types of local governments, be they counties, cities, or special districts.

Intergovernmental Sources of funding

According to the Tax Policy Centre, the main source of funding for municipal authorities is filed under intergovernmental transfers, and they account for 36% of the total money raised by these authorities (tax policy center, 2020). These transfers can come from the federal government or the state government. Most funding comes from the state government, representing 96% of all transfers. However, two-thirds of these transfers are allocated to education programmes. As for the 4% provided by the federal government, most goes to housing programmes (tax policy center, 2020).

Taxes and local sources of funds

The main tax mandate local authorities have is over property taxes, which generate the largest portion of their income outside of federal and state support (tax policy center, 2020; Moore, Ricks, & Little, 2022). This is followed by limited income and sales taxes. Other smaller forms of taxation, such as hotel taxes and business license taxes, provide less than 2% of the revenue (tax policy center, 2020).

The third main source of funding for local governments is charges and miscellaneous fees, which include everything from parking fees and penalties to water and sewage bills. These provide around 23% of the total value of the municipalities' income (tax policy center, 2020; Reynolds & Briffault, 2022).

Trends and expenditures

Despite the sources of funding remaining the same, the proportions have changed significantly over the last 40 years. Despite these changes, local governments have consistently raised 8–10% of the nation's total gross domestic product. This proportion of the national GDP peaked between 2007 and 2009 during the recession as they had to undertake a lot of the local relief effort. (Urban-Brookings Tax Policy Center, 2022; tax policy center, 2020).

As for their revenue from property taxes, it decreased by 4% between 1977 and 2017. This reduction was made up for by the increase in individual taxes and other sale taxes (tax policy center, 2020).

The source of funding that experienced the largest reduction was intergovernmental transfers, from 43% to 36% since the early 1980s (tax policy center, 2020) (Urban-Brookings Tax Policy Center, 2022). This occurred during the early years of the Reagan presidency, which suffered from economic deficits and significant reductions in public spending. Federal and intergovernmental funding for municipalities never recovered their proportion, and the difference between the lost funding was recovered through charges that the municipalities would get from their residents or users (tax policy center, 2020).

The expenses of local authorities have remained consistent over the years. As special districts are at the core of government service delivery in the US, their expenses reflect the priorities, types, and number of these special districts (Maciag, 2012). The most funded type of special district is school districts, followed by miscellaneous expenses, welfare, insurance trust expenditure, utilities, hospitals, highways, and police, respectively. (Moore, Ricks, & Little, 2022).

2.3.2. Municipal debt

When local governments desire extra finances, they must raise funds on the debt market. The municipal debt market has grown significantly over the past few decades, and with it has grown the financial services sectors that support this operation. The value of new issuances in 2022 was $339.6 billion, and the value of bonds traded was $13.8 billion. This brought the value of all outstanding municipal debts to four trillion dollars (Securities Industry and Financial Markets Association, 2022). To get to such a scale, there had to be several cogs in this financial machine.

Investment banking and public finances

Public finance banking usually refers to everything included in issuing new municipal bonds, from originating to structuring, underwriting, and some forms of financial advisory (Charbonneau, 2008).

Municipal bonds have two main routes to market, either competitive or negotiated issuances. In the first case, issuers release notice of sale to inform markets of the place and time to place bids. Issuances are then allocated to the lowest bidders. In the second case, the municipal government hires intermediaries who act in their best interest. These intermediaries are known as public finance investment bankers. In the *Handbook of Municipal Bonds*, Charbonneau lists their responsibilities as the follows:

- Developing an appropriate credit structure
- Developing the documentation around the issuance
- Conducting all necessary quantitative analyses
- Putting together the maturity structure and any option required

- Reaching out to rating agencies
- Marketing the bond
- Pricing the bond and justifying the price
- Underwriting the issue
- Assisting with closing the sale

Not all new issuances require all the services listed above; issuers select the services they need. Initially, municipalities overlooked the system due to fear of its costs; however, since the 1990s, local governments have shifted towards negotiated issuances (Charbonneau, 2008).

When there are multiple players bidding for specific issues, competitive bids tend to be cheaper for the municipality (Painter, 2020; Kidwell & Sorensen, 1983). This is the case in larger, more established municipal governments, such as New York City and Los Angeles, or in the case of states (Wood, Role of the Financial Advisor, 2008). However, when there are limited players in the market, negotiated offerings tend to be the norm and the cheapest, true to market (Kidwell & Sorensen, 1983). In recent literature, the domination of negotiated offerings compared to competitive offerings is clear (Painter, 2020).

Another main driver behind the growth of negotiated issuances is the complexity of the bonds. Before 1975, most bond issuances were general obligations, making them easier to understand and market. Since then, revenue bonds, which require a better understanding of the projects undertaken, have grown. There has also been the addition of market volatility, which has settled in developed economies since the initial petrol shock in 1973. This volatility encourages municipal governments to opt for negotiated issues simply because they can acquire more insight into timing for pricing. It also allows them to use finance professionals to manoeuvre the market to their advantage. (Charbonneau, 2008).

Financial Advisors & Municipal Bonds

As most municipalities have elected officials, they are knowledgeable of financial markets, and financial products may be limited. To remedy this issue, many issuers hire one or more financial advisors from all aspects of the financial wellbeing of the local authority. This includes the issuance of debt products as well as budgeting, financial planning, and matters related to the treasury. However, the scale of their involvement in bond issuance depends on the process being competitive or negotiated (Wood, Role of the Financial Advisor, 2008).

The role of the financial advisor is usually more involved in the negotiated process, as it requires more guidance. The process usually begins with the financial advisor selecting a team of investment bankers to execute the transactions. Once selected, the financial advisor monitors the progress of the bankers to ensure that their clients' wishes are abided (Wood, Role of the Financial Advisor, 2008). Experience plays a significant role in this process, as, in many cases, financial advisers who lack qualifications find themselves reduced being a box ticking exercise. This is usually vastly different to the case of issuers, who pursue financial issuances with highly established financial institutions.

Despite most issuers choosing to negotiate, many choose to compete. There are two main groups of these issuers. The first is larger states and municipalities with consistently high ratings, and the second is small, specialised districts raising small amounts, or amounts insufficient to attract the attention of the players in the negotiated market. In this case, the financial advisor must undertake all the responsibilities usually performed by the team of bankers. Further, in the case of competitive issuances, the issue date is determined in advance and cannot be modified to avoid adverse events in the local or national market (Wood, Role of the Financial Advisor, 2008).

Refunding

The role of financial advisors is more important when it comes to refunding municipal bonds, especially in early refunding, as most municipal bonds are refunded before reaching maturity(Wood, Municipal Bond Refunding, 2008).

Many scholars have tried to understand why municipalities refund their debt obligations earlier, especially because doing so appears contrary to their interests (Ang, Green, Longstaff, & Xing, 2017), deeming those who do ‘evil bankers’ and corrupt financial advisors; indeed, early refunding destroys any value gained from the option for the issuer (Robert & Spatt, 1993). Some academics have advocated that a comparison be made between the present value of interest between the refunded issuance and the one used to refund it (Kalotay & Abreo, Making the right call, 2010; Kalotay & May, The timing of advance refunding of tax-exempt municipal bonds, 1998). Others have tried to work on the real determinants of rarely refunding (Fischer, 1983); however, the most convincing explanation is that municipalities refund their debts earlier to control cash flow (Ang, Green, Longstaff, & Xing, 2017).

Ang, Green, Longstaff, and Xing (2017) find that municipalities who refund their bonds early usually do so at a loss. In fact, their Net Present Value is at a loss 85% of the time, and the total value of the NPV loss could cumulatively add up to $15 billion. This is because most local governments must balance their day-to-day budgets through taxes and revenues and are allowed to issue bonds for only capital-intensive projects (Briffault, The central place of States and Local Governments in American Federalism, 2008; Ang, Green, Longstaff, & Xing, 2017; Wood, Municipal Bond Refunding, 2008). This leaves them with three options to control their cash flow: layoffs, increasing taxes, and refinancing, and they choose the latter (Ang, Green, Longstaff, & Xing, 2017). This choice is further proven by the fact that municipalities tend to do this when tax revenues have decreased in the state, or when they foresee a tough economic time ahead. Thus, they favour a short-term reduction in outflow over an NPV loss (Ang, Green, Longstaff, & Xing, 2017).

2.4. Pollution in the United States

The US sits at an interesting intersection when it comes to the study of pollution, as the country tends to include a combination of strong government oversight, long term presence of pollution, intense industry, and a highly litigious society with strong incentives to expose chemical mismanagement.

Let’s start by justifying the importance of the legal system by understanding the litigious nature of the country. According to the American Bar association, the US has the highest number of lawyers per capita, standing at one lawyer for every 300 citizens. The US consistently appears in the top five most litigious societies. However, the target of these litigations tends to be businesses. Most businesses in the US (55%) face more than five lawsuits each year (Clements Worldwide, 2017). This aspect of business in the US warrants an important oversight of business practices, especially those that impact other people, such as pollution and contamination.

Starting with exposing chemical management, lawyers and courts sit at an interesting place in American society and oversight, a notion that has been represented in many American films, in which lawyers act on their morals against pollutive industry. This was clearest in the film *Dark Waters* by Todd Haynes (2020), which tells the true story of a lawyer who sued DuPont and exposed the true risks of perfluoroalkyl and polyfluoroalkyl.

Like most developed countries, the US appears to have suffered from offshoring and pollution havens. However, this is not the case; data from the US and the EU shows that their recent reductions in emissions come from increases in efficiencies and improvement in processes (Levinson, 2009; Brunel, 2017).

In the US, the initial fighters against pollution were states. However, this triggered fears of offshoring within the states, where industries would relocate from states with tougher regulations to those with relaxed regulations. These fears initially concerned air pollution and then water pollution; however, they were corrected in 1970 with the Clean Air Act and in 1977 with the Clean Water Act (Portney, 1990). This left the caveat that industries would move from the more polluted states, which were already above the federal standard, to the less polluted states, which were below the standard. This was corrected in the 1977 amendment for deterioration prevention (Levinson, 2009).

By preventing offshoring between states and then on the continent with NAFTA, the US has managed to keep most of its polluting industry at home, where they can be monitored and regulated (Levinson, 2009; Brunel, 2017). Aside from this, the US also monitors the pollution of the products, forcing producers to adapt, as with the catalytic converter.

The retention of highly polluted industries in the US also made many researchers use the country's economy as an example of how to account for pollution (Muller, Mendelsohn, & Nordhaus, 2011). However, a main reason why researchers were able to do this was because of the EPA.

2.4.1. The Environmental Protection Agency

The Environmental Protection Agency (EPA) was founded by President Nixon by executive order in 1970. It was the first agency established solely by executive order, without a legislative mandate from congress (U.S. Code, Congressional and Administrative News, 1970). The EPA is a combination of all the environmental departments in the federal government (EPA, 2022) and is a leading organisation when it comes to protecting the environment and monitoring emissions. It has developed many standards and programmes, many of which have been successful, such as the Toxic Release Inventory and greenhouse gases monitoring. However, the reputation of EPA has recently been tainted with the PFAs and PFOAs scandals.

The EPA initially operated on a principle of mutual trust with American industry. The EPA would ask academics and industry leaders about the chemicals that needed to be monitored and controlled. This system worked well until lawyers and scientists discovered that some industry leaders were hiding the known impacts of some chemicals. Since then, the EPA has been trying to understand this family of 'forever chemicals', even it is generally understood that they have reacted too late. This EPA failure is one of the largest oversight failures, especially as these chemicals have seeped nearly everywhere in the global water supply (Gilbert, 2019; Lerner, 2022).

2.4.2. Toxic Release Inventory

The Toxic Release Inventory (TRI) was founded in 1986 by an act of congress known as the Emergency Planning and Community Right-to-Know Act. This act was established due to the Bhopal chemical disaster in India, in which chemicals escaped from a factory at night, killing thousands of people, and prompted many Americans citizens and local and state governments to consider the possibility of such an event happening at home (EPA, 2022).

The programme began collecting chemical-release data in 1987. Every year after that, the number of chemicals varied, with continuous expansions in scope and quantity. The programme was also early to the internet, being made available in July 1998 (EPA, 2022).

Today, the EPA monitors around 770 chemicals, including those of new families, such as PFA and PFOA. These are monitored across the US and its territories, which account for 22,000 factories (EPA, 2022). However, when we began our research, the EPA monitored around 615 chemicals, which excluded forever chemicals. Nevertheless, the number of factories is consistent with what we found in our dataset. The breadth and scope of this dataset made this programme one of the most insightful of the EPA.

Since 1987, the EPA has released yearly reports. There is a two-year gap between when the data is acquired and when it is published. How much information and how many tools are made available for analysing the data depends on the current administration. With the current administration being Democrat, more details are reported, even preliminary results.

2.4.3. Pollution and the economy

Since the beginning of human development, pollution has been linked to human development. There is a growing number of climate researchers arguing that the Middle Age's ice age was caused by the Mongol empire, demonstrating in a historical context the link between human development and emissions (Bisaro, 2013). However, this link was shown in many scenarios before the ice age (Victor, 1971) and has been shown in more modern scenarios, such as the decrease in emissions during the 2008 financial crisis and an increase during the recovery (Magazzino, Porrini, Fusco, & Schneider, 2021). The most recent example of this correlation was the COVID-19 pandemic, during which air pollution decreased due to lockdowns (Venter, Aunan, Chowdhury, & Lelieveld, 2020).

When discussing the relationship between pollution and economic growth in each area, one must discuss the Kuznets Curve. This Kuznets curve is a statistical and empirical idea for which Simon Kuznets was awarded the Nobel Prize in economics in 1971 (Yandle, Bhattarai, & Vijayaraghavan, Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications, 2004). By the end of the century, the EKC had become the foundation of any technical conversation about the economy and the environment (Grossman & Krueger, 1991), as the data economists collected showed an inverted U-shaped relationship between environmental metrics and income (Yandle, Bhattarai, & Vijayaraghavan, Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications, 2004).

The Kuznets curve demonstrates that as income per capita increases, there is a clear deterioration in environmental measures. However, as income rises, societies move to less pollutive economies as environmental metrics become more important. Populations no longer regard decent environmental factors as premiums rather as rights (Yandle, Bhattarai, & Vijayaraghavan, Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications, 2004).

Before industrialisation, subsistence farming and basic economic activities had a limited impact on the environment. As society industrialised, the environment quickly deteriorated. However, as income increased, the population began requesting clean water and unpolluted air (Yandle, Bhattarai, & Vijayaraghavan, Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications, 2004; Lindmark, 2002; Munasinghe, 1999).

The hypothesis of the Kuznets curve split economists into two camps: those attempting to replicate and those probing for methodological, statistical, and theoretical issues (Yandle, Bhattarai, & Vijayaraghavan, Environmental Kuznets Curves: A Review of Findings, Methods, and Policy

Implications, 2004). However, one strong complaint is that, although the Kuznets curve may have been historically accurate, it may not be accurate going forward, as, with climate change, this relationship may be broken. Further, there must be places that manufacture and thus will be polluted.

With the development of international trade, many researchers have analysed other factors, such as property rights and the rule of law, as main factors in the Kuznets curve. Because a main factor in the turning point is a reduction in economic inequality, this cannot happen easily without rule of law (Yandle & Morriss, The Technologies of Property Rights: Choice Among Alternative Solutions to Tragedies of the Commons., 2001; Torras & Boyce., 1998; Bhattarai & Hammig, Institutions and the Environmental Kuznets Curve for deforestation: A Cross-country Analysis for Latin America, Africa, and Asia., 2001; Bhattarai & Hammig., Governance, Economic Policy, and the Environmental Kuznets Curve for Natural Tropical Forests., 2004). Other critics of the system have expressed that the Kuznets curve may not be available to developing countries, with weak governments and as trade evolves and the distribution of resources is curtailed by the international banking system (Anton Nahman, 2005).

2.4.4. Environmental Justice

The Kuznets curve directly leads to environmental justice. The EPA regard the curve as the fair treatment and meaningful involvement of all people, regardless of race, colour, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulation, or policies (EPA, 2022). The EPA further defines ‘fair treatment’ as no group suffering a disproportionate share of the negative environmental consequences of industrial, governmental, or commercial activities or policies (EPA, 2022).

Environmental justice as a movement began as a continuation of the civil rights movement, simply because minorities were poorer, and being poor increased vulnerability to pollution and emissions (Wilson, 2010). Poverty in the US is still a main indicator of how polluted an area is. The 'cancer alley' along the Mississippi River, one of the poorest areas in the US, has been a target for the most toxic releases (Wong, 2022).

The movement stalled for most of the 2000s, during the George W. Bush presidency. The main reason for this is attributed to the supreme court's ruling the Alexander v. Sandoval case in 2001, where the court refused to allow private lawsuits based on evidence of disparate impacts (Mohai, Pellow, & Roberts, 2009). There was hope among activists and researchers, that the environmental justice would be brought back to life by their toxic waste and race at twenty 1987-2007 report published by the United Church of Christ (UCC) in 2007, but it did not materialise into the theoretical revitalisation of the field. However, as the UCC's report found, among the most important indicators for pollution in the US were race and income (Bullard, Mohai, Saha, & Wright, 2007).

Due to the limitations of their legal impacts, the field found itself at a crossroad: continue fighting legal battles or develop the tools to better assess the impacts of toxicity (Sze & London, 2008). However, the conversation in the US about environmental justice was overtaken by that of climate justice on an international scale (Schlosberg & Collins, 2014), and, internally, many more tools were developed to better map and assess the impacts of toxic emissions.

2.4.5 Geographic Information System and pollution

One of the most important outcomes of the assessments of environmental justice is the development of techniques to understand the potential impacts of pollution in an area. There are three main established methods: spatial coincidence, distance based or buffer zone, and pollution plume modelling. These methods are combined with population estimations and geographic population modelling techniques (Chakraborty, Maantay, & Brender, 2011). Our work uses the first two methods. As for the third method, we will explain it as it is the most accurate and would provide an important scientific backdrop. However, we find ourselves unable to use it as we are limited by the capacities of our means.

Spatial Coincidence Analysis

Spatial coincidence analysis is the oldest and easiest of the three methods, as it could be done before the development of advanced computer analytics and GIS. This method allocates the risk burden of any point of release to the geographic area it falls within (Mohai & Saha, Reassessing racial and socio-economic disparities in environmental justice research., 2006) and is usually better suited for small areas, such as ZIP codes, congressional districts, or small cities (Goldman & Fitton, 1994; United Church of Christ Commission for Racial Justice Toxic Wastes and Race in the United States, 1987; Anderton, Anderson, Oakes, & Fraser, 1994; Been, 1995). However, the method has been used for larger areas, such as counties, albeit rarely (Chakraborty, Maantay, & Brender, 2011; Daniels &

Friedman, 1999; Hird, 1993). Despite being the oldest method, it is still used by the EPA and the UCC, as it is convenient for dealing with larger datasets and geographies (Bullard, Mohai, Saha, & Wright, 2007).

Figure 2.1: Spatial Coincidence Analysis Methodology (Chakraborty, Maantay, & Brender, 2011)

This method has been greatly criticised in the literature. Historically, the criticism has followed three main arguments, each of which was solved differently. The first argument is that the method tends not to differentiate between spatial units containing one and those containing more than one point of pollution. The second argument is known as the boundary effect and argues that a point of pollution may be so close to the boundary of another spatial unit that the point is equally exposed to the risk of the pollutants. Finally, this method assumes that the risk of exposure is equally distributed across the hosting special unit (Chakraborty, Maantay, & Brender, 2011).

The second and third arguments evolved to produce new methods, but the first argument was easier to address. Initially, researchers accounted for the number of facilities in an area (Cutter, Holm, & Clark, 1996; Burke, 1993; Mennis & Jordan, 2005; Fricker & Hengartner, 2001; Ringquist, 1997; Tiefenbacher & Hagelman, 1999; Cutter & Solecki, 1996). Another method of quantifying risk was to use the quantities of pollution released. This was largely helped by the arrival of the TRI datasets, which would provide a yearly volume of the chemicals released (Daniels & Friedman, 1999; Tiefenbacher & Hagelman, 1999; Bowen, Salling, Haynes, & Cyran, 1995; Ringquist, 1997; Bolin, et al., 2000; Kriesel, Centner, & Keeler, 1996). Researchers quickly started looking at methods to better estimate the risk of the emissions by including a toxicity metric (McMaster, Leitner, & Sheppard, 1997; Brooks & Sethi, 1997; Perlin, Setzer, Creason, & Sexton, 1995; Zhou & Li, 2021).

Distance Based Analysis

To respond to the boundary criticism made against the spatial coincidence method, another method was invented, called ‘distance-based risk’. The theory for this method is that the closer a place is to a point of release, the more at risk the place is. There are many ways to use this type of analysis, but the most used is the buffer method (Chakraborty, Maantay, & Brender, 2011), which assumes that the impact of the chemicals would be felt across a circular buffer zone around the point from which they were released (Figure 2). Although the radius of the buffer zone was usually chosen arbitrarily, the 0.5-miles and the 1-mile radii were the most frequent (Chakraborty, Maantay, & Brender, 2011; Maantay, 2007; Mohai & Saha, Reassessing racial and socio-economic disparities in environmental justice research, 2006; Mohai, Lantz, Morenoff, House, & Mero, 2009). Consensus over the circular shape of the buffer was quickly reached, as it was the shape that made most sense and could be used consistently across situations.

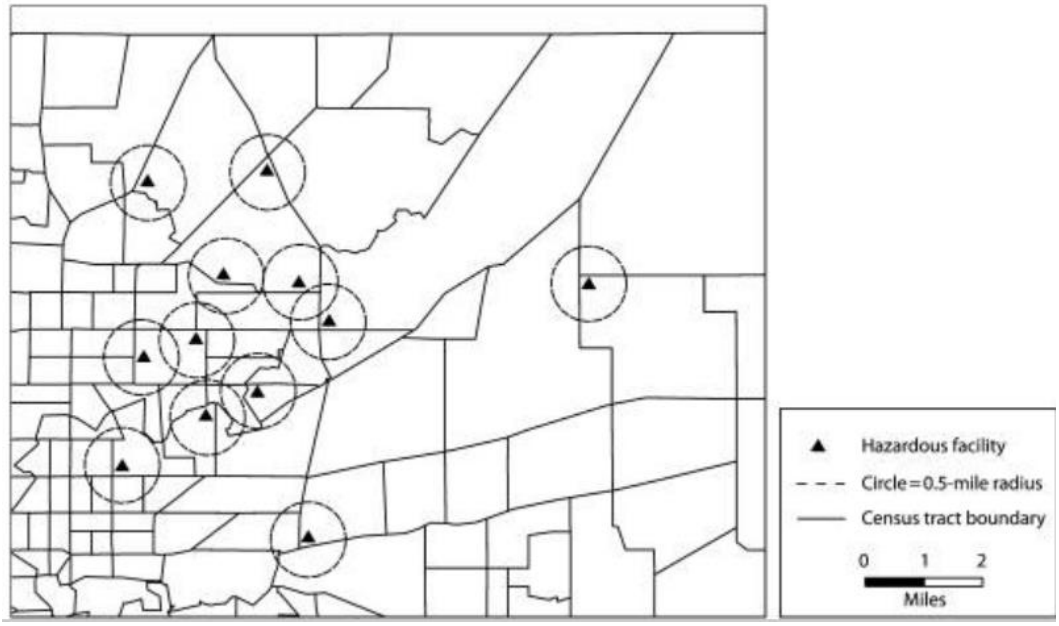

Figure 2.1: Circular Buffer around the facilities (Chakraborty, Maantay, & Brender, 2011)

Other forms of buffer zones were also developed – notably, a buffer zone in which the impact of the chemicals was corrected for the distance from the facility of release. This was enabled by advancements in the computing capacities of GIS systems (Mennis J. , 2002; Chakraborty & Zandbergen, 2007). As more advancements in GIS were achieved, measurements moved away from linear distances from facilities to more curvilinear and decay modelling to better estimate the impact of the chemicals. These methods would usually use natural logarithms to decay the impact of a chemical on its surrounding (Pollock & Vittas, 1995; Downey, 2006).

Pollution Plume modelling

Pollution plume modelling originated within the realm of air pollution; however, the same principles apply across other forms of emissions. This method assesses the direction in which pollution flows and measures the impact of the chemicals in the wake of this flow (Figure 3) (Chakraborty, Maantay, & Brender, 2011).

Figure2.2: Plume footprint Methodology (Chakraborty, Maantay, & Brender, 2011).

We Initially, we wanted to use this method in our research, but it quickly proved unfeasible, as it required greater knowledge of the geography, air flow, and water table of an area and was therefore unfeasible to carry out across the TRI dataset. This method is usually done on smaller scales, such for cities or counties. Thus, we opted to use the first two methods while correcting for toxicity and population.

Measuring Toxicity

The scientific measures of toxicity are the lethal dose 50 (LD50) and the lethal concentration 50 (LC50), both of which represent the lethal dose or concentration for which 50% of a population would die. The only major difference between them is that the LC50 is usually used for chemical vapours (Suvarna, Layton, & Bancroft, 2019). To assess the impact of the toxicity of the chemicals, we used both measures. We normalised all the chemicals by converting between the different species and the different intake methods (Honma & Suda, 1998; Suda, Tsuruta, & Honma, 1999). Chemists attempt to identify the species and intake methods for every chemical. The toxicology information of every chemical should account for the short-term (acute) and long-term (chronic) exposure of the chemical. Some chemicals provide both, such as skin exposure to acids, whereas others provide only long-term exposure, such as asbestos, lead, or nanotubes (Suvarna, Layton, & Bancroft, 2019).

2.4.6. The role of local activism and entrepreneurship

By the end of the 1960s, the US had undergone two separates but powerful transitions: the decade of love and hippie culture and the civil rights movement. These transitions built momentum for popular activism, which included strong activism for the environment.

This activism saw two main types of results: changing local laws and developing local initiatives to fight local issues. As time evolved, the second form of activism undertook its own transition, morphing into the concept of start-ups to that of place-based enterprise (Shrivastava & Kennelly, 2013). This type of entrepreneurship is created to address local issues.

These start-ups would cement the role of the private sector in the American strategy of fighting climate change. The role of private enterprise was expressed in two main ways, through a legal dimension and through innovation. The belief in innovating a way out of the climate crisis stems from the success of innovation during the last environmental crisis the US faced. Most notably, the invention of the catalytic converter permitted an 80% reduction of toxic car emissions. Events like these ended the smog crisis in large American cities and earned American innovations and industries a lot of political goodwill.

The concept of place-based entrepreneurship was further developed to be more purpose-driven. This type of entrepreneurship aims to solve one specific local problem. Given the growth of climate and sustainability challenges, purpose-driven start-ups tend to focus on solving these challenges (Cohen & Munoz, 2015).

2.5. Conclusion

The US is a strong and stable yet devolved government structure. Unlike other devolved democracies or systems, the country remains heavily industrialised and continues to produce a considerable percentage of the global pollution.

The strong governmental structure in the US has created institutions and agencies for monitoring many types of pollution, yet the intersection between pollution and governmental structures is still understudied. However, other sectors before ours – most notably, environmental justice– have studied the impact of pollution. Using the methodologies from these sectors and explained in this chapter allowed us to analyse the intersection between economic and environmental variables.

The US system is now over 200 years old. The system is convoluted and complex, with fine lines of responsibilities and jurisdiction. In our research, we navigated these jurisdictional fine lines by aiming for the jurisdictions we thought would be most impacted by the type of pollution studied.

3. Methodology: Mapping and Toxicity

3.1. Maps, Maps, and more maps

3.1.1. Mapping Jurisdictions

The main source of jurisdictional maps in the US is the Census Bureau. They release maps of all the states, counties, school districts, cities, and places in the nation. However, these maps tend to be fragmented into states, which was inefficient for our work. So, we imported all the maps and built four shapefiles (maps) that we then used for all future references. We extracted the information from the Google Earth folder and imported them into different shapefiles depending on the nature of the information. If the files included the boundaries of a state, they went into the state's shapefile and so on, leaving us with four main maps: states, counties, school districts, and places (cities).

As there were separate maps for each state and territory, this exercise helped us combine the information from roughly 320 maps. We used the 2017 Census Bureau maps, as these were the most accurate at the beginning of our research. Since the beginning of the work, we have updated the maps multiple times but did not see a major difference in our analyses. There were sometimes new unincorporated places appearing on the maps, but they were usually eliminated due to the lack of financial instruments issued.

3.1.2. Mapping municipal bonds

Mapping municipal bonds was the greatest challenge in our research. Like most researchers analysing municipal bonds, the database had to be built in layers. The first step starts at a central source of data known as the Municipal Securities Rule Making Board (MSRB) database. The MSRB is an institution charged with recording all municipal bond trades from 2005 onwards and has invested significantly in tracing the trades that were made before this mandate. Thus, we start by obtaining all the recorded bond trades, from which we extracted the bonds' identifiers, known as the CUSIP. We used these identifiers to collect the issuance information for each of these bonds. Most studies in the literature used Bloomberg; however, given the limitations of our data, we used Eikon Reuters.

Many geographic researchers analysing municipal bonds use the Mergent FISD dataset, which we were priced out of. Thus, we had to develop a methodology for identifying the geography associated with every bond issued. From our first step of collection, we obtained the issuance characteristics of 2.5 million bonds and then collected their issuance contracts. Most municipal bonds include a subsection titled 'location', which indicates the geography served by the issuer.

However, mapping issuer jurisdictions was a challenging task that required developing a methodology for attributing each district to one mapped entity. This was done in three steps: First, we matched the school districts to their maps, as they are the clearest and most easily identified. Second, we started from the smallest entity and work our way up. Finally, we matched those issued by places, counties, and states.

This initial methodology left us with a minority of bonds that would service multiple jurisdictions simultaneously. Thus, we abide by the following rules: if a jurisdiction serviced two or more cities in the same county, we identified the service area as the county, and if it serviced areas across two or more counties, we attributed the issuer to the state. This left us with an extremely small minority of bonds that served areas spanning two or more states, which we eliminated from our database. At the end of this process, we had assigned geography to every bond issued through the location listed in their contract.

Although the fidelity between the service area of the issuer and the geography we allocated may appear limited, knowing the convoluted nature of municipal districts in the US required using a broad methodology to assign the districts. As the rules for districts change significantly between states, the US contains 38,779 general-purpose local municipal governments and 51,296 special-purpose districts (Maciag, 2012). The boundaries for these districts are unclear, as the boundaries of the general-purpose districts overlap and intertwine with those of the special-purpose districts. This mess is illustrated by North Dakota, the state with the most local governments per capita. With a population of just under 800,000, the state averages 351.8 local authorities per 100,000 residents, out of which 227.5 are general-purpose authorities, and the other 125.3 are special-purpose districts. Thus, assigning the bonds to a geography larger than the special districts is justifiable. Further, this convoluted and complex geography of municipal districts is exacerbated by the lack of centralised mapping. Districts are fluid, as applying to start a new district is generally easy, meaning that the maps are always changing. When attempting to map the districts at the beginning of the research, we found that the only way to do so was to contact every district separately, which was simply unfeasible. Thus, our generalised methodology is justified.

3.1.2. Mapping of TRI factories

The easiest part of our mapping was mapping the TRI. The EPA provides both addresses and the geocoded locations of every release point in the database. A release point is any location that releases any of the 775 chemicals tracked, and most of these locations tend to be industrial facilities. These chemical releases are not voluntary disclosure by the factories; they are tracked and assessed by the EPA under threat of legal action by the agency.

We created an annualised database for every release point geolocated the points using their coordinates. To double the fidelity of our coordinates mapping to the addresses provided by the EPA, we randomly selected 100 release points and checked their addresses against their coordinates. The coordinates and the addresses were correct. This provided a map of all the release points that have ever been reported by the EPA since the TRI programme started. By mapping the database, we could also identify what chemicals were released in which location, and we could better understand the geographic nature of the chemical emissions. This meant that we could start in the second phase of our geographic analysis or associating the TRI release points and their chemicals with the local authorities.

3.1.3. Mapping the start-ups

For our final study, we mapped the universe of start-ups within the Preqin and Cleantech datasets. This was the most challenging part of our mapping, as we had only addressed of the start-ups, and in most cases, the addresses were not standardized.

We developed an algorithm using Geopy to obtain coordinates from the addresses in the dataset. Because of the limitations imposed by the different map providers, including Google Maps, Open Street Maps and Bing Maps, we designed the code to imitate a human for random addresses. The process was slow and inefficient; however, it was sufficient as a first stage of geocoding. Once this process was complete, was had reduced the dataset sufficiently to allow us to afford the geocoding capacities within the ArcGIS software.

Unlike our other studies about water pollution and chemical accidents, the data on air pollution was more global and was provided by the Organisation for Economic Cooperation and Development (OECD). These were air pollution measures based on larger urban agglomerations of cities. Thus, the start-ups had to be directly associated with the areas given to us by the OECD.

The methodology used for the mapping is standard, despite the differences in the theory of how we mapped the chemical releases and the start-ups. In the case of the start-ups, we did not need to consider the implications of chemical exposure areas or impact areas, as we were satisfied by analysing the start-ups as belonging to an urban agglomeration. There was no attempt to analyse the impact of start-ups outside these urban centres.

3.2. The Algorithm: locating the point of interests.

3.2.1. Requirements for the TRI chemicals

As explained in the literature review, there are three main methods for assessing the impact of toxic chemical releases in an area: spatial coincidence, buffer zone, and plume analysis. Plume analysis, despite its name, can be used to understand the impact of any chemical release; it just requires a detailed understanding of the flow of the chemicals. Although it is a superior method, we simply could not use this methodology, as it required taking field measurements. This methodology is usually used locally, at the city or county level. For larger or more comprehensive analyses, it is usually complimented by one of the other two methods. For robustness, we used both the spatial coincidence and buffer zone methods.

For the spatial coincidence method, we needed the algorithm to take a spatial area and report all the points of interest that fell within it. However, the buffer zone was more difficult to include in the algorithm as it would require us to create a buffer around 27 thousand factories. We did not have a graphic processing unit powerful enough to handle it. To simplify our approach, we ran our analysis from the space's perspective instead of the point's perspective; instead of reporting all the jurisdictions that fell inside the buffer zone of a factory, we reported all the factories within the buffer zone of a jurisdiction.

3.2.2. The GIS algorithm

The GIS algorithm (available in the appendix) is a combination of three algorithms, each of which produces a different buffer zone around a jurisdiction. The first provides all the factories within a jurisdiction, the second provides all the points of interest within the county and within a buffer of 500 m around the county, and the last does the same as the second but with a buffer zone of 1 km. For technical reasons, the analysis had to be done graphically rather than computationally, as the GIS software was more efficient on a graphical processing unit (GPU).

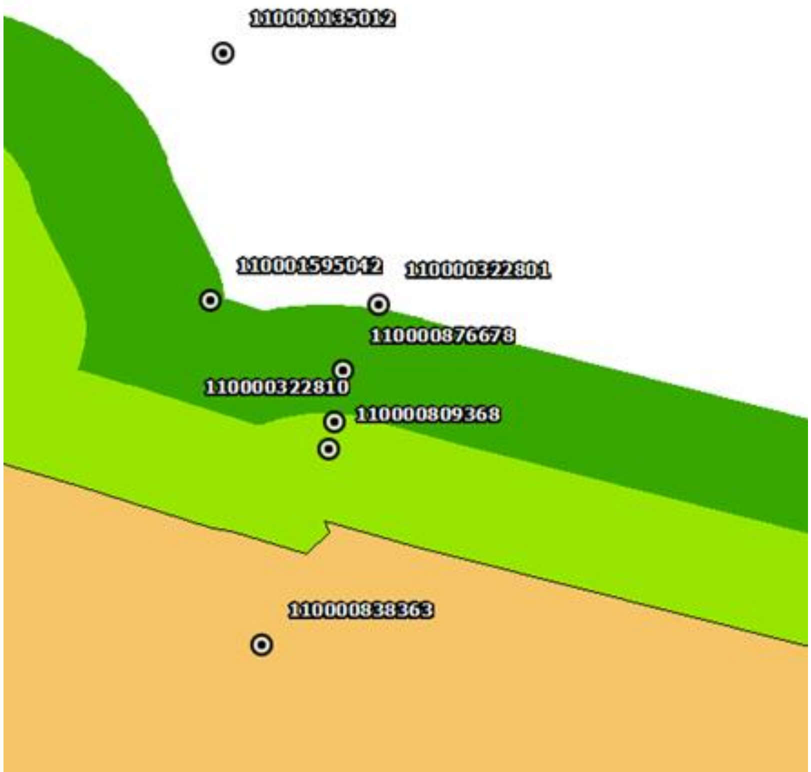

Figure 3.3.1: Northern section of New York City and the TRI facilities within, at 500m and 1km of the city.

The algorithm redrew jurisdictions at a time inside the GPU. It would then overlay the coordinates of all our points of interest and then produce a table of all the factories inside the jurisdiction. The table of the next jurisdiction would simply be concatenated to the previous.

For the buffer zones, the algorithm imported jurisdictions at a certain time. It analysed the boundaries of the surface area, drew a 500 m buffer zone around it, and then overlayed the points of interest and reported all the points that fell within the newly drawn area. This process was repeated for the 1 km buffer zone.

3.2.3. Implications for the start-ups

For the start-ups, the mapping did not require as much complexity. When mapping for our third study, we were interested in only the start-ups that fell within a surface area. Unlike the jurisdictions for the TRI factories, the map of the urban centres of interest was collected from the OECD. We had a lot less flexibility with the mapping of this dataset, as these were the areas in which air pollution was measured. Thus, we limited ourselves to the start-ups within the actual urban centre.

To do so, we extracted a section of our previous larger algorithm. Because this research was done on a global scale, and given the intense nature of the graphical operations, running the larger system would have taken too long. Thus, we extracted the section of our algorithm that reported the points of interest within the urban centre. Also, given our geolocation methodology, we had to adapt the allocation to accommodate for slight mistakes.

3.3. Toxic Release and Toxicity

3.3.1. Toxic Release Inventory Dataset

Before discussing the data, we must start by discussing the period in which this research thesis took place. I started my PhD thesis in 2018 and completed it in 2022. In 2018, the EPA and the executive branch of the US government were under the control of the republican executives who purposefully appointed officials known for their dislike of the environmental cause, especially within the EPA. Under their tenure, the availability of the data and the tools available to image the data were extremely limited. This has changed dramatically after the arrival of the Democrats in office. This also meant that our methodology and understanding of the data itself shifted when more information was shared. In this section, we will discuss only the most recent data.

The TRI dataset comes with multiple variables, indicating the factory, the chemicals, and the method of release. To use it, we identified the type of emissions we wanted to focus on. We combined the different methods of releases into four types: air, water, land, and one-time. Whereas the first three types are part of the production process, the last is accidental releases, which includes leaks or catastrophic releases that occur outside a factory’s normal production process. This aggregation is not an addition of ours, as it has been done in previous literature and is also how the EPA advises that the data be used.

Two more aggregates were made: total on-site emissions and total emissions. Total on-site emissions are all the emissions produced and released on-site whereas total emissions include chemicals produced on-site but later transported to other locations for further processing or release, such as those sent to landfills.

3.3.2. Accounting for Toxicity

Whereas the TRI dataset provides the quantities of the chemicals, it is limited when it comes to the toxicity of these chemicals. Since the Biden administration came into office, the tools and visualisations available to understand the impact of these chemicals have dramatically improved. The main database available via the EPA is TRI-Chip. This is a database of chemicals and their potential impacts; however, it is limited in the number of toxicity values it can provide.

As discussed in the literature review, few researchers have successfully included a metric of toxicity in finance. We believe that this is directly related to the lack of a scientific approach to the matter. Thus, we focused on the known impacts of the chemicals and their known toxicity in the chemical literature.

First, we combined a list of the chemicals in our sample period, which came to 614 chemicals. The TRI database not only provides the name of the chemicals but also their CAS numbers, which are tracking numbers in international databases. We then searched for each one of our chemicals on the ToxNet database. We collected measurements of toxicity for LD50 and LC50 and registered how the doses were administered. If the information was not available on ToxNet, we searched for it in the ECHA database. For the few chemicals in neither database, we scoured chemical literature to obtain a figure of toxicity. By the end, we had three chemicals for which we did not have a figure and thus gave them a toxicity of 0. This meant that they would be excluded from our calculations that involved toxicity.

The ToxNet database is owned and managed by the US National Library of Medicine. It is one of the oldest toxicity databases in the world and has been the cornerstone for toxicity information across the literature. Recently, the EU released its equivalent of ToxNet, which is ECHA. The ECHA tends to be more modern and, in our experience, had better coverage. However, we used the data from ToxNet as our principal source simply because it provided references supporting its data points, making our choices easier to defend.

Once collected, the toxicity dataset was a mix of LD50 and LC50 and a mix of intake routes. Thus, we had to standardise the different types of values. We brought all our values to the LD50 of an oral dose given to a rat. We did this by using the work of Takeshi Honma and Megumi Suda (1998), who studied the correlation between LC50 and LD50 in mice and rats. They helped us tackle the bulk of our workload, as most of the measurements taken were for these two species. However, there were measurements taken for other species, such as humans and pigeons. These LC50 and LD50 figures were slightly more challenging to convert, as we had to look for specific literature equating the two species.

However, the LD50 is only a limited metric when it comes to toxicity, as it provides a metric for acute toxicity but excludes other metrics related to the chemicals. Thus, we developed another metric. Unlike LD50, which was standardised and well-established in the literature, our metric was a much simpler metric developed directly out of the EPA's TRI-Chip database. In this database, the EPA provides categories for the potential impact of a chemical. These impacts, which are the reason for monitoring the chemical, are as follows: acute toxicity risk, chronic (non-carcinogenic) risk, carcinogenic risk, and environmental risk. For each chemical, we developed a metric ranging from 0 to 4, giving 1 point for each of the potential impacts. However, this left us with a dilemma for the older listed chemicals, as their effect in these categories was unknown. Thus, we created two different metrics: one in which we account for the unknown impacts by giving a point, and another in which we account for the unknown impacts by giving a zero. This effectively one metric for which we assumed the best-case scenario and another for which we assumed the worst range of impact possible. Some chemicals fell into this latter category; however, they were a small minority of our analysis.

In our work, the scenarios in which we assumed the bast-case impact is more accurate for a simple argument. If these chemicals posed a large danger to the population or environment, there would exist literature studying their impacts on society. This argument is further compounded by the fact that these chemicals were initially listed in 1987 – meaning, if their potential impact was significant, the resources would have been allocated for their studies.

We now had three separate metrics to measure the impact of chemical pollution in an area: a volumetric method which required analysing the mass of chemicals released, a toxicity approach for correcting the volume of chemicals released by the LD50 of these chemicals, and an impact approach to account for the damage the chemicals released could have on their surroundings.

3.3.3. Aggregating chemical toxicity

To better account for the impact of the chemicals, we devised a method of aggregating the chemical pollution released in a specific jurisdiction. To do so we had to account for both the location and the toxicity of where the chemicals were released.

Volumetric aggregation

In this methodology, we standardised the units that measure the mass of chemicals released to m^3. We then summed the number of chemicals released within an area. We did the same with the buffer zones.

$$Chemical\ Pollution_j = \sum_i Volume\ of\ Chemical_{ij}$$

Where *i* stands for every unique chemical released in area *j*. This sum is done for every jurisdiction – once for within and once including the buffer zone, thus giving us a metric for the volume of chemicals released.

Toxicity through LD50

Unlike the other metrics included in our research, LD50 has an inverse relationship with the toxicity of the chemical. This is because the LD50 indicates how much it would take to kill half a population. Thus, the smaller the LD50, the more toxic the chemical. To adapt the formula for the LD50, we divided the volume of chemical *i* released in area *j* by the LD50 of the chemical. This increased the impact of the chemical proportionally to its toxicity.

$$Chemical\ Pollution_j = \sum_i \frac{Volume\ of\ Chemical_{ij}}{LD50_i}$$

Impact factor

The other metric we built is one for measuring the impact factor of the chemicals, thus accounting for the potential social and environmental costs of each release. We had developed two different metrics for this purpose. The first, for when the impact of a chemical was not identified by the TRI-Chip database, assumed the worst-case scenario; and the second did the same, as when the impact was not identified, it assumed that it did not have that impact. Thus, the formula used for aggregating the chemicals was as follows, where the volume of the chemical is multiplied by its impact factor (ranging from 0 to 4):

$$Chemical\ Pollution_j = \sum_i Volume\ of\ Chemical_{ij} * impact\ factor_i$$

Holistic metric

The holistic metric corrected the volume of chemicals released by both the impact factor and the LD50, thus providing a scientific metric for the toxicity of the chemical through the LD50 and its impact on society and the environment through the impact factor. To do so, we combined the previous formulas into one, first dividing the volume of a chemical *i* by its LD50 before multiplying it by its impact factor.

$$Chemical\ Pollution_j = \sum_i \frac{Volume\ of\ Chemical_{ij}}{LD50_i} * impact\ factor_i$$

For all the metrics, we wanted to obtain a single number representing chemical pollution. Thus, we simply summed all the different chemicals after our corrections to obtain a metric for the amount and impact of all the chemicals released within the jurisdiction.

3.3.4. Correcting for jurisdictional controls

To better understand the impact of chemicals, we had to contend with the dilemma proposed by George Berkeley as follows: ‘If a tree falls in a forest and no one is around to hear it, does it make a sound?’. In our context, the question could be changed to: ‘If a chemical is released in an area where it does not impact anyone, has it even been released?”

Thus, we needed to account for the population of the jurisdiction of the chemical released. This approach is rooted in the literature, especially in that on environmental justice. Further, the same argument that justifies the impact factor of the chemicals can be extended to account for the population characteristics of the jurisdiction: a mildly toxic chemical released in the middle of Manhattan would have a significantly larger impact than a much more toxic chemical released in the middle of the Nevada desert or the northern tip of Alaska.

Thus, we accounted for two more metrics for each jurisdiction: population and density. Whereas the population was simply collected from the Census Bureau, the density figures were calculated using the population collected earlier and the areas obtained from the GIS maps we created. We called these controls ‘demographic controls. We also attempted to use the area of a jurisdiction as a control; however, we could not find literature backing this metric, and the metric did not produce significant results.

$$Impact\ Chemical\ Pollution_j = Chemical\ Pollution_j * demographic\ contols_j$$

This new metric was readapted for each of the chemical metrics we developed. Thus, we accounted for the volume of the chemicals and their nature and impacts as well as the populations in the impacted jurisdictions, providing a holistic metric to the pollution.

3.4. Conclusion

Using the methodologies explained in this chapter, we mapped 2.5 million bonds and tens of thousands of factories and start-ups. These methodologies, despite being rudimentary in some extent (i.e., reading bonds issuance contracts), allowed us to have a much more accurate dataset of the locations of the bonds.

The algorithm we built allowed us to reproduce both the circular buffer zone methods and the spatial coincidence method. The algorithm uses coordinates to locate specific points within special areas and can recognise items within 500 metres and 1 kilometre.

Further, because all chemicals are different, we built a comprehensive structure to account for toxicity and environmental impact. For toxicity, we used the LD50 measurements, which is the standard used in chemistry to determine how toxic a chemical is. As for the environmental impact, we built our own coefficients from the data provided by the EPA on the chemicals.

4. Does chemical pollution make a county poorer? Evidence from the US municipal market

Authors: Moustafa Ramadan, Andreas Hoepner, Alfonso Dufour

4.1. Abstract

This paper looks at the impact of chemical releases on municipal bonds issued by a county. We used over 225,000 bonds that we allocated to counties around the United States. We found that the quantity of chemicals released is correlated with an increase in the issuance yield of the local authority's bonds, and this correlation is significant for short-term maturities. This short-term relevance of the chemicals is in line with the half-life of the chemicals in the toxic release inventory, indicating a causal relationship. We also ran a placebo test to validate that the higher yield is related to only the chemical pollution.

Further confirming causation, we used the passing of local chemical restrictions and regulations to run causal inference tests. We used the passing of green chemistry laws in some states as a clean-up signal to the market. Using a propensity score-matched difference in differences, we found that when the states chose to implement these laws, there is a positive improvement in the yield of the counties.

4.2. Introduction

Since the early 2000s, the United States has been rocked by several large-scale water scandals that have greatly lowered public confidence in the water administration of the country. These scandals have ranged from the local issue like that of Flint Michigan, to those national in scale, such as forever chemicals. This came at a time when most environmental justice and pollution literature were focused on air pollution, greenhouse gases, and climate change (Chakraborty, Maantay, & Jean D. Brender, 2011; Brinkman & Miller, 2021; Lee & Cavoski, 2022).

Despite the general distraction in academia, there have been growing calls to better understand the water issues in the US. These calls have usually come from other professionals, such as journalists or lawyers, before joining the national discourse (Bilott, 2019). They would subsequently join the national discourse through movies and documentaries, which have now become numerous (news.sky.com, 2021; Moore, 2018; Gussman & Plumb, 2014; Sarni, Clark, & Burnett, 2019; Hosea, 2019). There are also moments where the stories make it to the big screen, with big actors and interests (Haynes, Dark Waters, 2020).

The public outcry has become so significant that many politicians and local governments have felt compelled to intervene. There is no case more galvanising to the movement than that of Flint, Michigan, where a series of local and state government failures led to the poisoning of an entire city. It is also the best showcase for the power exercised by these local governments over the everyday lives of its citizens (Sarni, Clark, & Burnett, 2019).

Despite the environmental focus on more pressing and global issues, many healthcare researchers have studied the water pollution issue in the US. Notably, they have found that in the period between 2010 and 2017, over 100,000 cases of lifetime cancers are due to contaminated water. They also found that the level of chemical contaminants in drinking water is on average four times the acceptable limit. They aimed to use these findings to create a case for water cleanliness as an easy public health win (Evans, Campbell, & Naidenko, 2019). This pressure led to the Infrastructure and Jobs Act of 2021, which commits $15 billion to upgrading and improving the water infrastructure (American Water Works Association, 2022).

The conversation was historically seen as unnecessary, as a combination between the state environmental authorities and the federal EPA kept tight control on chemical releases, especially considering that failures in the system were rare. However, this changed with the advent of the PFAs and PFOAs. For a long time, these chemicals were not reported or monitored by the EPA although the chemicals industry knew their risks. The EPA is currently trying to remedy this failure; however, despite their best efforts, they are still well behind the curve. It is still reported that the EPA does not know the full extent of the quantities released, and new data is continually updated (Reade & Yiliqi, 2021). As the water quality issue penetrates more into the public sphere of knowledge, the severity of the reaction is becoming increasingly serious. Thus, it demands a more serious reaction from local and federal politicians. Clean drinking water is a fundamental right in developed countries.

The public outcry to water pollution has ranged from simple protests to congressional hearings like the one on the 10 February 2016 (Govinfo.gov, 2016). When situations escalated in places like Flint, Michigan, President Barack Obama intervened, as did the Army (Sarni, Clark, & Burnett, 2019). News of the poor water quality usually came with public relations issues for the local governments involved and at times would escalate to the point of forcing the federal government to become involved (congress.gov, 2016).

The drinking water in the US is handled through a complex system of water districts, who may interact with each other and get water from each another. Water districts can also break away and merge at will, making them complicated to track (Briffault, 2008). These fall under the category of special districts, a system so complicated and convoluted that many states may not even know how many districts they have, despite these districts having an aggregate budget of nearly $100 billion (Briffault, 2008). These districts manage over 148,000 public water systems across the nation, in three different categories: community water systems, non-transient non-community water systems, and transient non-community water systems. The first supplies water year round to a population; the second supplies water to at least 25 people more than six months a year, such as a school or seasonal areas; and the last supplies water to places where people do not stay for long, such as gas stations and campgrounds (epa.gov, 2022). All of these have different rules of supply and maintenance.

To avoid having to deal with these complex district structures, we used geographic and administrative jurisdictions of the counties. While this assumption may be flawed in some exceptions, the water districts generally fall under the responsibility of the county's operations.

Given the crucial role of these municipal administrations and their finances, they bear a sizeable impact on employment, quality of public life, number of public services, and even economic growth (Adelino, Cunha, & Ferreira, 2017; Dagostino, 2018; Green & Loualiche, 2021; Yi, 2021; Baicker, Clemens, & Singhal, 2012).

However, there has also been a growing trend in recent literature trying to understand the link between municipal finances and sustainability, with municipal bonds being affected by green certification, climate change, environmental regulations, and extreme weather events (Baker M. , Bergstresser, Serafeim, & Wurgler, 2018; Painter, 2020; Goldsmith-Pinkham, Gustafson, Lewis, & Schwert, 2020; Jha, Karolyi, & Muller, 2020; Jerch, Kahn, & Lin, 2020). However, there has been limited research studying the links between pollution and municipal bonds, as they must deal with the reverse causality between pollution and economic factors controlling municipal finances and thus bonds (Agrawal & D. Kim, 2021).

Despite this limitation, some research has been done to better understand the link between water quality and municipal finances. This work initially focused on municipal insurance (Agrawal & D. Kim, 2021) and then on the PFAS and PFOAS crisis (Huang & Kumar, 2022).

Despite these recent papers, one of the main advantages of our work is the nature of our data on pollutions and emissions. Whereas the initial analysis focused on municipal insurance, we focus on the issuance yield, which has a more significant impact on the lives and finances of the municipalities in the long term.

Our paper addresses water pollution generally by using the Toxic Release Inventory (TRI) to address more continuous threats of pollution. Despite Huang and Kumar (2022) showing causality between pollution and municipal finances, given their sole focus on PFA and PFOA, the researchers may have been the exception to the rule. We add to their proof more generally by using difference in differences and local green chemistry laws to show that there is a clear local link between general water pollution and municipal issuance yields.

This paper also contributes to the existing literature on local issues affecting municipal finances, such as underwriter location (Butler, 2008), political corruption (Butler, Fauver, & Mortal, Corruption, Political Connections, and Municipal Finances, 2009), and the opioid crisis (Cornaggia, Hund, Nguyen, & Ye, 2021). We are also contributing to the existing water pollution literature and its impact on consumers (Gorton & Pinkovskiy, 2021), healthcare (Danagoulian, Grossman, & Slusky, 2020), housing prices (Muehlenbachs, Spiller, & Timmins, 2015), and housing stocks (Christensen, Keiser, & Lade, 2019). We add to this literature by addressing the impact of general pollution on municipal issuances.

The first contribution of this paper is to add further insight to the impacts of chemical pollutions released into the water table on the finances of local governments. To our knowledge, this is the first paper that uses the median lethal dose and develops an impact factor to measure the potential impact of chemicals in finance. We believe this is also the first paper that measures the market reaction to green chemistry laws in the municipal market. Despite other papers in finance analysing toxicity (Hsu, Li, & Tsou, 2022), we are the first paper to delve into as much details as possible to develop an impact coefficient and LD50 for every chemical in the financial literature.

4.3. Data and methodology

The three main types of data used in this research are financial, environmental, and geo-demographic. We collected the bond market data from the Municipal Securities Rule Making Board (MSRB). This board records any municipal bond trade taking place after 2005. We used the bond identifiers to collect the issuance characteristics of each bond from Reuters. The release of industrial chemicals into the water table was collected from the Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI).

The TRI programme was started in the late 1980s in the aftermath of the Bhopal disaster in India. The programme tracks a range of industrial chemicals considered health or environmental risk. To better understand the risks associated with each chemical, we combine information collected from the EPA's TRI-CHIP database with that of ToxNet and the ChemIDplus. The first of these databases provided us with the four possible impacts to the chemical: acute, chronic (non-carcinogenic), carcinogenic and lastly, environmental. As for the ToxNet and the ChemIDplus, they provide us with the metric LD50. The Tox-Net and ChemIDplus services are operated by the US National Library of Medicine. We also use the European Chemical Agency (ECHA) to complete some of the missing LD50 values.

The third database is the geographic and demographic datasets and controls. While the county boundary maps and the population of the counties were collected from the US Census Bureau, we opted to use our Geographical Information Systems (GIS) model to obtain a surface area of each jurisdiction. We also collected economic characteristics for each county from the National Business Bureau and the water consumption figures from the United States Geological Bureau.

4.4. Model Specification

$$Yield = \beta_1 * ln\left(Adjusted_{chem_{release_{Water}}}\right) + \beta_2 * Bond\ Controls + \beta_3 * State * Year\ FE + \epsilon$$

The model used was a simple panel regression, as seen in the literature. We controlled for a state fixed effect and a year fixed effect. As the errors were geographical, we followed the lead of Marcus Painter (2020) and clustered our errors on the geography of the issuers.

4.5. Dependent variables

Following in the footsteps of other researchers, we assumed that the risks associated with a county would be reflected in the yield of its municipal products. More importantly, the yield at issuance should carry a minimal trading bias and only remember the value of the bond and its underlying risk.

4.6. Explanatory variables

First, we mapped all the TRI facilities in the US and its territories. We then used GIS to overlap these facilities with the maps of counties obtained from the Census Bureau. We developed a GIS model to identify which factory fell within which county. The identification step was done twice more to indicate all the factories within 500 m of the county's boundaries, and the last one was for factories within 1 km of the county. Both these extra layers were used in our robustness tests.

Before aggregating the chemical releases on a county level, we controlled for the harmfulness of the chemical. To do so, we used two factors: the impact factor and the median lethal dose (LD50). The fully aggregated version of the correction looks like the equation below; however, we tested every factor separately (Table 4.6).

$$Adjusted\_chem\_release\_Water_{Jt} = \sum_{j}\left(\frac{Mass\ of\ Chemical\ Released_{jit-2} \ *\ Impact\ Assuming\ Worst_{jit-2}}{LD50_{jit-2}}\right) *\ Demo\_control_{Jt}$$

The first metric was built using the data from TRI-CHIP to estimate the potential impact of the chemicals. We scored the substances between 0 and 4 based on their potential impact. Each chemical received a 1 for each of the following categories: acute risk, chronic (non-carcinogenic) risk, carcinogenic risk, and environmental risk. When the impact of the chemical was unknown, we assumed the worst possible implications for the chemical. We also built another chemical exposure variable to remove our assumptions for robustness testing. We ran multiple regressions across our period to determine which of the corrections used on the chemical provided the best result for our analysis.

The second metric we used was the LD50. We collected the toxicity from the Tox-Net and completed it with data from ChemIDplus. This toxicity data had different intake methods and different tested species; some were LD50, and some were LC50. To harmonise this data, we used the work of Honma and Suda (1998) and converted all the variables to the LD50 of rats, as this is the dominant metric. We excluded the chemicals for the substances for which we could not find a metric.

However, our chemical risk did not pose any threat in empty locations. Thus, we controlled the risk by adjusting for the demographic control. We multiplied the risk of the chemicals by the county's density, as the chemical risk is multiplied by that of the people exposed to the risk. For robustness, we also built the same variables; however, instead of multiplying by population, we controlled for density and divided by the area of the counties.

As seen in the formula, we delayed the chemical released by two years. The reason for this delay is that the EPA takes up to two years to release new data – meaning, the information is available two years after the fact. However, population, density, and area metrics tend to be stable and thus can be inputted without the delay.

To correctly identify the different chemical risks in a county, we first mapped all the TRI release points, using the EPA's longitude and latitude data. We then overlapped this toxicity map to the map of counties obtained from the Census Bureau. Our Geographic Information System (GIS) model then looked at each county and identified all the release points within the county's perimeter. We created two robustness variables for robustness: the first accounted for all the release points within the county and up to

500 m outside its borders, and the second robustness variable used the same logic but for 1 km outside the county's borders.

4.7. Control variables

We used the control variables used in previous literature. These controls were if the bonds were callable, puttable, insured, bank qualified, new money, pre-refunded, competitive, general obligation, maturity in years, and state and year fixed effect (Baker M. , Bergstresser, Serafeim, & Wurgler, 2018; Painter, 2020). We also added controls to capture any missing products, such as the sinkable options and the three-month risk-free rate. Both returns were insignificant in our analysis, indicating why they were not included in previous literature. Although our data is missing the state taxable variable that our data providers did not have, we included federal taxes and alternative minimum taxes.

For the bond ratings, we used the approach of Cantor and Packer (1997), a process that has been used by multiple academics working on municipal bonds (Painter, An inconvenient cost: The effects of climate change on municipal bonds, 2020; Baker, Bergstresser, Serafeim, & Wurgler, 2020). We collected all bond ratings from S&P, Moody's, and Fitch and converted the ratings to their S&P equivalent, and they only keep bonds rated at issuance. The ratings were then converted into numbers, with 1 assigned to 'AAA', 2 set to the next highest, and so on; the last rating we accounted for was 16, or 'B-'.

4.8. Green Chemistry law

4.8.1. Significance of green chemistry laws

Green chemistry and green chemistry regulations have changed significantly since the beginning of the 20th century. Aside from the fact that they are becoming popular, with eight states having implemented them, as of 2019, there are four more with similar laws on their agendas (Millar, 2019).

Around 2016, there was growing hope that the passage of the new Frank R. Lautenberg Chemical Safety for the 21st Century Act (LCSA) would fill the gap posed by an advancing chemical industry controlled by outdated chemical regulations. Many states estimated that there was no need to further implement new chemical regulations, as most of their demands would have been covered by the LCSA. This new law was intended to reform the nation’s Chemical Safety Regulations and Toxic Substances Control Act by providing the EPA with the necessary funding to continuously evaluate the risks of new chemicals (Millar, 2019). However, this dream never materialised. Under pressure from continuous lobbying and amendments, the Toxic Substances Control Act’s amendments never analysed establishing proper green chemistry division (Millar, 2019). This was before the Washington, DC, district court decision to force the EPA to revisit their implementation of the LCSA programme (United States Court of Appeals for the Ninth Circuit, 2019).

The continuous threats to the LCSA forced the states to want their own frameworks to limit the use of chemicals they define as dangerous. In the past two decades, states have move to ban many consumer products or the use of specific chemicals within their borders. Other forms of chemical control laws reiterated the existing framework of the TRI programme by forcing manufacturers to disclose the chemicals they use or release (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019). Some states have even gone as far as attempting to implement interstate chemical controls, as in limiting products using specific chemicals to enter their states despite being manufactured outside (Millar, Green Chemistry – The State of the States, 2015). However, the legality of these laws was dubious at best and were never implemented.

To prevent being involved in this wormhole of legal complication, many states looked at passing targeted legislations to address specific chemical issues. This legislation came to be known as green chemistry laws, which are typically marketed under the guise of protecting children's products, requiring these chemicals to be reported publicly to state agencies. Associated with these laws are a list of chemicals that need to be monitored and reported (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019).

Despite state-level variations in the laws, most green chemical laws have the shared aim of eliminating the chemicals in their high-risk list from the products in the state. The idea is that doing so forces manufacturers to disclose these chemicals, thus encouraging them to either suffer reputational damage or phase them out. Some states go a step further by conducting alternative assessments on riskier chemicals, encouraging their regulatory authorities to restrict or ban these chemicals (Millar, Green

Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019).

Despite the passing of the LCSA, the states still see a need to fill the gaps in chemical regulations. These regulations and green chemical laws tend to affect importers, manufacturers, distributors, and retailers, and they garner public support as a transparency measure (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019). This public support helps protect these laws against lobbyists.

4.8.2. Michigan, California, and Connecticut

Michigan, California, and Connecticut passed legislation that qualified as ‘green chemistry laws. However, unlike their counterparts, the impact of these laws is insignificant on the issuance yield (Table 4.9 to table 4.11).

Michigan was the first state to have a proper green chemical initiative. However, the initiative was limited in scope, as it was done through an executive directive in 2006. This meant that it lacked the teeth to enforce the order despite the well-meaning motivations behind the directive. The programme encouraged the elimination of toxic chemicals from consumer products but had no implementation mechanism (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019). The main reason why Michigan didn’t need such a strong implementation or enforcement mechanism was mainly due to its existing controls of the chemical substances that existed since the 119 Act of 1967, or anything smaller than what was already on the books, especially an initiative that lacked an enforcement mechanism (legislature Michigan, 1967).

California is one of the strictest states when it comes to controlling and regulating chemicals. Thus, why do green chemical laws not impact the municipal bonds issued by the local authorities in that state (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019)? In 1986, California released an all-encompassing law controlling chemical releases and regulating their use. This regulation is continuously being updated and includes nearly 1,000 chemicals as of March 2021 (California Legislative Information, 2022).

Connecticut passed a green chemistry law in 2008 but showed no impact in our analysis. However, despite being labelled a green chemistry law, the law is simply a lead level restriction. The state never intended to use its 'State Child Protection Act' to restrict the other chemicals despite the law requiring the authorities to identify a list of toxic substances. Connecticut used other laws and restrictions to limit and regulate specific chemicals, such as bisphenol A (BPA), and another for the levels of cadmium in children's products (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019).

Even though these three states are said in the literature to have passed or participated in the green chemistry trend (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019; Millar, Green Chemistry – The State of the States, 2015), their laws were limited in scope and in many cases redundant. In the cases of Connecticut and Michigan, the lack of enforcement and use of other laws to achieve the desired objectives rendered any potential shock value of the law moot.

4.8.3. Main-Washington Group

What we call the ‘Washington group’ is a group of states that followed the lead of Washington and Maine to develop robust laws to protect the environment. These states are Maine, Washington, Minnesota, Vermont, and Oregon. Vermont does not have any highly polluted counties; thus, it is not present in our difference in differences analysis.

Except for Washington, each of these states passed restrictive laws during our period, banning or restricting the use of over 1,000 chemicals. Washington which started with only 66 chemical and chemical families but has since passed on average one new restriction every year. All these states have in their lists, chemicals that they aim to phase in each period (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019).

In the case of Oregon, the law had been passed in only our sample period, as reporting started in 2018. This inclusion of Oregon into our sample was important, as it allowed us to clarify what seemed more important to the market: passing the legislation or its actual application. It was clear that the market expected the application once the laws were passed, thus only reacting to the laws (Millar, Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019, 2019).

4.9. Synthesis of results

4.9.1. General results

The result of our general analysis showed that the impact of the chemicals released was significant for all issuance with maturities up to and including 10 years (table 4.6). This result was consistent across chemical calculation methodologies. We also found the result to be significant when analysing the chemical releases within the county, up to 500 m outside the county and up to 1 km outside the county (table 4.7).

4.9.2. Green chemistry Difference in Differences

To analyse the impact of passing green chemistry laws, we ran a propensity score-matched difference in differences (Painter, An inconvenient cost: The effects of climate change on municipal bonds, 2020). The propensity scores were obtained using a logit regression, in which the score was 0 if the county had no TRI chemicals released into its water according to the most recent EPA toxicity report, and 1 if the county did.

To obtain the controls for the logit regression, we started by creating averages that included all the issuers in a specific county. We averaged the number of issues per year, the number of CUSIPs per issue, the issue size, and the rating of the issuer. The reason behind this was simply that there could be multiple issuers in the same county (a hospital district, a park district, police, or fire department), each having their different rating and characteristics. This was not an issue in the general regression, as it did not have to be aggregated on geography, whereas in this case, it did. Out control group are polluted counties in states that did not pass green chemistry laws, while our treatment group are counties in states that did.

The other controls included in the logit regressions were the area of the county, its population, the overall gross domestic product in US dollars, and the amount of water consumed by industrial activity inside the county.

The propensity score-matching was recalculated four times in our sample period: 2001, 2005, 2010, and 2015. At the beginning of our sample, we used the water consumption figures from 2000 because the figures for 2001 were unavailable, as the water consumption survey is done only once every five years.

The results shown in Table 4.8 indicate that the passing of these laws reduced yield of the counties within these states across all time frames. This conclusion stands when we run the difference in differences analysis state by state.

4.10. Robustness tests

4.10.1. Robustness for the general regression

For our robustness test, we started by testing all the assumptions made when building the chemical release variables shown in Table 4.6. These results showed that the main scientific measure of toxicity, LD50, reduces the significance.

We then ran our regression testing for the assumptions in our custom impact factor by removing the worst possible effect assumptions. This also showed that the impact factor assuming the worst possible effect was more significant in the 5–10-year period.

We ran our regressions using year by state fixed effects (table 4.6). However, we also ran our regressions with separate state and time fixed effects and obtained similar results, concluding that releasing chemicals into the water table has a small yet significant impact on yield.

The last assumption tested was the demographic control. Initially, we had an inkling that the impact of the chemicals would depend on the size of the population put at risk. However, we wanted to make sure that this impact was dependent on population and not the area impacted. However, as we saw from the results of the short term, the significance of the population is higher than that of density, showing that the market considers the magnitude of potential victims rather than the density.

To prove that this significance is directly associated with the chemical release risk, we used the propensity score to match between a polluted county and a non-polluted county within the same state. We then regressed the yield of the bonds issued by the clean counties with the pollution risk from their polluted match. Returning an insignificant result showed that the risk was directly related to only the chemical pollution in the water stream and not to any other characteristic.

4.10.2. Robustness for the Green Chemistry Laws

Recently, several researchers have come out to criticise the idea of staggering difference and differences (Baker, Larcker, & Wang, 2021). The best way we found to answer these fears is by running the propensity score-matched difference in differences separately for each of the states in our sample, thus proving that our analysis holds on the individual level before holding generally on the group level.

In doing so, we observed that all the states in the Washington group had a significant result for the medium-to-long-term maturity bonds. For

California and Connecticut, the results were insignificant. However, for Michigan, we saw an increase in the cost of issuance in the short term and a reduction of the cost in the long term. However, no major changes occurred in the medium term. Michigan has struggled considerably with water pollution since the beginning of the millennium, and we believe that this was simply market fears over the clean-up costs that could be associated with the green chemistry initiative. However, the long-term reaction is optimistic, as it sees the market lower borrowing costs.

This is the case for all states in the group, except for Washington, which saw no immediate change on the short-term bonds. This is explained by the fact that Washington had the slowest implementation of the chemical restrictions. Michigan is also a peculiar situation, where the event is correlated with a higher yield on the short term. However, we believe this is the impact of a different event that occurred in the state around 2007, which was more significant than a simple directive with no enforcement mechanism: after the 2006 elections in Michigan, the two parties disagreed on a fiscal policy, resulting in a shutdown in 2007, a political risk that will persist with Michigan for the foreseeable future.

4.11. Discussion and Conclusion

Throughout this paper, we set out to answer two simple questions: Does the market account for the risk of releasing chemicals directly into the water table of a county? Is there any power that a local authority has to regulate this risk?

As for the first question, according to our analysis, the market penalises counties that have a higher volume of chemicals released into their water table by 0.38BP, and the effect is more pronounced when correcting for the impact and toxicity of the chemical 0.65BP. This penalisation exists for only bonds below five years of maturity. This may be because it is much more difficult to assess the risks for bonds further into the future. However, most of the chemicals tracked have a half-life of around 10 years, which means the impact of the chemicals and the risk associated with them should be greatly reduced for longer maturities.

However, there seems to be a causation between chemical releases and economic benefits in the medium term. The TRI chemicals are released from factories, which most likely hire from the local population. This means that, in the medium term, the local government would benefit from the influx of cash coming from the stable jobs provided by the presence of these factories. The volume of chemicals released or their toxicity does not have a significant impact on the issuances of the municipal bond markets past the five-year maturity. When accounting for the two-year delay in data, the driver behind the penalty paid by highly polluted local authorities is the pollution, in this case represented by the release of chemicals into the water table. This is further confirmed by the results of our difference in differences.

Regarding the second question, during the late 2000s, a push was made for a stricter restriction on the release of chemicals. This came during a wave of controversies about pollution and toxic substances found in the water. Many states started to implement green chemistry laws. During the period studied, we found that these laws were the most important inter-state chemicals regulation, thus allowing us to build a proper difference in differences. In the states where these regulations were taken seriously by legislators and enforced with severity, the laws had a positive impact on the issuance yield of the counties. We called these states the Washington-Maine group.

The question of why the penalty paid by the polluted authority is only on the short-term maturities whereas the impact of the green chemistry laws and the chemical restrictions are seen on all maturities remains. We believe that the answer to this question has two main sides. The first is that green chemistry laws remove any possible risk of the most harmful chemicals in the future, thus presenting a shock to the system by forcing factories to abide by these new rules. On the other side, in states where these laws and regulations are not passed, the risk of chemicals released this year may have diminished, but the release points can still release the same chemical or any similar one, showing that the risk persists.

Table 4.1: New Issuance of Municipal Bonds

This table shows the bond issuances of all the bonds reported in the MSRB dataset. These are bonds issued between 2001 and 2018. These bonds were issued by institutions within the county that did not belong to a city or a school district.

	N	Mean	Median	Standard Deviation
Yield (%)	225464	2.63	2.61	0.012
Is Callable	225464	0.44	0	0.497
Is Puttable	225464	0.001	0	0.033
Is Sinkable	225464	0.084	0	0.28
Bond Insurance	225464	0.14	0	0.35
Insured by Mortgage	225464	0.002	0	0.0497
Bond Rating	225464	3.39	3	1.93
Issue Size (MM$)	225464	53.48	14.48	1.19E+08
log Number bonds per issuance	225464	2.88	2.89	0.52
Federal Tax Status	225464	0.062	0	0.24
AMT Tax Status	225464	0.012	0	0.11
Pre-Refunded	225464	0.083	0	0.28
Competitive	225464	0.62	1	0.49
General Obligation	225464	0.43	0	0.495
3 Months T-Bills	225464	0.51	0.13	0.86
Maturity in years	225464	9.62	8.65	6.20

Table 4.2:Bond Issuances by State

This table presents the percentage of the total issuance by State. Texas is the state that has the biggest number of bonds issued. However, during our analysis, we use California as the baseline as it is the second biggest issuer and a state notorious for its chemical regulations. Thus, allowing us to have a baseline of relatively clean counties.

State		State		State	
Alaska	0.25	**Louisiana**	0.77	**North Dakota**	0.38
Arizona	0.63	**Maine**	0.46	**Ohio**	2.63
Arkansas	0.21	**Maryland**	3.25	**Oklahoma**	0.68
California	5.54	**Massachusetts**	3.88	**Oregon**	0.69
Colorado	1.59	**Michigan**	3.46	**Pennsylvania**	6.01
Connecticut	3.47	**Minnesota**	2.65	**Rhode Island**	0.50
Delaware	0.13	**Mississippi**	0.37	**South Carolina**	1.39
Florida	3.45	**Missouri**	1.56	**South Dakota**	0.15
Georgia	2.09	**Montana**	0.20	**Tennessee**	2.66
Hawaii	0.57	**Nebraska**	0.47	**Texas**	15.02
Idaho	0.01	**Nevada**	0.52	**Utah**	0.56
Illinois	2.38	**New Hampshire**	0.17	**Virginia**	2.40
Indiana	1.22	**New Jersey**	7.61	**Washington**	2.81
Iowa	0.89	**New Mexico**	0.47	**West Virginia**	0.17
Kansas	2.31	**New York**	5.82	**Wisconsin**	2.09
Kentucky	1.07	**North Carolina**	2.83	**Wyoming**	0.15

Table 4.3: Demographic Controls

The demographic variables are not run separately into the regression except as a robustness check, to make sure our results are not driven by them. Area is calculated from the shapefiles obtained from the census bureau and our own models. It is then used to calculate the density.

	N	Mean	Median	Standard Deviation
Density	225464	471.08	240.50	857.12

Table 4.4: The chemical release into water table adjusted for demography

This table presents the summary statistics for log of the chemicals released into the water table. The chemicals are multiplied by the population they might put at risk. The first variable represents the chemicals released into the water table inside the county, the second variable is for the chemicals released within the county or up to 500m outside the boundary or the county. the last variable is the same as the 500m, but this time extended to 1km

	N	Mean	Median	Standard Deviation
Chemicals within the county * Density	225464	4.57	3.25	4.70
Chemicals within 500m of the county * Density	225464	4.69	3.51	4.72
Chemicals within 1km of the county * Density	225464	4.79	3.69	4.72

Table 4.5: the changes of correcting with LD50 and Impact Factor

To show that the changes made to the data by correcting releases by the LD50 and the impact factor. We use the example of population in this case, as the changes on the data would essentially be the same for density. We only present the figures within the county for the same logic. Impact W means that when the impact of the chemical is not known in one of our criteria, we assume that the chemical has the worst possible impact. Impact B, assumes the opposite, showing that when the impact of the chemical is unknown, we assume that it has no impact.

	N	Mean	Median	Standard Deviation
Chem (Tonne)*Den	225464	4.57	3.25	4.70
Chem (Tonne) / LD50 (mg/kg) * Den	225464	1.93	0.62	2.93
Chem (Tonne) * Imp W * Den	225464	5.11	4.08	5.01
Chem (Tonne) / LD50 mg/kg (all)*Imp W * Den	225464	2.20	0.78	3.25
Chem (Tonne) *Imp B * Den	225464	4.98	3.64	5.03
Chem (Tonne) / LD50 mg/kg (all) * Imp B * Den	225464	2.03	0.69	2.85

Table 4.6: General regression corrected for LD50 and Impact Coefficient

In this table we present the regression results for emissions within the county. The letters express the different variables and how they are calculated, which can be seen in table 4.5. Imp W and Imp B are also explained in table 4.5.

*** p<0.01, ** p<0.05, * p<0.1

Variables	**Letter**
Chem (Tonne)*Density	A
Chem (Tonne) / LD50 (mg/kg) * Density	B
Chem (Tonne) * Imp W * Density	C
Chem (Tonne) / LD50 mg/kg (all)*Imp W * Density	D
Chem (Tonne) *Imp B * density	E
Chem (Tonne) / LD50 mg/kg (all) * Imp B * density	F

	Mat <=5	**5< Mat <=10**	**10< Mat <=15**	**15< Mat <=20**	**20 < Mat**
A	0.0038*** (0.0009)	-0.0007 (0.0015)	1.6E-6 (0.0013)	0.0011 (0.0015)	0.0005 (0.0019)
B	0.0058** (0.0018)	-0.0021 (0.0026)	-0.0013 (0.0022)	0.0003 (0.0024)	-0.0002 (0.0026)
C	0.0036*** (0.0008)	-0.0008 (0.0014)	-8.63E-5 (0.0012)	0.0011 (0.0014)	0.0005 (0.0018)
D	0.0054*** (0.0016)	-0.0018 (0.0024)	-0.0011 (0.0021)	0.0005 (0.0023)	-0.0002 (0.0023)
E	0.0035*** (0.0008)	-0.001 (0.0014)	-0.0003 (0.0012)	0.0009 (0.0014)	0.0005 (0.0018)
F	0.0065*** (0.0017)	-0.0017 (0.0027)	-0.0009 (0.0023)	0.0009 (0.0026)	4.53E-5 (0.0029)
R-Squared	0.9513	0.9799	0.9891	0.9922	0.9917
Observations	61320	71124	49842	30622	12556
Controls			**Yes**		
State by Year FE			**Yes**		

Table 4.7: General Regression Results Within and around the county

Number (1) represents the chemicals released into the water table inside the county, (2) is for the chemicals released within the county or up to 500m outside the boundary or the county. (3) is the same as the 500m but this time extended to 1km. We split the maturities of the bonds into 5-year increments, as to not have our results significant due to volume. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	Mat <=5	**5< Mat <=10**	**10< Mat <=15**	**15< Mat <=20**	**20 < Mat**
(1)	0.0054*** (0.0015)	-0.0018 (0.0024)	-0.0011 (0.0021)	0.0005 (0.0023)	-0.0002 (0.0023)
(2)	0.0053*** (0.00015)	-0.001 (0.0023)	-0.0014 (0.002)	0.0003 (0.0022)	-0.0003 (0.0023)
(3)	0.0052*** (0.0015)	-0.002 (0.0023)	-0.0013 (0.0011)	0.0005 (0.0022)	-0.0005 (0.0023)
R-Squared	0.9513	0.9799	0.9891	0.9922	0.9917
Observations	61320	71124	49842	30622	12556
Controls			**Yes**		
State by Year FE			**Yes**		

Figure 4.1: Map showing the states who passed green chemistry laws

This map shows the states that have passed green chemistry laws between 2000 and 2017. These states fall into two categories: States that had pre-existing laws and states that did not.

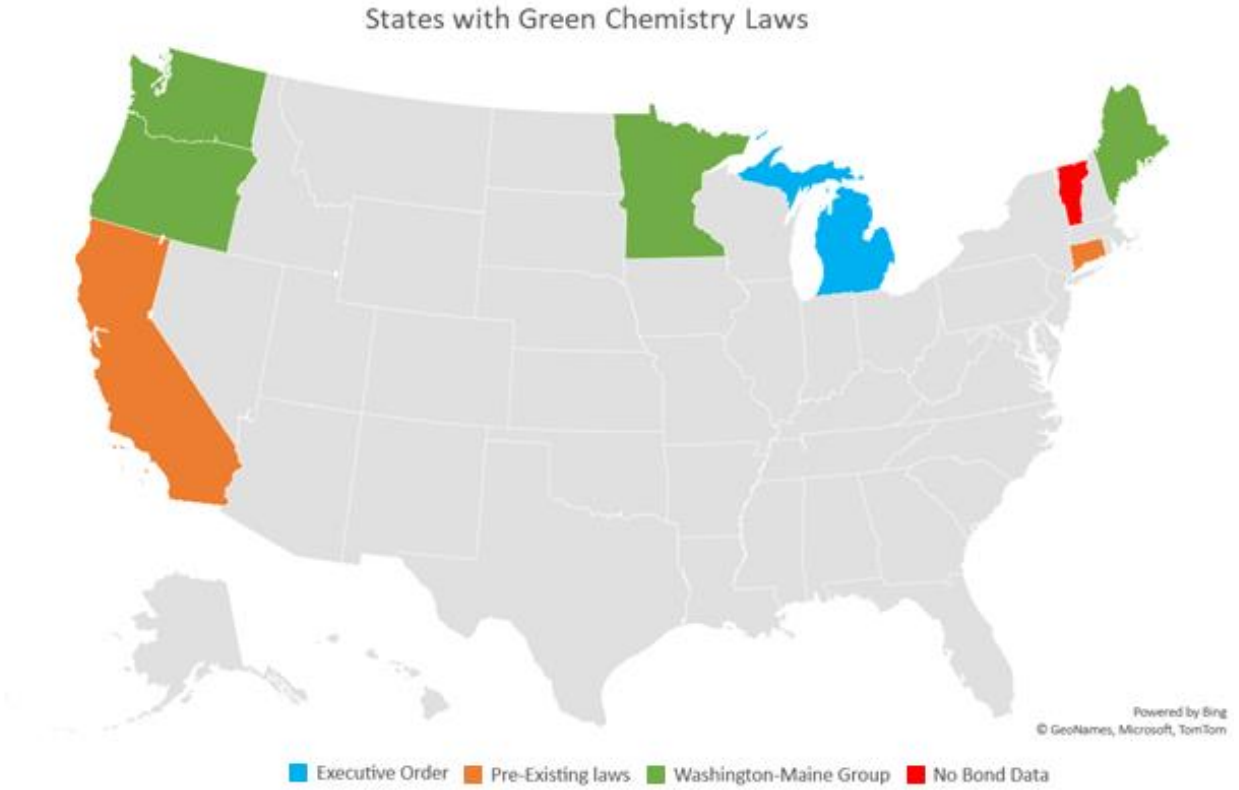

Table 4.8: Diff-in-diff staggered result of the Washington-Maine Group

The results in table A are for a regression where the chemical releases are corrected for the impact factor only. Results in table A show the results for the regression where the chemicals are both corrected for LD50 and the Impact factor. Only one R-squared in included for each period as the difference in value is infinitesimally small. We only correct for the best assumption of the chemicals impact. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

A	**Mat <=5**	**5< Mat <=10**	**10< Mat <=15**	**15< Mat <=20**	**20 < Mat**
DiD Results	-1.070*** (0.172)	-1.1441*** (0.264)	-0.98*** (0.1608)	-0.801*** (0.1244)	-0.881*** (0.2472)
R-Squared	0.7951	0.8043	0.7914	0.7678	0.832
Observations	7375	9881	7405	4825	2253
Controls			**Yes**		
State by Year FE			**Yes**		

B	**Mat <=5**	**5< Mat <=10**	**10< Mat <=15**	**15< Mat <=20**	**20 < Mat**
DiD Results	-0.903*** (0.1598)	-1.135*** (0.2397)	-0.978*** (0.1427)	-0.829*** (0.136)	-0.949*** (0.2888)
R-Squared	0.7918	0.8021	0.7926	0.7702	0.8215
Observations	7487	10007	7500	4969	2306
Controls			**Yes**		
State by Year FE			**Yes**		

Table 4.-9 to 4.15: State by State Diff-in-Diff results

The results in the following tables show the results for the regression where the chemicals are both corrected for LD50 and the Impact factor. Only one R-squared in included for each period as the difference in value is infinitesimally small. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4.9: Difference in Difference results for the state of Michigan.

	Mat <=5	**5< Mat <=10**	**10< Mat <=15**	**15< Mat <=20**	**20 < Mat**
DiD Results	0.501*** (0.1812)	0.0976 (0.154)	0.0986 (0.117)	-0.108 (0.1117)	-0.1951* (0.1134)
R-Squared	0.9049	0.9548	0.9785	0.9868	0.9879
Observations	5831	7882	5657	3658	1390
Controls			**Yes**		
State FE			**Yes**		

Table 4.10: Difference in Difference results for the state of California.

	Mat <=5	**5< Mat <=10**	**10< Ma <=15**	**15< Mat <=20**	**20 < Mat**
DiD Results	-0.0872 (0.3102)	-0.245 (0.1501)	-0.1218 (0.175)	-0.2156 (0.1753)	-0.0825 (0.1696)
R-Squared	0.626	0.5354	0.9785	0.9854	0.9886
Observations	9533	11340	8319	4728	2659
Controls			**Yes**		
State FE			**Yes**		

Table 4.11: Difference in Difference results for the state of Connecticut.

	Mat <=5	5< Mat <=10	10< Ma <=15	15< Mat <=20	20 < Mat
DiD Results	-0.0872 (0.3102)	-0.245 (0.1501)	-0.1218 (0.175)	-0.2156 (0.1753)	-0.0825 (0.1696)
R-Squared	0.626	0.5354	0.9785	0.9854	0.9886
Observations	9533	11340	8319	4728	2659
Controls			**Yes**		
State FE			**Yes**		

Table 4.12: Difference in Difference results for the state of Maine.

	Mat <=5	5< Mat <=10	10< Ma <=15	15< Mat <=20	20 < Mat
DiD Results	N/A	-0.7024** (0.3546)	-1.2124*** (0.2723)	-2.0584* (1.221)	N/A
R-Squared	N/A	0.7734	0.8446	0.8492	N/A
Observations	N/A	535	405	315	N/A
Controls			**Yes**		
State FE			**Yes**		

Table 4.13: Difference in Difference results for the state of Washington.

	Mat <=5	5< Mat <=10	10< Ma <=15	15< Mat <=20	20 < Mat
DiD Results	-0.3406* (0.1918)	-0.2179 (0.1989)	-0.2416*** (0.0882)	-0.2314*** (0.0642)	-0.1358 (0.1351)
R-Squared	0.9109	0.9641	0.982	0.9881	0.9888
Observations	3907	5221	3755	2500	1200
Controls			**Yes**		
State FE			**Yes**		

Table 4.14: Difference in Difference results for the state of Minnesota

	Mat <=5	5< Mat <=10	10< Ma <=15	15< Mat <=20	20 < Mat
DiD Results	-0.2943 (0.1848)	-0.3537*** (0.1131)	-0.4319*** (0.0631)	-0.3078*** (0.0759)	-0.453*** (0.1448)
R-Squared	0.9358	0.974	0.9867	0.9908	0.7628
Observations	2323	3252	2615	1755	746
Controls			Yes		
State FE			Yes		

Table 4.15: Difference in Difference results for the state of Oregon

	Mat <=5	5< Mat <=10	10< Ma <=15	15< Mat <=20	20 < Mat
DiD Results	-0.2185 (0.1676)	-0.75*** (0.1005)	-0.7223*** (0.1005)	-0.543*** (0.1131)	-0.6881*** (0.148)
R-Squared	0.9314	0.966	0.9844	0.9904	0.9938
Observations	833	999	725	399	196
Controls			Yes		
State FE			Yes		

Table 4.16: Placebo Test

The table below shows the results of the placebo test. The test matches highly polluted counties with clean counties within the same state. It shows that there are no significant results, thus the risk measure is directly associated with the emissions. The results (a) are for a regression where the chemical releases are corrected for the worst impact factor only. Results (b) show the results for the regression where the chemicals are both corrected for LD50 and the Impact factor. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	Mat <=5	**5< Mat <=10**	**10< Mat <=15**	**15< Mat <=20**	**20 < Mat**
A	0.0007 (0.0013)	-0.0003 (0.0018)	-0.0028 (0.0022)	-0.0021 (0.0028)	-0.0019 (0.0041)
R-Squared	0.8536	0.8661	0.8512	0.8583	0.8656
Observations	16160	19850	13641	7569	3190
Controls			**Yes**		
State by Year FE			**Yes**		

	Mat <=5	**5< Mat <=10**	**10< Mat <=15**	**15< Mat <=20**	**20 < Mat**
B	0.0033 (0.0038)	0.0035 (0.0048)	0.006 (0.0053)	0.0026 (0.0082)	-0.0009 (0.0065)
R-Squared	0.8705	0.8777	0.8653	0.8689	0.8695
Observations	11054	13794	9588	5418	2176
Controls			**Yes**		
State by Year FE			**Yes**		

5. Cities and Towns… institutions at the mercy of chemical accidents?

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5.1. Abstract

We analysed the effects of chemical accidents on municipal issuances of cities and places around the United States. We found that most recent literature on municipal bonds in the US covers extreme weather events and climate change but do not cover extreme events resulting from direct human activity. We also found that the smallest villages and largest cities suffer the impact of these chemical accidents most.

To analyse the remedy to these events, we used the ongoing debate on medical monitoring laws to understand how they help relieve the responsibility of these events. The US's medical expenses problem is an ongoing issue; thus, relieving this pressure from the population makes a major difference. This reduction of the yield of municipal bonds within states that have medical monitoring laws is complimented by an increase in the yield of corporate bonds in those states.

5.2. Introduction

On 17 April 2013, as parents were getting their kids ready for bed in the city of West, Texas, it seemed like every other night. Little did they know that the West Fertilizer company plant down the road was on fire. At ten minutes to eight, the ammonium nitrate in the plant exploded, levelling the factory, and damaging every building in the city. The explosion killed at least 15 people and injured over 260 (J.Willey, 2017). The damage of the explosion became even more pertinent when the local population and the local government found out that the facility had only one million dollars in liability; the factory used an obscure Texas law that allows fertiliser storage facilities to function at full capacity without liability coverage (Swanson & Dunklin, 2013).

Despite being an extreme case, this was far from the only case in which a chemical leak or mismanagement led to disastrous consequences to a place in the US. Events like these occur regularly, ranging from the catastrophic, such as that of the Brunswick chemical plant near Savanah Georgia to much smaller ones (The Associated Press, 2022; CBS47/ FOX30, 2022). However, these events are not just limited to operational facilities; these chemicals can still threaten the prosperity of a town even when not in use. The case of the old Piney Point phosphate mine near Tampa Bay, which used radioactive materials, is a perfect example; due to a leak in the wall, over 300 homes had to be evacuated (Associated Press, 2021), and the entire area became a safety risk until the issue was resolved by emergency crews (bbc.com, 2021).

Unlike other forms of chemical releases, chemical accidents are not part of the normal industrial process and thus are more difficult to predict. Homeland security, in combination with other national organisations, performs risk assessments to manage and plan for these events (Congressional Research Service, 2006), but many of these events are undisclosed to the public.

The 9/11 attacks provided the right wing of US politics with an argument against the public disclosure of accident risks. Some went as far as questioning the Right to Know Act (Davis, 2002). Many groups, whether professional, trade, or simply lobbying for the chemical industry, have strongly opposed the release of this information to the public. Their main argument is that terrorists can use this information to target the most vulnerable facilities or the facilities that would have the biggest impact (Congressional Research Service, 2006).

However, advocates for environmental disclosures and right-to-know argue that this information helps hold the facilities accountable, a task usually left to the local population to petition the court for when other national organisations have other priorities. The facilities are usually backed by investment groups, who argue that investors should know the litigation risks of the companies they are investing in (Congressional Research Service, 2006). Depending on the party in power, the balance of the conversation has shifted between both sides of the debate. However, these assessments have been left outside the public sphere.

For their part, the Security and Exchange Commission (SEC) has looked at addressing the concerns of investors. Some of their climate initiatives were suggested by congress in an attempt to resolve this debate (United States Government Accountability Office, 2004). However, many investors found themselves unfulfilled with the SEC requirements. Thus, charities and organisations focused on environmental disclosures, such as the Carbon Disclosure Project, grew.

Over the last two decades, the risk of terrorism threats has not materialised. As predicted by the congressional research services, the risk of the accidents would ultimately come from the chemical leaks instead of actual terrorist activities (Congressional Research Service, 2006).

As mentioned earlier, the policy on disclosure has not been consistent between the different administrations. Republican administrations in general landed on the more security-inclined side of the fence (Gibbons, 2022) despite calls for further restrictions and reversal for other chemical disclosure programmes by the major republican power groups (most notably, the federalist society who strongly argues that in the US, chemical disclosures are too easily available to the public) (Cochran, 2002; Slavitt, Cote, & Hannah, 2003; Eilperin, 2019). With the recent shift in the Supreme court under the Trump administration, the security side may get a longer-lived shift in their direction. However, the Democrats tried to walk a fine line between security and right-to-information. Barack Obama started by introducing some legal protections despite withholding a lot of information from the public, and Joe Biden has recently reintroduced these rules (Gibbons, 2022).

Due to this back-and-forth debate and changes in public policy, many academics have argued for a more balanced approach (Dahl, 2004).

However, a balance is yet to be found, with firms trying to limit disclosures and the public wanting to know more.

This has left a major question unanswered: is there a government database for chemical accidents in the United States? The short answer is no. The risk assessments, which include the number of incidents in the last 3–5 years, exists, but only for this period. Further, the sizes of incidents are not always available in these assessments.

Recently, studies investigating the adverse effects of climate change and pollution on municipal bonds have generally focused on the long-term risks of climate change – notably, the rise in sea level (Painter, An inconvenient cost: The effects of climate change on municipal bonds, 2020; Goldsmith-Pinkham P. , Gustafson, Lewis, & Schwert, 2021). These studies greatly influenced the methodology of our own, as they also measured the long-term effects on bond yields. Extreme weather events, such as hurricanes, have been shown to reduce local revenues, starting a cascade that ends by lowering municipal ratings (Jerch, Kahn, & Lin, 2020), showing that there is a link between extreme events affecting local authorities and their yields in both the primary and the secondary market.

A large chunk of the income of local authorities, especially cities and school districts, is directly related to property taxes and valuations. Thus, anything impacting this income directly results in less income for local authorities. In fact, there has been a growing body of real estate literature showing how rising sea levels and disaster risks affect real estate prices and lender behaviour towards certain geographies (Bernstein, Gustafson, & Lewis, 2019; Murfin & Spiegel, 2020; Nguyen, S. Ougena, & Sila, 2021).

Thus, real estate disaster risks should be directly related to the yield of municipal bonds.

However, despite this growing body of literature, little information on man-made disasters, such as industrial accidents, exists. First, this type of event is like other natural disasters in that it is also determined by geography – in the case of industrial accidents, by the proximity to a factory. Second, unlike natural disasters that have a negative impact on only local economies, the chemical accidents risk is directly related to jobs and economic activity provided by the factories that create the risk. We should see balance between economy and risk more strongly in midsize cities, which tend to have specialised economies built around single industries, in which case the risk of chemical accidents is a vital issue for the survival of the city. This may not be the case for larger or very small cities; for the former, their economies are not dependent on one industry, and they should thus see only the large clean-up costs and the medical risks to their population; and for the latter, such accidents would threaten agricultural yields and thus the livelihood of the town.

To fill the literature gap around industrial accidents, we used the reliability of the TRI to our advantage. The TRI database records accidental releases of the monitored chemicals, providing a record of all industrial accidents in which a TRI chemical was released. Although this database may not provide a complete picture of all the industrial accidents in a year, it is the most accurate indicator currently available and can even be used to indicate the size of an event by the volume of chemicals released.

This search is peculiar in its geography, so instead of counties or states, the geographies needed to be smaller and denser to be impacted by the chemical accidents. Thus, we focused our research on places in the US. Places are designations with any form of urban government and range from large cities like New York or Los Angeles to smaller towns or villages of less than 2,000 people.

It is important to clarify how the EPA defined a One-Time Release or chemical accident. The EPA notes that these events are the result of chemical releases that should not have occurred in the normal production process. They include spills, natural disasters, or even catastrophic size incidents. They must also be handled in a non-routine manner.

Our investigation had three stages. In the first stage, we analysed how chemical accidents impacted the municipal bond issuances of places in the US. We did this by running a series of regressions, in which the explanatory variables included control factors that provided a transparent picture of the impacts of the event of the accident and of the nature of the chemicals released. In the second stage, we analysed how places of different sizes experienced the impacts of these industrial events. We did this by running separate analyses for different places with similar population sizes. Finally, in the third stage, we wanted to prove causality by analysing the medical costs of exposed populations. We did this by using several state legislations known as ‘medical monitoring laws. These laws require polluters to compensate for any medical damage to the population, sometimes subjecting polluters to significant damages.

5.3. Data and methodology

5.3.1. Data

Our approach combined data from multiple sources. The main sources were chemical release data, financial data, and geo-demographic data. We used the dataset from the Municipal Securities Rulemaking Board (MSRB) to identify the bonds issued by cities in the US. Because MSRB records only municipal bonds traded after 2005, we used this database to collect the bond identifiers and then collected the issuance details from Reuters. From these details, we calculated the issuance yield of the bonds. To identify the location of the security, we read the issuance contract of every bond, which allowed us to then allocate the securities to cities.

As for the data on the accidents, we used the TRI, which is published by the EPA. This data was more generally used to indicate the amount of pollution released by a factory or plant. We used this information in the TRI dataset about one-time releases to identify facilities that had production accidents involving the release of chemicals. We then corrected these chemicals for their toxicity and general impact.

We also collected demographic data from the US Census Bureau. We used the population as part of our metric mainly because places designated by the Census Bureau are the most densely populated areas in counties. However, we ran separate analyses by grouping places with different population sizes, to understand how they can be impacted differently.

5.3.2. Dependent variables

The dependent variable in this study was the issuance yield of the municipal securities. We focused on the yield at issuance rather than on the secondary market yield, as the price of the issuance should reflect only the fundamental value of the bond and its underlying risks. We did not believe that a bond would have any bias introduced by speculators or traders at issuance, giving us a proper, unbiased valuation of the municipal authorities' financial risks.

5.3.3. Explanatory variables

We built our explanatory variables by mapping all the release points in the TRI dataset. We then obtained the map of places in the US from the Census Bureau. We then used a GIS model to allocate the TRI release points to the places they fell within.

Our main explanatory variable in this analysis is the "ONE_TIME_RELEASE" category from the TRI release data. This category indicates quantities of controlled substances released into the environment due to uncontrolled events. These events can range from simple non-routine malfunctions to larger spills and catastrophic accidents. However, the data does not specify which type of incident occurred. Thus, we recorded any value above 0 as a non-routine event, and we used the volume of chemicals released as an indicator of the size of the event. All chemical accidents that did not release TRI chemicals were not registered in this dataset.

The volume of the released chemicals can provide only a limited perspective on the risks of the chemicals released. Thus, we used the methodology developed in Chapter 3 to provide a clearer picture of the dangers of the chemicals. We used the LD50 dataset collected from TOXNET and the impact factor we developed from the EPA TRIChip database. We multiplied the mass of chemicals released by the population size of the impacted population and then aggregated the chemicals at the city level.

$$Adjusted\_accident\_release_{jt} = \sum \left(\frac{Mass\ of\ Chemical\ Released_{it-2} * Impact_{it-2}}{LD50_{it-2}} \right) * Population$$

Our data showed 7,196 incidents between 1998 and 2017. This translates into 18,147 incident-years, impacting 563 cities and places that issued municipal securities. At such a scale, these chemical malfunctions and accidents are widespread, and the extreme ones can upend places.

5.3.4. Control variables

Following previous literature, we numerated bond ratings from 1 to 17, with 1 being the highest rating (AAA in Standard and Poor) and 17 (CCC+) being the lowest rating we consider in our analysis; anything below CCC+ in Standard's and Poor ratings was ignored (Cantor & Packer, 1997; Painter, An inconvenient cost: The effects of climate change on municipal bonds, 2020). We account for only the bonds with ratings at issuance; any bonds without a rating at issuance was excluded from our analysis (Painter, An inconvenient cost: The effects of climate change on municipal bonds, 2020).

The bond ratings were collected separately from the issuance variables, and thus the ratings and issuance were matched on their dates. As we used only bonds rated at issuance, we had to account for ratings that may have arrived after issuance. Thus, we allowed for the matching of bonds and ratings with up to one week of difference to account for late ratings or public holidays.

Our study also included most of the control variables present in recent literature; we controlled for callable, puttable, insured, bank qualified, new money, competitive, general obligation, log of maturity in years, and year-by-state fixed effect (Painter, An inconvenient cost: The effects of climate change on municipal bonds, 2020; Goldsmith-Pinkham P. , Gustafson, Lewis, & Schwert, 2021; Baker M. P., Bergstresser, Serafeim, & Wurgler, 2018). Although we were unable to collect state taxability information, we account for federal tax and alternative minimum tax. We also control for the number of bonds by issuance and the size of the issuance (Painter, 2020).

Unlike other research, this subject requires great sensitivity towards the moment the knowledge reaches the market. Information dissipates to the market soon after incidents only in the most catastrophic circumstances. In fact, the information is not known until the EPA releases the newest TRI data, which is always two calendar years after the calendar year of the release. Further, the EPA indicates only that chemicals have been released each year, without specifying the date of the incident. Thus, we were compelled to analyse using two different approaches.

The first approach was by introducing a one-calendar-year delay (Hsu, Li, & Tsou, 2022). This delay was before the EPA released data, in which case we determined whether the information was communicated to the market, or whether the market had insight into the event. The second approach was by introducing a two-calendar-year delay, in which we recorded events when the EPA released data. Although this approach contrasts with existing literature, this delay provided more accurate results for the primary bond market, which is when the market should have more insight and should know that an event has occurred.

We ran the analysis for both delays to determine which was more delay has the bigger explanatory power, and we ran the same analysis both as events and quantities of chemicals released.

5.4. Medical Monitoring

5.4.1. What is medical monitoring?

Legally, medical monitoring is a claim in which a claimant seeks to recover the costs of medical examinations not yet present at the time of the lawsuit (Behrens & Appel, 2020). This type of claim has two main arguments, one medical and one judicial. The medical argument is underpinned by the public health benefits of early disease detection and the reduced risks and costs associated with early diagnosis (Beeler & Sappenfield, 1987). The justice argument is that plaintiffs find themselves paying for tests that they would not have needed were it not for the actions of defendants. Medical monitoring is “a remedy designed to provide healthy plaintiffs with the means to undergo periodic medical testing deemed necessarily to facilitate the early detection of diseases caused by toxic substances” (Behrens & Appel, 2020).

Historically, there has been major disagreement between states on the legal value of medical monitoring. Chemical firms have argued about being subjected to endless and unlimited liability whereas affected populations have argued that they are victims of the firms’ decisions. Many courts, such as that of Oregon, have argued that, for a claim to be valid, there must be injury. However, other courts have argued that the limited definition of 'injury' as present in the law does not reflect modern reality, in which there is a better understanding of causality, and is also inconsistent with other cases in which claimants obtain compensation for latent injuries (Beck, 2009; Beeler & Sappenfield, 1987).

However, in 1997, the US Supreme Court recognised the risk in non-injury claims of flooding the legal system with claimants who are otherwise insured. Thus, the court rejected the claim but refused to overturn existing rulings in different states. By doing so, the court allowed local and state courts and to be the main arbiters in the issue. This action maintained the existing divide between federal and state law, and the right to medical monitoring claims has since become state-dependent (Behrens & Appel, 2020).

Jurisdictions that recognise medical monitoring claims require the claim to meets the following requirements (Behrens & Appel, 2020):

- Significant exposure
- The exposure is to a proven dangerous chemical.
- Causal link with the behaviour of the defendant
- An increase in the risk of contracting serious latent diseases.
- Reasonable necessity for the plaintiff to undergo periodic testing that are not done in a routine examination.
- Monitoring procedures that make early detection possible

There are major differences between medical monitoring states on whether there must be a beneficial treatment or cure as a likely result of early detection and on whether a defendant's conduct must be the cause of the exposure or increased risk. The main disagreement, however, is at what level the risk supports the claim (Behrens & Appel, 2020).

5.4.2. Experimental design

For the sake of simplicity, we consider two camps: states that have accepted medical monitoring and states that have rejected it. We also assume that both camps are monoliths, with little difference between them, and that negligence, or lack of preparation, is a sufficient legal argument, which could vary greatly between states. There are three other camps in legal literature that we do not consider in our difference in differences analysis: states that will likely accept medical monitoring, states that are likely to reject it, and states in which it is unknown.

For our difference in differences, we considered only states that had a clear position on the matter. We ran a propensity score-matching, in which we matched places in medical monitoring states to places in non-medical monitoring states. We matched them on population, area, issue size, county GDP, and issuer rating. We implemented a non-replacement matching to prevent introducing bias in our difference in differences regression.

As most medical monitoring laws were established in the 1990s, the shock is the occurrence of an accident. Thus, we placed the following constraints: one city in a medical monitoring state must match with a city in a state without medical monitoring, and both states must have had an accident in the same year.

5.4.3. Medical Monitoring and debt products

Given the high costs of healthcare in the US, our argument in this case is that, with medical monitoring, the population would have better access to early diagnosis and treatment, which should translate to a lower risk for local authority, as the population does not have to pay for medical expenses and, in extreme cases, does not suffer reduced life expectancy. For example, water pollution leads to higher pressure on healthcare (Danagoulian, Grossman, & Slusky, 2020). In these extreme cases, populations experience negative equity as the demand for their properties crash, and they find themselves hostages to the pollution (Muehlenbachs, Spiller, & C. Timmins, 2015). There exists anecdotal evidence of these issues in Parkersburg, West Virginia, and Flint, Michigan.

There has been growing criticism in the literature of staggered difference in differences regressions (Baker, Larcker, & Wang, How Much Should We Trust Staggered Difference-In-Differences Estimates? , 2021). Thus, the best way to argue the causality between debt product and the medical monitoring provision is to trace the risk. We argue that places in medical monitoring states have a lower risk exposure to uncontrolled chemical releases. This reduction of risk should be transferred to the companies running and operating the facilities where the incidents occur. Thus, we generated a list of all factories who had a chemical release incident in the states with medical monitoring. From there, we generated a list of the firms that operated and owned these factories. We research each firm and their parent companies, making a list of their identifiers. Using the Trace dataset, we obtained the CUSIPs of the bonds issued by these corporations, which we then used to get the issuance details of these corporate bonds.

We excluded all firms with plants in both types of states. We then propensity score-matched the factories in the medical monitoring states with the plants in the other states. We matched the factories on the quantity of chemical emissions they released in air and water and on land. For two plants to match, they must have had their first one-time release in our sample period in the same year. Despite the matching being done on the plants themselves, we assumed that the risk would be felt across the all the parent companies of the plants. However, for this part of the study, we were limited by the nature of the companies; only public American companies were included in the dataset. This meant that if the polluter was a private company whose parent was, say, a public German company, the company was not included in the dataset. This limited us to 18 matches of companies within the same sector.

5.5. Synthesis of results

5.5.1. hypothesis

We start by hypothesizing that chemical accidents are an added risk for the finances of a place. Even despite a possible insurance cover, that would cover the physical damages incurred, the health and exposure of the population is still much harder to quantify. In a country where all healthcare is private, it would leave a place poorer and in more need on the long run. Thus, we claim that a chemical accident should discourage investors from holding long term bonds of the cities impacted and that should be reflected in the issuance yield of these bonds.

We also hypothesize that when there is a legal recourse that helps the victims of the accidents from incurring a fraction of the long-term costs, by relocating it to the corporate, this should be directly reflected in the issuance yield of the bonds.

5.5.2. General regression results

In the first set of results, we ran our analysis on both one-year and two-year delays to better understand what the market reacted for, either the event or the release of TRI data (table 5.7). We ran our first analysis to see if the bonds issued a year after the incident were impacted, and we did the same for those issued two years after the incident.

We found that any long-term issuances released regardless of delay showed a 99% statistically significant higher yield. We then ran our analysis with the quantities of released chemicals from the factories during their one-time release incidents. In this set of results, we found that the two-year-delay regressions showed higher significance in even the shorter maturities – specifically, chemical emissions corrected for LD50 tended to be more significant, supporting the claim that the toxicity of the chemicals released plays a significant role in the determination of risk by the market. We then reran our analysis, correcting for both the event and the quantity of chemicals released, and found that the longer-term maturities and events both lost significance. However, the medium-term maturities, and especially those corrected by the LD50 of the chemicals, remained significant. From this point, we continued our analysis on the volumetric quantities of chemicals released and the variable corrected for LD50. We estimated that these variables were sufficient to determine the impact of accidents on municipalities.

We also performed our analyses while splitting the issuances by population size. However, there is no federal government categorisation of village, town, city, etc.; the federal government deals mostly with metropolitan areas, which is not representative of local authority jurisdictions. For the smallest places, we used the California standard of 2,000 residents; however, for the other cities, we used arbitrary metrics of 10,000, 50,000, and 100,000.

These results showed two clear groups impacted by chemical accidents: places with less than 2,000 residents and places with more than 100,000 residents. The places with midsize population centres were not impacted by accidental releases. The smaller municipalities had a much smaller number of issuances, and few issuances with above 15 years of maturity; however, they were impacted by the chemical release for any bonds with a maturity larger than five years. As for the large cities with more than 100,000 residents, we found that for any maturity above five years, these cities were impacted much more by the toxicity of the chemicals released than by the volume of the chemicals released.

5.5.3. Robustness

To verify the robustness of our results, we tested our chemical assumptions about the impacts and the LD50 of the chemicals. We also ran a placebo test. However, many local authorities similar in size and economic variables were typically close in proximity to each other. Thus, we introduced a new constraint to our matching: we defined a ‘clean place’ as a place that did not have an accident within its boundaries or within a radius of 500 m of its boundaries. We used the propensity score calculated earlier to match the cities between those that had accidents and those that did not. Both places matched had to be in the same state to avoid any legislative differences between them. This produced insignificant results, suggesting that the risk in a place is related to the possibility of accident.

5.5.4. Medical Monitoring Results

Our analysis shows that cities within medical monitoring states have a lower risk and thus must pay a lower issuance yield in their bonds. However, to prove that this risk is associated with one-time chemical releases, we must show that this risk is transferred elsewhere. Thus, we ran the same difference in differences for the companies of the plants that had accidents and found that the risk is transferred to the corporations. The controls used for the corporate bonds as the ones established in literature (Baker M. P., Bergstresser, Serafeim, & Wurgler, 2018; Ge & Li, 2015; Caramichael & Rapp, 2022). However, the transfer of the risk is imperfect, as the increase of yield for the companies is not perfectly matched to the decrease of the municipalities' yield.

5.6. Discussion

As stated in the introduction, due to the war on terrorism, the EPA no longer releases the potential and probability of an accident of factories in the US. This meant that the gap of information for accidents risk had to be filled from elsewhere. The only historical, and viable alternative to learn about chemical accidents was the TRI-monitored facilities and their one-time-release incidents. This also does not include any information about the cause of the release, whether criminal or accidental.

We found strong evidence that chemical accidents impact the yield of municipal issuance. However, we also found that this tends to affect the smallest and largest urban areas more than it does the rest.

As for the smaller areas, we believe that this is because of the nature of their economies. Small towns tend to be either agricultural towns or small industry or factory-based economies. Both cases are significantly impacted by any risk of chemical accidents and even more by actual accidents, as accidents could pose serious consequences for potential crop yield or could force factories to be halted or to shut down – all issues posing serious risk to the long-term economic viability of the town.

As for mid-size towns, they are not impacted by these chemical accidents. In fact, we found an insignificant reduction in the yield of their issuances. Those of a smaller size would be urban areas still dependent on single sectors, but they would have larger factories and plants owned by larger companies. As the urban areas become more populated, this trend continues, in which the municipalities benefit more from the industries' presence than they do losing to the risk of chemical accidents, thus producing the negative yet insignificant correlation between the accidents and the volume and toxicity of the accidents.

The number of cities in the US with more than 100,000 people is small, around 300 in 2020. In these cities, the economies tend to be more diversified, and due to their higher population density, the impact of chemical accidents could be much more significant. Thus, we believe that the impact of the chemical reactions is exacerbated by the risk on the population. This is further confirmed by the fact that, for shorter maturities, the significant results are those of the LD50. Thus, higher maintenance and infrastructure investment is needed to maintain the safety of the residents.

Local authorities earn a significant portion of their income through property taxes, which have an important valuation component – meaning, large cities risk a much greater value loss in properties than do smaller urban areas.

Medical monitoring has been long argued as the antidote to the risks of chemical pollutions and was even argued as the antidote of the significant PFOAS pollution released in the DuPont scandals. However, the people of Parkersburg won their claim for medical monitoring to be paid for by DuPont. However, there are legal loopholes and other restrictions, which means that polluters often find ways to avoid paying their obligations. Nevertheless, chemical companies rightfully argue that when they do meet their obligations, the money ends up sitting unused in a fund.

Whatever the specific consequences of the pollution, polluters, and claimants, medical monitoring laws are an effective way of managing the risks of chemical pollutions and chemical accidents, as they transfer risk from the local governments to the polluters.

5.7. Conclusions

This paper we show that there is a clear impact of chemical and industrial events on the prosperity of places in the US. Mid-size cities do not see much effect from chemical accidents, but the largest and smallest cities do. However, despite events being significant, the more explanatory variable is the size of the event. Further, when the information is released by the EPA in the form of the TRI data, it is much more important than the occurrence of the event itself, as this when the information is released to the public.

Medical monitoring is a good method for minimising the worst effects of chemical accidents on the finances of cities and places. The bond issuance yield for cities in medical-monitoring states is significantly lower than that for cities in non-medical-monitoring states. The success of these laws is evident in the yield of corporate bonds, which show a clear increase in their issuance yield.

We believe that the reason of that success is because these laws transfer the risks of long-term medical costs from the public institutions, in this case cities to the corporate sector, a risk that is reflected in the reduction of issuance yield of municipal bonds and in an increase in the issuance yield of corporate ones.

Table 5.1: New Issuance of Municipal Bonds

This table shows the bond issuances of all the bonds reported in the MSRB dataset. These are bonds issued between 2001 and 2018. These bonds were issued by institutions belonging to a city or an equivalent entity.

	N	Mean	Median	Standard Deviation
Yield (%)	340793	0.025798	0.025402	0.012465
Is Callable	340793	0.428157	0	0.494812
Is Puttable	340793	0.000804	0	0.028344
Is Sinkable	340793	0.089591	0	0.285595
Bond Insurance	340793	0.089306	0	0.285186
Insured by Mortgage	340793	0.001235	0	0.035126
Bond Rating	340793	3.519289	3	1.756549
Issue Size (MM$)	340793	74530143	13865000	2.06E+08
log Number bonds per issuance	340793	2.953438	2.944439	0.551645
Federal Tax Status	340793	0.090354	0	0.286689
AMT Tax Status	340793	0.012192	0	0.109743
Pre-Refunded	340793	0.058942	0	0.235516
Competitive	340793	0.662558	1	0.472838
General Obligation	340793	0.466976	0	0.498909
3 Months T-Bills	340793	2013.337	2013	3.017509
Maturity in years	340793	0.483386	0.1035	0.842355

Table 5.2: Bond Issuances by State

This table presents the percentage of the total issuance by State. Texas is the state that has the biggest number of bonds issued. However, during our analysis, we use California as the baseline as it is the second biggest issuer and a state notorious for its chemical regulations. Thus, allowing us to have a baseline of relatively clean counties.

State		State		State	
Alaska	0.18	**Louisiana**	0.59	**North Dakota**	0.76
Arizona	1.80	**Maine**	0.53	**Ohio**	3.36
Arkansas	0.83	**Maryland**	0.66	**Oklahoma**	1.17
California	6.50	**Massachusetts**	1.95	**Oregon**	1.07
Colorado	1.39	**Michigan**	2.14	**Pennsylvania**	1.60
Connecticut	1.13	**Minnesota**	7.80	**Rhode Island**	0.09
Delaware	0.11	**Mississippi**	0.46	**South Carolina**	0.89
Florida	0.15	**Missouri**	2.06	**South Dakota**	0.20
Georgia	2.25	**Montana**	0.14	**Tennessee**	2.29
Hawaii	1.17	**Nebraska**	1.00	**Texas**	14.53
Idaho	0.05	**Nevada**	0.30	**Utah**	0.81
Illinois	0.15	**New Hampshire**	0.40	**Virginia**	0.16
Indiana	4.73	**New Jersey**	2.27	**Washington**	1.64
Iowa	2.70	**New Mexico**	0.54	**West Virginia**	2.21
Kansas	3.52	**New York**	6.71	**Wisconsin**	0.09
Kentucky	2.40	**North Carolina**	2.06	**Wyoming**	6.22

Table 5.3: Demographic Controls

The demographic variable is not run separately into the regression except as a robustness check, to make sure our results are not driven by them.

	N	Mean	Median	Standard Deviation
Population	340793	427629.8	50077	1396729

Table 5.4: The chemical release into water table adjusted for demography.

This table presents the summary statistics for log of the chemicals released by the accident. The chemicals are multiplied by the population they might put at risk.

	N	Mean	Median	Standard Deviation
Size of Accidents within the county * population	340793	9.508226	11.54549	340793

Table 5.5: the changes of correcting with LD50 and Impact Factor

To show that the changes made to the data by correcting releases by the LD50 and the impact factor. We use the example of population in this case. Impact W means that when the impact of the chemical is not known in one of our criteria, we assume that the chemical has the worst possible impact. Impact B, assumes the opposite, showing that when the impact of the chemical is unknown, we assume that it has no impact.

	N	Mean	Median	Standard Deviation
Chem (Tonne)*Pop	340793	1.159974	0	2.720143
Chem (Tonne) / LD50 (mg/kg) * Pop	340793	0.276049	0	1.057318
Chem (Tonne) * Imp W * Den	340793	1.38157	0	3.132899
Chem (Tonne) / LD50 mg/kg (all)*Imp W * Pop	340793	0.382498	0	1.253203
Chem (Tonne) *Imp B * Pop	340793	1.33814	0	3.079971
Chem (Tonne) / LD50 mg/kg (all) * Imp B * Pop	340793	0.364423	0	1.209729

Table 5.6: General Regression of the Accident Event

In this regression we indicate an accident by 1 and the lack of accident by 0. We want to see if the impact of the accident is felt more severely directly after the accident (1 calendar year lag) or when the information is made public by the EPA (2 calendar year lag). We find that the release of the information by the EPA is more significant. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

		Mat <=5	5< Mat <=10	10< Mat <=15	15< Mat <=20	20 < Mat
Accident Event	**1 Year Lag**	0.0025 (0.0092)	0.0184 (0.0127)	0.0166 (0.0129)	0.0413*** (0.0136)	0.0416** (0.0171)
	2 Year Lag	0.0106 (0.0105)	0.0169 (0.0138)	0.017 (0.0134)	0.0344** (0.015)	0.0386** (0.00165)
R-Squared		0.7707	0.794	0.7924	0.7745	0.7754
Observations		95023	114239	76422	47509	17869
Controls				**Yes**		
State by Year FE				**Yes**		

Table 5.7: General Regression of the Accident size

In this regression we estimate the size of the accidents using the quantity of the chemicals released. We also correct these chemicals for their toxicity and the size of the population impacted. At this level we start noticing that the 2-calendar year lag becomes more significant than the 1 calendar year lag. Especially when corrected for the impact coefficient assuming the best outcome and the LD50. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Variables	**Letter**
Chem (Tonne) * Pop	A
Chem (Tonne) / LD50 (mg/kg) * Pop	B
Chem (Tonne) * Imp W * Pop	C
Chem (Tonne) / LD50 mg/kg (all)*Imp W * Pop	D
Chem (Tonne) *Imp B * Pop	E
Chem (Tonne) / LD50 mg/kg (all) * Imp B * Pop	F

		Mat <=5	5< Mat <=10	10<Mat <=15	15<Mat <=20	20 < Mat
A	1 Year Lag	-0.0001	0.0013	0.0013	0.0032***	0.003**
		(0.0008)	(0.0012)	(0.0011)	(0.0011)	(0.0013)
	2 Year Lag	0.0011	0.0024**	0.002*	0.0027**	0.003**
		(0.0009)	(0.0012)	(0.0011)	(0.0012)	(0.0013)
B	1 Year Lag	-0.0009	0.0013	0.0015	0.0053***	0.0055***
		(0.0015)	(0.002)	(0.0017)	(0.0018)	(0.0021)
	2 Year Lag	0.0018	0.0045**	0.0045***	0.0051***	0.0054***
		(0.0016)	(0.0018)	(0.0016)	(0.0019)	(0.002)
C	1 Year Lag	-4.13E-15	0.0012	0.0012	0.0032***	0.0028**
		(0.0007)	(0.0011)	(0.001)	(0.001)	(0.0012)
	2 Year Lag	0.001	0.0021*	0.0018*	0.0025**	0.0027**
		(0.0009)	(0.0011)	(0.001)	(0.0011)	(0.0012)
D	1 Year Lag	-0.0006	0.0015	0.0017	0.0049***	0.0049**
		(0.0013)	(0.0018)	(0.0016)	(0.0017)	(0.0019)
	2 Year Lag	0.0016	0.004**	0.0039**	0.0046***	0.005***
		(0.0014)	(0.0017)	(0.0015)	(0.0018)	(0.0018)
E	1 Year Lag	4.12E-5	0.0014	0.0013	0.0033***	0.0027**
		(0.0008)	(0.0011)	(0.001)	(0.001)	(0.0012)
	2 Year Lag	0.0011	0.0024**	0.002*	0.0027**	0.0028**
		(0.0009)	(0.0011)	(0.001)	(0.0011)	(0.0012)
F	1 Year Lag	-0.0004	0.0019	0.0018	0.0052***	0.005***
		(0.0013)	(0.0018)	(0.0016)	(0.0017)	(0.0019)
	2 Year Lag	0.0018	0.0046***	0.0042***	0.0049***	0.0051***
		(0.0015)	(0.0017)	(0.0016)	(0.0018)	(0.0018)
R-Squared		0.7707	0.794	0.7923	0.7747	0.7754
Observations		95023	110332	76422	47509	17869
Controls				**Yes**		
State by Year FE				**Yes**		

Table 5.8: General Regression of the Accident size and Event

It is evident from the result that the event had a much smaller explanatory power than the size of the accident itself. It also shows that the 2-year lag has a higher explanatory power than the 1-year lag. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	Mat <=5		5< Mat <=10		10< Mat <=15		15< Mat <=20		20 < Mat	
Lag	**1 Year**	**2 Year**	**1 Year**	**2 Year**	**1 Year**	**2 Year**	**1 Year**	**2 Year**	**1 Year**	**2 Year**
Accident Happened	0.0268	-0.0047	0.0319	-0.0354	0.0166	-0.0303	0.0169	0.0257	0.044	0.0266
	(0.0219)	(0.0201)	(0.0249)	(0.0234)	(0.0255)	(0.0255)	(0.0298)	(0.0309)	(0.0487)	(0.0435)
A	-0.0023	0.0014	-0.0013	0.0051**	-1.69E-07	0.0043**	0.0022	0.0008	-0.0002	0.001
	(0.0019)	(0.0018)	(0.0024)	(0.002)	(0.0022)	(0.0021)	(0.0025)	(0.0027)	(0.0037)	(0.0033)
Accident Happened	0.0165	0.0048	0.028	-0.0058	0.0221	-0.0133	0.0338*	0.0195	0.0256	0.0198
	(-0.0029)	(0.0137)	(0.0172)	(0.0184)	(0.0178)	(0.0187)	(0.0182)	(0.0189)	(0.027)	(0.0261)
B	-0.0029	0.0012	-0.0019	0.0052**	-0.001	0.0059***	0.0014	0.0029	0.0027	0.0033
	(0.0022)	(0.002)	(0.0026)	(0.0024)	(0.0023)	(0.0022)	(0.0024)	(0.0025)	(0.0033)	(0.0032)
Accident Happened	0.0247	-0.0061	0.0272	-0.0405	0.0124	-0.0327	0.0131	0.0237	0.0457	0.0247
	(0.0234)	(0.0218)	(0.0267)	(0.0248)	(0.0273)	(0.0273)	(0.0317)	(0.0335)	(0.0519)	(0.0465)
C	-0.0019	0.0014	-0.0007	0.0051**	0.0003	0.0041**	0.0023	0.0009	-0.0003	0.0011
	(0.0019)	(0.0018)	(0.0023)	(0.002)	(0.0021)	(0.0021)	(0.0025)	(0.0027)	(0.0036)	(0.0033)
Accident Happened	0.0174	0.0045	0.027	-0.011	0.0202	-0.0179	0.0319	0.017	0.0268	0.0163
	(0.0151)	(0.0147)	(0.0182)	(0.0195)	(0.0188)	(0.02)	(0.0195)	(0.0203)	(0.0302)	(0.0287)
D	-0.0025	0.0011	-0.0014	0.0052**	-0.0005	0.0057**	0.0015	0.0028	0.0021	0.0033
	(0.0021)	(0.002)	(0.0025)	(0.0024)	(0.0022)	(0.0022)	(0.0024)	(0.0025)	(0.0034)	(0.0032)
Accident Happened	0.0218	-0.0145	0.0247	-0.0482*	0.008	-0.0509*	0.0094	0.0036	0.025	0.0155
	(0.0236)	(0.0222)	(0.0267)	(0.0253)	(0.0266)	(0.0265)	(0.0321)	(0.031)	(0.0548)	(0.0478)
E	-0.0016	0.0022	-0.0004	0.0059***	0.0007	0.0056***	0.0026	0.0024	0.001	0.0018
	(0.0019)	(0.0019)	(0.0024)	(0.002)	(0.0021)	(0.002)	(0.002)	(0.0025)	(0.0038)	(0.0033)
Accident Happened	0.0162	0.0023	0.0251	-0.013	0.0167	-0.0243	0.0309	0.0094	0.0149	0.0137
	(0.0155)	(0.015)	(0.0187)	(0.0201)	(0.0191)	(0.0203)	(0.0201)	(0.02)	(0.0318)	(0.0301)
F	-0.0023	0.0015	-0.0009	0.006**	-5.49E-06	0.0068***	0.0018	0.0039	0.0035	0.0037
	(0.0022)	(0.002)	(0.0026)	(0.0024)	(0.0023)	(0.0023)	(0.0025)	(0.0025)	(0.0036)	(0.0034)
R-Squared	0.7707		0.794		0.7923		0.7747		0.7754	
Observations	95023		110332		76422		47509		17869	
Controls			**Yes**			**State by Year FE**			**Yes**	

Table 5.9: The impact of accident size on different cities by size

In the next series of tables, we look at the impact of accidents by the size of the place. These regression shows that the smallest places and the biggest cities are the most affected by the accidents, whereas the midsize places are not as financially impacted. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

		Mat <=5	5< Mat <=10	10< Mat <=15	15< Mat <=20	20 < Mat
Pop > 2k	E	0.0585 (0.0409)	0.1518*** (0.0334)	0.1049*** (0.021)	N/A	N/A
	F	0.1176 (0.0822)	0.9131*** (0.1876)	0.6438*** (0.129)	N/A	N/A
R-Squared		0.8191	0.8384	0.8765	N/A	N/A
Observations		2591	2814	1804	N/A	N/A
Controls				Yes		
State by Year FE				Yes		

		Mat <=5	5< Mat <=10	10< Mat <=15	15< Mat <=20	20 < Mat
2k >= Pop > 10k	E	0.002 (0.0054)	0.004 (0.0058)	0.0124 (0.0077)	0.006 (0.0075)	-0.0059 (0.014)
	F	0.0057 (0.0096)	0.0083 (0.0119)	0.0302** (0.0148)	0.0145 (0.0112)	-0.0178 (0.0211)
R-Squared		0.803	0.8255	0.8274	0.8286	0.8718
Observations		15842	16934	10008	5174	1849
Controls				Yes		
State by Year FE				Yes		

		Mat <=5	5< Mat <=10	10< Mat <=15	15< Mat <=20	20 < Mat
10k >= Pop > 50k	**E**	-0.0005 (0.0023)	-0.0006 (0.0025)	-0.0043* (0.0025)	-0.0034 (0.003)	-0.0044 (0.0048)
	F	-0.0034 (0.0047)	-0.0039 (0.005)	-0.0105* (0.0054)	-0.0072 (0.0064)	-0.0133 (0.0091)
R-Squared		0.7962	0.805	0.8206	0.8115	0.8606
Observations		33700	37361	23637	13780	4148
Controls				**Yes**		
State by Year FE				**Yes**		

		Mat <=5	5< Mat <=10	10< Mat <=15	15< Mat <=20	20 < Mat
50k >= Pop >100k	**E**	0.0004 (0.0022)	-0.0017 (0.0027)	-0.0009 (0.0024)	-0.0015 (0.0031)	0.0014 (0.0073)
	F	-0.0002 (0.004)	-0.007 (0.0044)	-0.0026 (0.0043)	-0.0035 (0.006)	0.0003 (0.0099)
R-Squared		0.7943	0.8159	0.8133	0.8098	0.8478
Observations		15140	17515	12041	7488	2336
Controls				**Yes**		
State by Year FE				**Yes**		

		Mat <=5	5< Mat <=10	10< Mat <=15	15< Mat <=20	20 < Mat
100k >= Pop	**E**	5.28E-05 (0.001)	0.0013 (0.0012)	0.0016 (0.0011)	0.0023** (0.003)	0.0031** (0.0015)
	F	0.0005 (0.0016)	0.0037** (0.0019)	0.0042** (0.0017)	0.0043** (0.0017)	0.0065*** (0.0023)
R-Squared		0.784	0.8131	0.7926	0.7742	0.7624
Observations		27750	35708	28932	19986	8982
Controls				**Yes**		
State by Year FE				**Yes**		

Table 5.10: Placebo Test

To make sure the risk we are witnessing is associated with the cities affected by the accidents, we perform a placebo test. Keeping in mind that places of similar sizes and similar economies are usually found in proximity of each other we wanted to prevent cross-contamination. To do so we defined an unaffected city, as a place who did not have an accident with 0.5km of its boundaries within the period of our study. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Mat <=5	**5< Mat <=10**	**10< Mat <=15**	**15< Mat <=20**	**20 < Mat**
E	0.0008 (0.0018)	0.0032 (0.0019)	0.0028 (0.0021)	0.0033 (0.0025)	0.0081 (0.005)
F	-0.0008 (0.0023)	-0.0014 (0.0028)	-0.0009 (0.0033)	-0.0019 (0.0043)	0.0009 (0.0076)
R-Squared	0.9494	0.9775	0.9882	0.9921	0.991
Observations	10629	12440	8408	5199	1707
Controls			**Yes**		
State by Year FE			**Yes**		

Figure 5.1: Map of the US showing the states that accept medical monitoring legal actions.

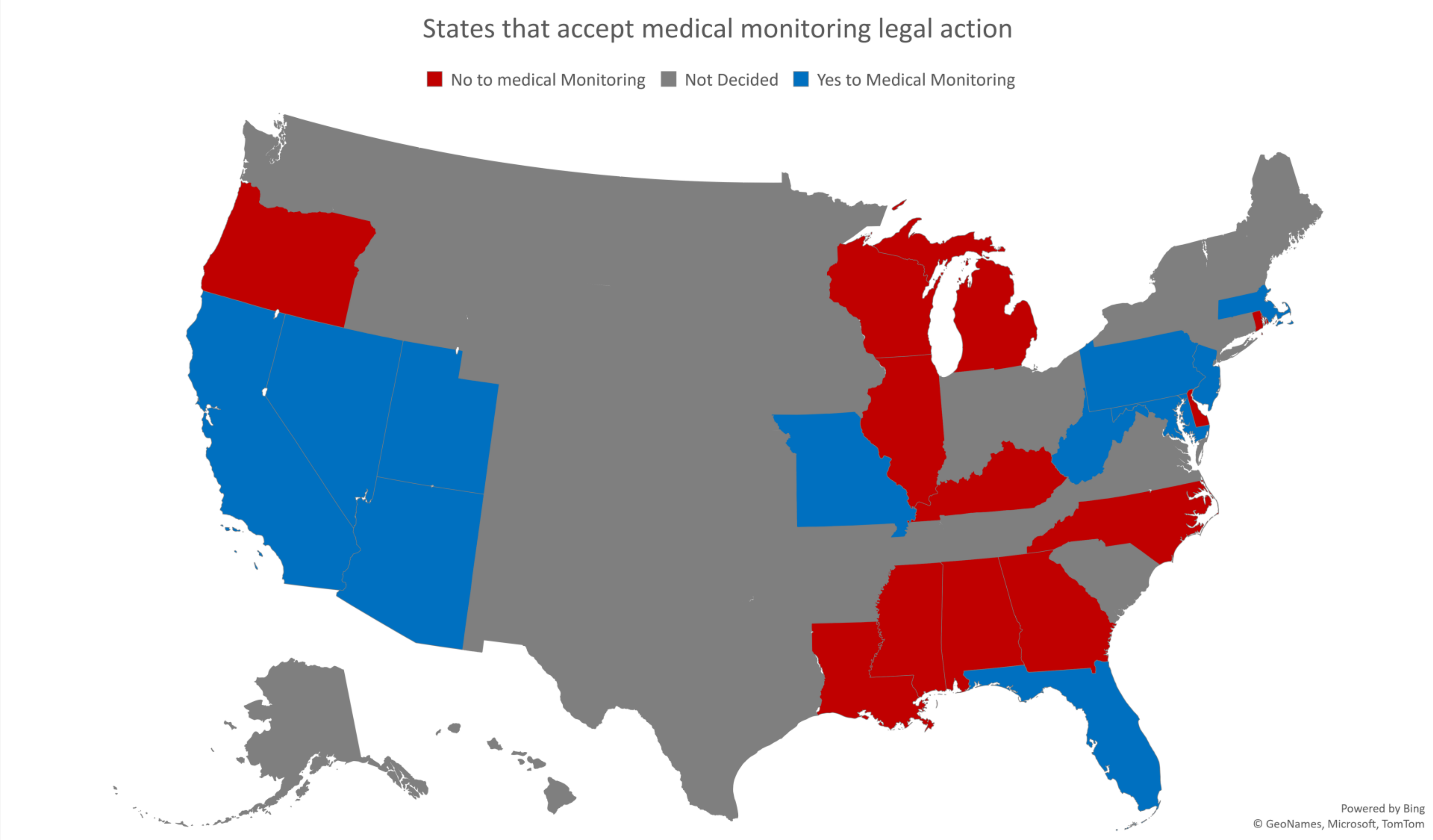

Table 5.11: Difference in Difference between places in states that accept Medical Monitoring and states that reject it.

This table presents the result from a propensity score matched difference in difference. We match the cities on population, area, issue size, GDP of the county they are in, and issuer rating. For two cities to match they must also have had their accident in the same year. We consider only the first time an accident occurs as the shock. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	Mat<=5	**5<Mat <=10**	**10<Mat <=15**	**15<Mat <=20**	**20< Maturity**
Interaction	-0.1674 (0.1717)	-0.3975** (0.1996)	-0.359** (0.1612)	-0.4143* (0.2375)	-0.9131** (0.4073)
R-Squared	0.759	0.758	0.7333	0.7488	0.7795
Observations	5101	6563	5291	3665	1676
Controls			**Yes**		
State by Year FE			**Yes**		

Table 5.12: Corporate bond issuance Difference in Difference

This test aims to check if there is an opposite result in the corporate sector. It aims to show that the risk is moved from the public finances to the private sector. To do so, we match all the factories that did have an accident with a medical monitoring state with factories that did have accidents in states that reject medical monitoring. We then use the issuance yield of their parent companies' bonds. The factories are propensity score matched on the volume of chemicals in their normal cycle of production on the chemical types and methods of release. The standard errors-based county clustering is presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	No FE	**Time FE**
Interaction	1.3793*** (0.2889)	0.6701*** (0.1161)
R-Squared	0.8333	0.6466
Observations	5638	5638
Controls	**Yes**	

6. Are Cities Venturing Green? A Global Analysis on the Impact of Green Entrepreneurship on City Air Pollution

Authors: Cojoianu, T.F., Hoepner, A.G.F., Hu, X., Ramadan, M., Veneri, P., Wójcik, D.

6.1. Abstract

Situated at the intersection between environmental entrepreneurship and urban sustainability, our paper seeks to investigate the links between city-level green venture ecosystems and the ability of urban centres to reduce air pollution. Using a large dataset of 12,834 urban centres from around the world and their associated yearly average particulate matter (PM2.5), we show that an increase in the cumulative number of green start-ups drives the lowering of PM2.5 levels. Looking closely at the subsectors that drive the results, we observe that the urban centres which hosted increased numbers of innovators in smart grid technologies, energy efficiency and wind energy generation (the low carbon energy sector overall) also experienced a decrease in air pollution over the 2010 – 2019 period. Thus, our study is a global analysis of the environmental impact of green entrepreneurship on local air pollution.

My Contributions to this paper:

I undertook all the data preparation, cleaning, and mapping in the initial phase. I also performed sections of the empirical analysis and the entire difference in difference. With the help of T. Cojoianu, I participated in the write up.

6.2. Introduction

Air pollution causes harm to human health and other living beings. Ample evidence has shown that exposure to air pollution impacts health, cognitive performance, labour productivity and educational outcomes (Currie et al., 2014; Zhang et al., 2018; Zheng et al., 2019; Zivin and Neidell, 2012). Globally, air quality issues have resulted in protests, public outcry around the world (Zalakeviciute et al., 2021). Technological advances have been crucial to addressing the air pollution problem. The 1970 smog for instance, brought in the "Clean Air Act" which led to significant investments into environmental technologies, specifically in the transport sector, and the invention of the catalytic converter (Palucka, 2015).

Hence, in the past decades, as governments have retreated from being providers of a wide range of environmental and social services, the spotlight has been on entrepreneurs to solve society's challenges through innovation (Malen & Marcus, 2017; York & Venkataraman, 2010). Entrepreneurs' response to this phenomenon was through "place-based" enterprise, which developed into purpose-driven urban entrepreneurship (Shrivastava & Kennelly, 2013; Cohen & Muñoz, 2015). These entrepreneurial ventures start with the sole purpose of solving a specific societal issue, be it environmental or not. The growing impact of environmental issues on the collective mind has pushed these ventures to become more environmentally aware. Indeed, green entrepreneurs and venture capital investors are now at the forefront of solving many environmental problems, investing and developing new materials and clean technologies that in theory it should have a positive environmental impact

(Vedula et al., 2021). This expectation from entrepreneurs has been also seeded by investors, as the concept of impact investing emerged in the aftermath of the financial crisis. In particular, the investment community was looking for a path to redemption in the general public's eyes, whereby investments would be needed to address environmental outcomes (Agrawal & Hockerts, 2019a).

Although historically the literature on green entrepreneurship is rather limited in studying knowledge spill overs (Cojoianu et al., 2020b; Colombelli and Quatraro, 2017), the influence of social norms on green entrepreneurship entry (Meek et al., 2010; Vedula et al., 2018; York and Lenox, 2014), the growth and scalability of green ventures (Doblinger et al., 2019; Parker et al., 2019) and the prosocial intentions of entrepreneurs (Moroz et al., 2018), it has become apparent that there is a substantial gap in linking green entrepreneurship with real environmental outcomes (Vedula et al., 2021), and particularly within the spatial context in which impact occurs.

Situated at the intersection between environmental and urban entrepreneurship, our paper seeks to understand whether cities with VC-backed green can faster reduce their air pollution levels (proxied by the yearly average PM2.5 levels), for 12,834 urban centres around the world between 2010 – 2019. As sustainable urban entrepreneurship is a novel topic, and the previous literature does not fully allow us to form strong convictions on hypotheses, similarly to Cojoianu et al. (2020), Feldman et al. (2019), and Moeen and Agarwal (2017) we employ an exploratory research design to unveil the impact of (green urban) entrepreneurship on an important and city-level relevant environmental indicator, air pollution. By using the best-in-class venture capital and private equity datasets from Preqin and Cleantech Group comprising over 378187 investment deals and 167256 VC-backed start-ups, our paper finds that during the period 2010 – 2019, cities with larger cumulative number of green start-ups have decreased their air pollution. We also find evidence, but slightly weaker, that the total cumulative number of VC backed start-ups in an urban centre is also conducive to better air quality. Looking closely at the subsectors that drive the results, we observed that the urban centres which hosted increased numbers of innovators in smart grid technologies, energy efficiency and wind energy generation (the low carbon energy sector overall) also experienced a decrease in air pollution over the 2010 – 2019 period.

Our study is structured in the following way. In section 2, we build the theoretical background for sustainable urban entrepreneurship and theorize how green entrepreneurs can influence environmental outcomes in the context of an urban centre. In section 3 we detail the data and methodology, followed by the synthesis of results in section 4. We discussed our findings and concluded in section 5.

6.3. Theoretical background and research questions

6.3.1. The emergence of green entrepreneurship

Entrepreneurship is the discovery and creation of new goods, ventures, and markets (Shane and Venkataraman, 2000) and relies on creativity, problem solving capabilities of individuals and firms (Hsieh et al., 2007). The global transition to sustainable development goals has prompted a new generation of entrepreneurship. Through business model, technological, financial and social innovation, these "green entrepreneurs" are agents for social and environmental change (Anderson, 1998), operating at the forefront of addressing some of the biggest challenges of our time (Malen and Marcus, 2017; York and Venkataraman, 2010).

Research on green or environmental entrepreneurship has its roots in economic sociology as well as institutional economics (Dean and McMullen, 2007; Russo, 2001), and has been focused historically on explaining the emergence of market-based solutions to environmental problems that are the result of market failures and the inability of governments to regulate environmental externalities (Cohen and Winn, 2007; Cojoianu et al., 2020b; Dean and McMullen, 2007). A significant number of studies have investigated knowledge spillovers in the context of green entrepreneurship, and the inherent spatial dimension of these spillovers, often at the level of city, region or start-up cluster level (Audretsch and Feldman, 1996; Cojoianu et al., 2020b; Colombelli and Quatraro, 2017; Vedula et al., 2018). Knowledge spillover scholars have argued that entrepreneurship opportunities emerge due to an expected valuation asymmetry of uncommercialised knowledge between knowledge creators and potential entrepreneurs who seek new opportunities and have the absorptive capacity to integrate new knowledge created (Acs et al., 2009; Audretsch and Keilbach, 2007; Cojoianu et al., 2020b; Qian and Acs, 2013). Furthermore, the incentive to produce green knowledge and start new green ventures is unusual, as it is often characterized by the "double externality" issue, which has to do with the fact that green knowledge has positive externalities not only in the innovation stage but also in the diffusion stage, by reducing environmental harm compared to conventional technologies (Cainelli et al., 2015; Rennings, 2000).

Thus, in taking a first step to understand the impact of green ventures on society, entrepreneurship scholars have been interested in studying the prosocial intentions of entrepreneurs as an early indicator of green entrepreneurship (Pacheco, Dean, & Payne, 2010). The source of these motives are understood to lie within the traits identity of entrepreneurs (Vedula et al., 2021; York et al., 2016), who may have both commercial and impact goals. These dual goals are not prevalent only in entrepreneurs themselves, but also within their funders. This has been the case with impact investors, which aims to simultaneously deliver two objectives: (i) social and environmental benefits and (ii) financial returns for a desired investment risk level (Cojoianu et al., 2021). Cojoianu et al. (2021) find that find that impact investing firms to be younger than ESG investment firms and more labour intensive. Impact investing firms are more likely to be owned by governments, particularly in Europe. They invest over-proportionally in agriculture, cleantech and education sectors and partner with academia in particular to measure and track their impact. Impact investing, Barber et al. (2019) indicating that impact investors indeed balance both objectives and hence display willingness to forgo return for social good and that they mainly invest in private financial markets such as venture capital and private equity.

This has important implications for public policy, as Cojoianu et al. (2021) show that many captive investment arms of government institutions are looking to deploy capital in start-ups that make a difference to the environment or to social issues, in addition to have sound commercial business models. The paper suggests that as many governments around the world have retreated from providing environmental and social benefits, these responsibilities have been shifted onto market agents and lower tiers of government authority (Clark, 2012; Cojoianu et al., 2021; OECD, 2010). This paper fills the research gap to understand whether economic actors could contribute to the mitigation of environmental externalities of business.

Although the intention to generate extra-financial returns may be there, Vedula et al. warn that the "implicit assumption of many entrepreneurship researchers and practitioners is that entrepreneurship is an inherently positive process at the individual, organizational, and societal levels" (Vedula et al., 2021, p.36). However, this is not always the case (Baumol, 1996; Shepherd, 2019), leading to further environmental degradation such it in the case of fossil fuel entrepreneurship (Cojoianu et al., 2020b). Furthermore, studies focusing on green entrepreneurship have yet to link the process of entrepreneurship with actual societal impact (e.g., air pollution reduction, climate change mitigation, biodiversity conservation at the city-region level) and have focused mostly with drivers of entry, growth and innovation of green solutions, regardless of whether these make an actual difference or not. To some extent, the literature has recognised that the success of green entrepreneurs depends also on social movements (Meek et al., 2010; Vedula et al., 2018), policy interventions (Cojoianu et al., 2020b) as well as partnerships with different types of stakeholders: cities and municipalities, universities or corporate incumbents (Doblinger et al., 2019), but has yet to understand how green entrepreneurship results in positive environmental outcomes, in particular at the city-region level.

This research gap is significant, and addressing it has important policy implications. If entrepreneurship is indeed a key enabling channel to solve environmental issues, then in addition to more stringent environmental regulation (Cojoianu et al., 2020b), both national and more devolved levels of government should also promote entrepreneurship and benefit from the environmental spill overs they generate. Institutional theory contends that organisations are both grounded in and shaped in the regulatory, social and cultural environments that they operate in (Bruton et al., 2010; Scott, 1995). Besides knowledge spill overs and the characteristics of specific entrepreneurs, the formal regulatory setting (Cojoianu et al., 2020b) as well as local pro-environmental norms are a significant driver of green entrepreneurship (Vedula et al., 2018). To alleviate concerns that the same factors drive air pollution reduction in our empirical testing and not entrepreneurs themselves, we include a global proxy for air pollution legislation and design a difference-in-differences robustness test to understand whether indeed VC-backed green entrepreneurship is a statistically significant driver of local air pollution reduction.

In this light, in the next section we explore the link between green and urban entrepreneurship and seek to understand potential mechanisms through which (green) entrepreneurs can improve the environmental outcomes at the city-region levels.

6.3.1. Green entrepreneurship and sustainable urban development

Cities have a huge role to play in fostering entrepreneurship. Innovators congregate in cities to benefit from economies of scale, agglomeration of economic activities and infrastructure (Brown, 1975; Dieperink and Nijkamp, 1987; Martin and Sunley, 1998). Skilled labour cluster towards urban centres, providing and drawing from knowledge spillovers that encourage innovation. As such, cities are centres of all knowledge including of environmental innovation.

Urban centres are also foci of capital. Investors clusters in these regions to take advantage of economic opportunities, providing capital for innovation. The 2008 global financial crisis and concerns on climate change, resource scarcity prompted a global sustainable finance agenda which is an attempt by investors to regain societal trust through financing projects that deliver not only financial gains but also environmental and social outcomes (Agrawal and Hockerts, 2019; Benedikter and Giordano, 2011). In this light, urban centres are ideal testing grounds for new solutions at the intersection between human-environment interactions (Schroeder et al., 2013).

Green urban entrepreneurs, unlike traditional environmental entrepreneurs who focus on market-based solutions towards solving government failures, need a better appreciation of public versus private goods, how these are delivered at the neighbourhood, city, regional or global level and how commercial solutions can bridge the gap between governments, private sector actors and urban level environmental and social well-being (Cohen and Muñoz, 2015). In addition, entrepreneurship scholars acknowledge widely that entrepreneurs cannot succeed on their own and that they must work closely with other stakeholders, and in particular their clients, in order to unveil promising commercial opportunities (Cohen and Muñoz, 2015; Doblinger et al., 2019). Thus, partnerships with devolved levels of government including municipalities and cities are crucial to fulfil the promise of urban entrepreneurship as a place-based solution.

Cohen and Muñoz (2015) argued that while all entrepreneurs are embedded in a place, depending on the geographic scale at which an entrepreneur operates, either neighbourhood, city or global level, the opportunity context and interaction between entrepreneurs and cities varies. Urban entrepreneurs who operate at the neighbourhood level, while benefit from enhanced social cohesion, tends to be project based and relatively small-scale, although some projects or ventures may scale to provide city level solutions. At the city level, urban entrepreneurs often require collaborations with civil society and most certainly the involvement of local city governments or municipalities. On the other hand, global urban entrepreneurs are those who are able to successfully scale solutions across cities, whether domestically and/or internationally, and are both locally embedded in their home cities as well as globally embedded in the cities they provide services to (Chen and Tan, 2009; Cohen and Muñoz, 2015). Therefore, to understand the role of green entrepreneurship in urban sustainability transitions, it is highly important that we understand the spatial embeddedness of entrepreneurs, the interactions between entrepreneurs, cities and other stakeholders were involved in the delivery of environmental and social benefits to urbanites. (Yu and Gibbs, 2020).

For the purposes of our paper, we seek to investigate the impact that city level as well as global green urban entrepreneurs have on their host cities. We contend that both city level and global green urban entrepreneurs can influence their host cities (i.e. the cities they have been founded in) for the interactions that they have with numerous stakeholders within the city, through the commercial solutions they offer to cities and municipalities as well as through the green knowledge spillovers they generate within the local economy (Cojoianu et al., 2020b). Furthermore, as Cojoianu et al. (2020) have shown, green knowledge creation is appropriated not only by green entrepreneurs, but also by conventional entrepreneurs who want to incorporate green principles within their modus operandi (Isaak, 2016).

We look closely at air pollution, given its geographical contextuality and local relevance. The key drivers of air pollution differ across geographies. In countries such as China, in key economic areas, pollution is driven by coal, flat glass, coke, and steel production. In less central economic areas, the reason for air pollution is known to be coal, coke, and power generation(Wei et al., 2017). This shows that in both areas, the main sources of pollution in both areas are directly related to energy production as coal and coke are both strong persistent drivers. In Europe and the US, as they are slowly phasing out coal and coke, other drivers such as transport become more salient (Colvile et al., 2001.; Gürçam et al., 2021; Oolen & Rothenberg, 2019). Air pollution can be impacted in multiple ways by entrepreneurship. We review below several mechanisms: i) entrepreneurs sell products and services which reduces the dependency on air polluting industries (e.g. renewable energy displaces conventional energy, energy efficiency measures reduce the reliance on fossil fuels, electric cars sold locally by entrepreneurs as their host cities become the testbeds for innovation – example: San Francisco becoming a test site for electric driverless cars), ii) green entrepreneurs seeking to change environmental legislation (Cohen and Winn, 2007; Cojoianu et al., 2020b) or iii) VC-backed green entrepreneurship generates significant green knowledge spillovers which are absorbed in polluting incumbent business models and companies (Audretsch and Feldman, 1996; Cojoianu et al., 2020b; Vedula et al., 2018).

Given the many ways in which green venture capital can influence air pollution in urban areas, similarly to Cojoianu et al. (2020b), Feldman et al. (2019), and Moeen and Agarwal (2017) we employ an exploratory research design. Thus, our hypotheses are the following:

Q1. Are venture capital cities more likely to reduce their air pollution than non-venture capital cities?

Q2. Does the presence of green VC-backed urban start-ups enhance the ability of cities to reduce their air pollution?

Q3. What kind of technologies developed in cities by VC-backed green entrepreneurs are related to a reduction in air pollution?

6.4. Data and methodology

6.4.1. Data

Dependent variable

Our dependent variable which proxies the average air quality within a city over a year is the average population mean exposure to PM2.5, which was estimated by the OECD based on the Global Burden of Disease 2019 (GDB) project data. The input raster files, available at a resolution of 0.1x0.1

degree (approximately 11 x 11 km at the equator) provide for each grid cell and for each year, the population-weighted average concentration in PM2.5 (in µg/m3). These raster files were combined with the Urban centre's geometries and the GHS 2015 population grid to compute the population-weighted average for each urban centre. The PM2.5 concentration grids were first multiplied by the population grid. The sum of all the cells intersecting the same urban centre was then divided by the population within the same urban centre (computed using the same population grid). In total, our dataset covers PM2.5 levels for 12,834 urban centres around the world for the years 1990, 1995, 2000, 2005 and continuously between 2010 – 2019. Given the 5-year gaps up to 2010, as well as independent and control variable availability, we focus our study over the 2010 – 2019 period.

Independent variables

Our key explanatory variables are obtained from merging two leading commercial research providers: Preqin, one of the top global providers of robust data on private financial markets, which is increasingly used in academia (Ang et al. 2018; Barber et al. 2019; Harris et al. 2014; Nadauld et al. 2019). This dataset is complemented by Cleantech Group, which is a data provide specialised on green venture capital and private equity start-ups and deals around the world (Doblinger et al., 2019). Both datasets have coverage of start-ups and deals since early 2000, however, the data completeness is particularly enhanced for our study period 2010 – 2019.

Using the two data providers above, and the green taxonomy provided by Cleantech Group, using ArcGIS, we match each of our 167256 start-ups and their addresses with the 12,834 urban centres in our database. Based on this, for each urban centre, we build six key independent variables: the number of cumulative green start-ups, cumulative green start-up funding ($), the number of total cumulative green start-ups, cumulative total start-up funding ($), the number of new start-ups founded in a given urban centre (lagged one year), and the amount of new funding received by all start-ups in the urban centre (lagged one year). Our identification of green urban entrepreneurs relies on the definition of Cleantech Group, which encompasses entrepreneurs in the following sectors: advanced materials, agriculture, air pollution, biofuels, biomass, energy efficiency, energy storage, fuel cells, geothermal, nuclear, recycling, solar, transportation, water and wind energy (see Figure 4).

Control variables

For a select number of cities (1,572), we are able to collect additional control variables from Mergent Online: yearly GDP per capita, total workforce and unemployment rate for the largest urban centres in our database.

6.4.2. Model specification

In this paper we use a fixed effects OLS model as our primary model with standard errors clustered at the city-level, and further complement our analysis by employing a Mundlak model (as explained below). For robustness purposes and to test for reverse causality, we employ Godfrey et al. (2020)'s reverse causality minimisation procedure and also employ longer lags in our independent variables. Our main findings also hold for these alternative specifications.

Fixed-effects models can only provide an estimation of within-cluster variation (in our case within regional variation), and cannot estimate the effect of the average variation between regions (Cojoianu et al., 2020a; Schunck and Perales, 2017). Random effects models, on the other hand, assume that the within-cluster variation and between-cluster variation are statistically the same. However, when this is not the case, the results of the random effects model are often meaningless (Bell et al., 2019). The solution to these issues is to estimate a random effect model which features time-varying covariates expressed as deviations from the individual-specific means. This estimation strategy allows us to differentiate within- and between-regional effects and thus, we can leverage the strengths of both random- and fixed-effects models (Bell et al., 2019; Schunck and Perales, 2017). A between-within estimator used to estimate our econometric models is specified by equation 1 below:

$$y_{i,t} = \beta_W\left(x_{i,t} - \bar{x}_i\right) + \beta_B\bar{x}_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

In equation 1, the effect of the independent variable $x_{i,t}$ on $y_{i,t}$ is divided in: β_W which represents the average within region variation of $x_{i,t}$, and β_B which explains the remaining between region average variation. The model in equation 1 can be re-written in a mathematical equivalent form as shown in equations 2 and 3, so that the resulting coefficient on $\bar{x}_i$ represents the contextual effect (the average between region effect while keeping $x_{i,t}$ constant), and β_W can be still interpreted as the average within region variation of $x_{i,t}$. The model written in the form of equation 3 is also known as the correlated random-effects model (Wooldridge, 2010) or the Mundlak model (Mundlak, 1978; Schunck and Perales, 2017).

$$y_{i,t} = \beta_W x_{i,t} - \beta_W \bar{x}_i + \beta_B \bar{x}_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

$$y_{i,t} = \beta_W x_{i,t} + (\beta_B - \beta_W)\bar{x}_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

Hence, we follow the Mundlak (1978) model (equation 3) and report both within urban centre effects (β_W) and contextual between urban centre effects ($\beta_B - \beta_W$), to understand the source of the variation that explains the variation in air pollution across our dataset.

6.5. Synthesis of results

Figure 1 depicts the distributional change of air pollution between 1990 and 2019. Overall, air quality has improved slightly over time. However, there are significant regional differences. Most notably, the highest value of air pollution increased to above 200 PM in the mid-2000s, compared to below 200 PM in the 1990s. Figure 2 shows the global distribution of air pollution by cities more clearly. In 2019, the distribution of air pollution hotspots in the world concentrates along the equator, most notably central Africa, south Asia and east Asia. Countries such as India, Pakistan, Bangladesh, China, and Nigeria have some of the worst air pollution problems.

Over time however, air pollution problems are improving in some regions and deteriorating in others. Figure 3 shows the difference in global distribution of air pollution change by cities between 2019 and 2010. Here we observe a different perspective. The green areas indicate regions of air quality improvement, namely Europe, north America, mid and south China are experiencing better air quality. In India, coastal regions of South America, Ethiopia, Indonesia, Saudi Arabia on the other hand, air quality is worsening at an alarming rate.

Figure 6.4 shows how green technologies private investment has evolved over the last two decades. In the 1990s, there were limited investment in clean technologies. Advanced materials and energy efficiency were popular choices. In the 2000s, biofuels, biochemicals and solar investments took off, reaching to 4.7 billion and 2.1 billion USD respectively. The financial crisis in 2008 resulted in a dip in green investment, although the impact did not last long. Investment in clean technologies increased significantly to over 40 billion by 2012, where wind and solar technologies became the focus. Between 2013 and 2019, a second wave of investment in green technologies occurred. During this period, investors shifted towards transportation, agriculture and food related green technologies with an impressive 64 and 16.5 billion USD respectively in 2018.

The geography of global green venture capital centres is not surprising (Table 6.1); however, Table 6.2 shows novel insights on cities with the most progress in air quality improvement, which shows that the majority of the Top 20 is monopolised by the United States.

Our statistical models (Table 6.3) show that urban centres who have a higher historical number of VC-backed green start-ups are associated with a lower air pollution level over the period 2010 – 2019 (Models 1-7). The regressions are log-log models; hence the coefficients are to be interpreted as elasticities. Model 1 suggests that a 50% increase in the average cumulative green start-ups within a city is related to a 25% reduction in air quality over the 2010 – 2019 period. The statistical significance of the coefficient holds when controlling for the total cumulative number of start-ups in a region, the amount of VC/PE funding an urban centre is receiving and region city economic variables. The decrease in air quality is related to city-level increases in GDP and total labour, which shows the relationship between economic activity and air pollution. We investigate further and show that the variation in air quality is driven by the difference in cumulative green start-up numbers between cities, and less so (although still statistically significant) by the increase in cumulative green start-ups within cities. Interestingly, we do not find that VC centres in general are more likely to reduce their air pollution, as the reduction is driven primarily by the presence of green start-ups and not by an overall start-up ecosystem. This means that cities are unique in terms of their industry composition and the population exposure to PM2.5 and this uniqueness explains to a great proportion the variation over our sample. Although the average exposure to PM2.5 across cities can be very different, the year-on-year variation and downward/upward trending over time can be statistically significantly explained by the variation in the presence/absence of VC-backed green entrepreneurship.

At the sub-technology level (Table 6.5), we find that only green VC centres that have historically developed their green start-up ecosystems around the grid, energy efficiency, wind and low carbon materials sectors are those that are driving the overall results. While we expected for clusters who specifically had air pollution and transportation start-ups to also exhibit a strong air pollution reduction potential, this was not statistically significant when we implement our full models.

We conduct further robustness tests that seek to alleviate endogeneity concerns, particularly with respect to reverse causality and missing variable issues. As cities themselves run numerous programs to attract green entrepreneurs and given that it is possible that green urban entrepreneurs are attracted by leading cities who tackle air pollution in the first place (Cohen and Muñoz, 2015; Yu and Gibbs, 2020), through the methodology presented further, we seek to isolate the effect that cities who lead on air pollution reduction have on green entrepreneurship from the impact of green entrepreneurship on urban air pollution.

To do so, we use the method developed by Godfrey et al. (2020), who proposed a Granger-style reverse causality minimisation procedure, which can be used in the absence of a natural experiment. The method involves the following steps: First, we regress cumulative green entrepreneurship$_{i,t-1}$ on lagged air pollution$_{,t-2}$, to separate green entrepreneurship into two components, one which is driven by city air pollution, and one which is unrelated to city air pollution. The latter is the sum of the intercept and the disturbance term of the regression. We name this term orthogonalized cumulative green entrepreneurship. We confirm that orthogonalized green entrepreneurship$_{i,t-1}$ obtained this way has two very important properties: i) it has a zero (or very close to zero) correlation to air pollution and ii) a Granger causality F-test for air pollution$_{,t-2}$ causing orthogonalized green entrepreneurship$_{,t-1}$ is insignificant. As a final step, we regress air pollution$_{i,t}$ on our orthogonalized cumulative green entrepreneurship measure$_{i,t-1}$ and the associated control variables. We find that the effect of cumulative green entrepreneurship on urban air pollution retains its sign and significance as in our main models. We conduct an analogous process to disentangle the effect that air pollution has on the overall start-up ecosystem from the effect of cumulative start-ups on air pollution (Table 6.6).

In addition, to further check our results' reliability, we conduct a difference-in-differences analysis around new air pollution legislation passed around the world between 2009 – 2020, coinciding with our dataset. To obtain these legislations, we manually map and investigate air pollution legislation data from Ecolex, an online database that keeps track of all environmental legislation passed worldwide. Out of all the countries in our sample period, 65 had passed legislation about air pollution or air pollution after 2009. We define the shock as any new law passed between 2009 and 2020. We explore the differences in the air pollution reduction after the introduction of new legislation in each country, between green VC cities and non-green VC cities. A green VC city is a city that has hosted at least one green start-up between 2000 and the year of legislation change, and a non-green centre is an urban area that does not have a single green start-up. Using propensity score matching, we match these two city types using the cumulative number of start-ups across sectors within the city. The matches are limited to within the country and rebalanced every year until the legislation change event. To get the best estimate of the impact of the laws, and due to the constraint of matching within the same country, we opted for replacement matching. The results confirm that green VC cities reduce their air pollution faster than non-VC cities following legislation change (Table 6.8). This effect is most prominent across African and Latin American cities (we are unable to test this in North America as we could not observe country level legislation changes as these are enacted mostly at the states level, e.g., US). We also re-run our initial models by introducing the number of all air pollution legislations in force for a given year and country as an independent variable, which we also lag one year (this was run across all countries), and the effect remains unchanged (Table 6.7).

6.6. Discussion and conclusions

In responding to the call of Vedula et al. (2021) and Acs, Qian, Wu & Zheng (2021) to further the research agenda on how entrepreneurship delivers environmental and/or social returns, in particular related to the sustainability of urban centres, our paper seeks to understand whether green VC backed entrepreneurs have positively impacted air pollution levels in the urban centres they have been founded. On an extensive sample of 12,834 urban centres from around the world, we show that during the period 2010 – 2019, cities with larger cumulative number of green start-ups have decreased air pollution (proxied by PM 2.5) more than those with no green start-up ecosystems. Looking closely at the subsectors that drive the results, we observed that the urban centres which hosted increased numbers of innovators in smart grid technologies, energy efficiency and wind energy generation (the low carbon energy sector overall) also experienced a decrease in air pollution over the 2010 – 2019 period. Our difference-in-differences analysis suggests that this effect is particularly prominent in African and Latin American cities.

Our study builds on the emerging literature on sustainable urban entrepreneurship, in particular on the framing of Cohen and Muñoz (2015), by analysing how VC backed green entrepreneurs, who operate both at the city level as well as the global city network level, influence the air pollution of their host urban centres. In addition, we expand the literature on green entrepreneurship which so far hasn't analysed the real environmental and social impacts that entrepreneurship has on society, but was rather limited in studying knowledge spill overs (Cojoianu et al., 2020b; Colombelli and Quatraro, 2017), the influence of social norms on green entrepreneurship entry (Meek et al., 2010; Vedula et al., 2018; York and Lenox, 2014), and the growth and scalability of green ventures(Doblinger et al., 2019; Parker et al., 2019).

While our study can't test the mechanisms through which green urban entrepreneurship impacts the air pollution levels of an urban centre, we would like to take the opportunity to reiterate the most plausible channels. First and foremost, sustainable urban entrepreneurs can impact the air pollution level of their host urban centres through their products and services that they provide directly to cities and municipalities, by replacing the existing polluting infrastructure with less polluting and lower carbon alternatives such as it is the case in the energy sector (which drives the bulk of our results) or the transportation sector which I've historically responsible for a large part of the local air pollution problem. This may be possible because of more stringent air pollution legislations which can enable new entrants or new entrants seeking to change the legislative setting through policy entrepreneurship. This legislative change which allows for green entrepreneurs to flourish may need significant time till new entrants gain a critical mass, enough to be noticed and prioritised by policymakers (Georgallis et al., 2019). Furthermore, green entrepreneurship can generate significant knowledge spill overs which are absorbed across different industries (Cojoianu et al., 2020b; Qian and Acs, 2013), which can occur through supply chain interactions, human capital mobility and other opportunities to exchange tacit and codified knowledge about the green sector. Environmental specific knowledge, however, may be more complex and sophisticated than other types of knowledge (Cainelli et al., 2015), as green knowledge is often characterised by the "double externality issue" through the generation of positive (unmonetized) externalities at both the innovation as well as the diffusion stage (Cainelli et al., 2015; Rennings, 2000). It is entirely possible that green entrepreneurs generate knowledge spillovers which in turn translate into knowledge and commercial opportunities to tackle air pollution. While we are unable to test the exact mechanism, we document a statistically significant relationship between VC-backed green entrepreneurship and air pollution in urban area which calls for further research onto the research of impact mechanisms.

Our research has multiple and important implications. For entrepreneurship researchers and urban scholars, our study lays the foundation towards understanding the real environmental impacts of green entrepreneurship on their local environment. Our study further adds to the emerging literature on impact investing, which changes the paradigm on the study of entrepreneurial ventures from financial success only, to considering both financial and extra financial returns as equally important (Barber et al., 2021; Cojoianu et al., 2021). Our study further frames VC-backed green entrepreneurship as a key generator of positive environmental externalities which are manifested at the local level. This opens up the opportunity for further theoretical and empirical studies that study in depth the mechanisms through which entrepreneurs impact the natural environment (Demirel et al., 2019; Ghisetti, 2018). The paper is highly relevant for the global policy environment around sustainable finance regulation and green taxonomies, which aim to clarify which economic activities substantially contribute to environmental objectives such as pollution prevention or climate change. Thus, it prompts policy makers to consider new entrants as substantial contributors to positive environmental change and move away from a policy objective that optimises for “greening” incumbents. Our research also moves away from the intention and goals of new ventures of generating extra-financial returns to empirically testing whether these can be materialised in the case of impact on air pollution (Vedula et al., 2021).

Our study is not without its limitations. While we deal with the issue of reverse causality through Godfrey et al. (2020) and our study is robust to longer lags and alternative model specifications, our empirical setup is not necessarily causal, although we provide further robustness tests on the impact of air pollution legislation on cities with green VC start-ups vs. those without green start-ups. Secondly, we are only able to collect additional control variables for just over 12% of our sample cities, but we are reassured that the results hold. Finally, measuring air pollution across geography and space is inherently hard to do, hence, we rely on the proxies developed by the OECD and the Joint Research Centre European Commission. Finally, our study lacks the partnerships data or public procurement datasets which could have further provided insights on the mechanisms through which green urban entrepreneurs impact the quality across urban centres. We leave these worthwhile endeavours to future research.

Figure 6.1: Air pollution distribution change over time between 1990 and 2019.

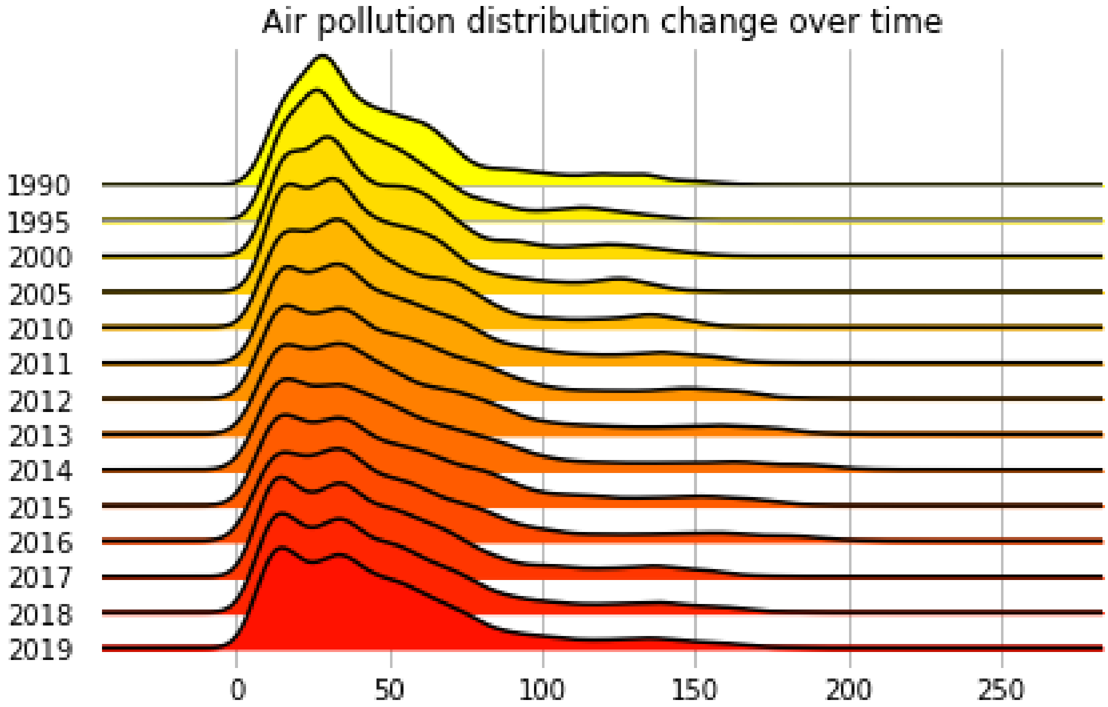

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Figure 6.2: Global distribution of air pollution by cities in 2019, as measured in PM 2.5. Total number of cities included: 11,134. Data from the OECD and the Joint Research Centre of the European Commission

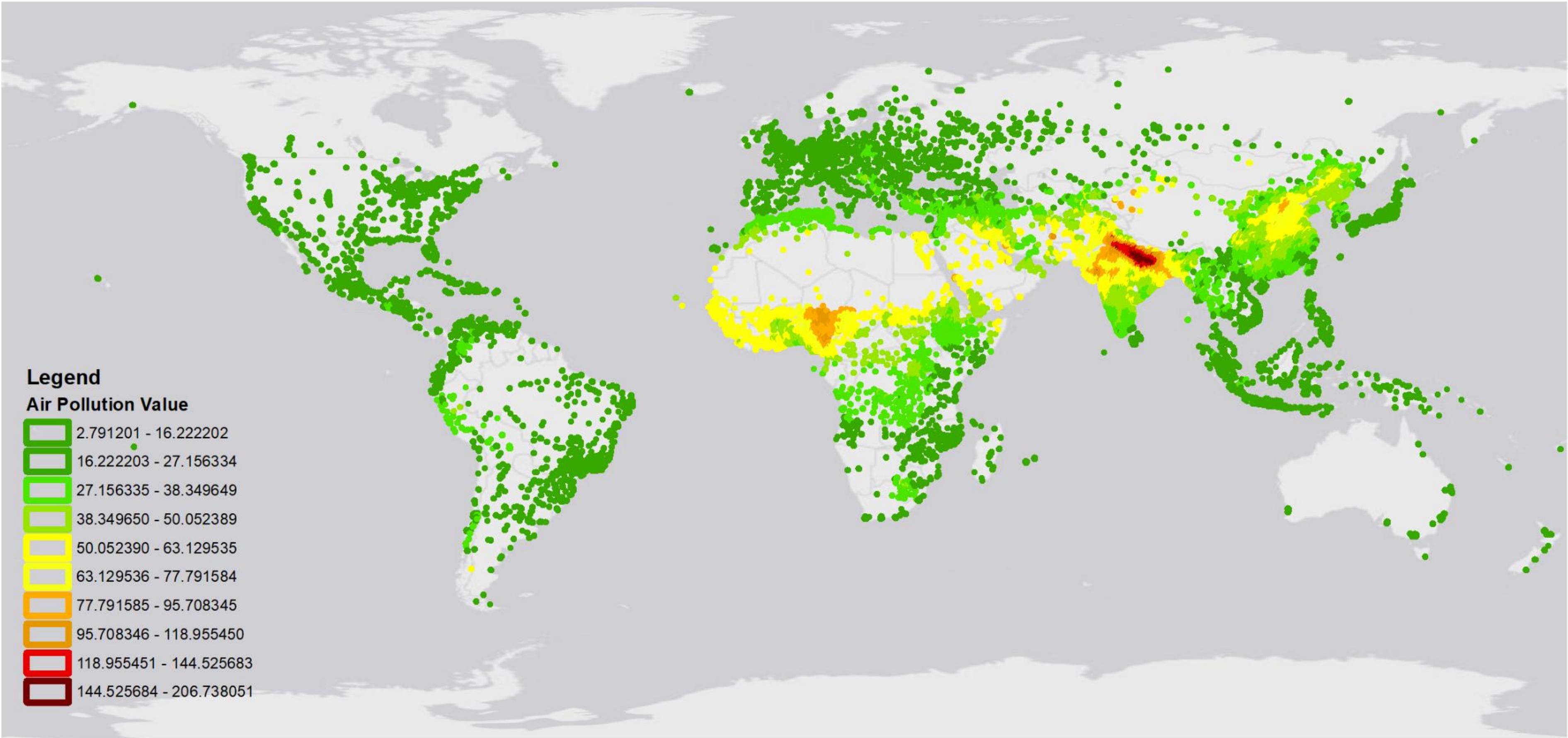

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Figure 6.3: Difference in global distribution of air pollution change by cities between 2019 and 2010, as measured in PM 2.5. Data from the OECD and the Joint Research Centre of the European Commission.

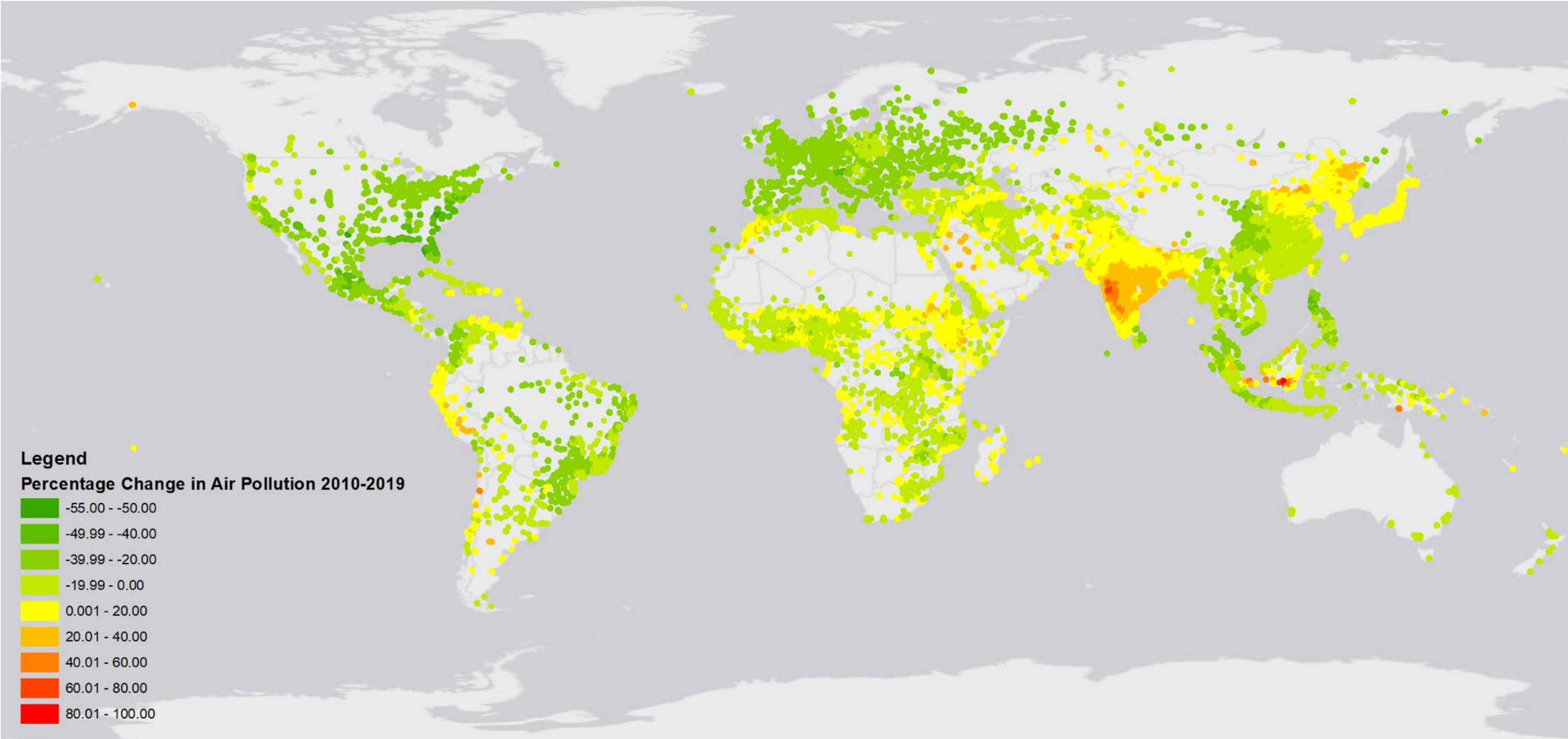

Figure 6.4: Evolution of green technologies between 1990 and 2019. Data from Preqin and CleantechGroup.

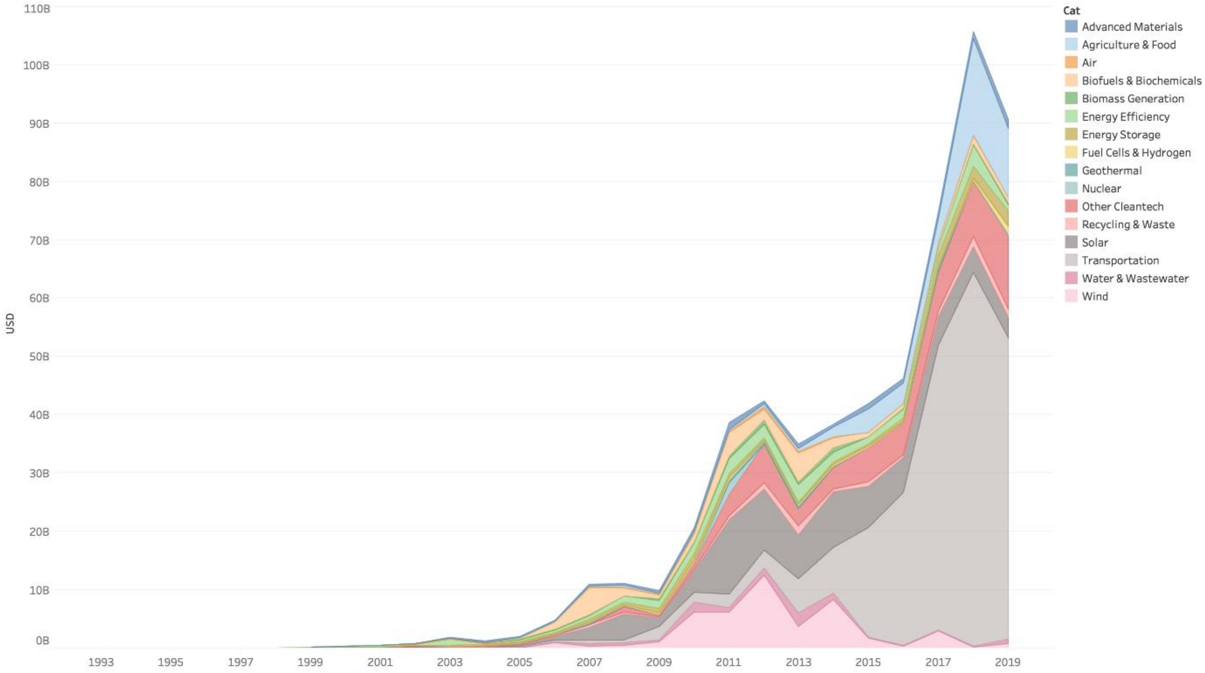

Table 6.1: Top 20 cities with most cumulative green start-ups (2000 - 2019). Data from Preqin and CleantechGroup.

City/Urban Area	Number of Green Start-ups founded
San Jose	1303
Paris	1055
Los Angeles	800
Sao Paulo	477
London	462
New York	451
Boston	362
Toronto	356
Delhi [New Delhi]	323
Mumbai	306
Berlin	298
Rotterdam [The Hague]	261
Guangzhou	256
Dortmund	224
Singapore	220
Tel Aviv	219
Amsterdam	190
Tijuana	187
Seattle	181
Vancouver	180

Table 6.2: Top 20 cities with most air pollution (PM2.5) reduction (2000 - 2019)

		Air pollution		
City/Urban Area	**Country**	**2000**	**2019**	**% Change**
Greensboro	United States	17	8	-53.87%
Tampa	United States	13	6	-52.15%
Bradenton	United States	11	5	-51.92%
Durham	United States	16	8	-51.77%
San Angelo	United States	15	7	-51.18%
Winston-Salem	United States	16	8	-50.96%
Cary	United States	16	8	-50.39%
Spring Hill	United States	11	6	-49.87%
Raleigh	United States	15	8	-49.51%
Tï¿½xpam	Mexico	36	19	-49.00%
Palm Bay	United States	9	5	-48.87%
Cocoa	United States	10	5	-48.76%
Fayetteville	United States	15	8	-48.57%
Tuscaloosa	United States	17	9	-47.59%
Mestre	Italy	44	23	-47.40%
Roanoke	United States	14	7	-47.37%
Poza Rica	Mexico	35	19	-47.36%
Baguio	Philippines	41	22	-47.10%
Orlando	United States	11	6	-47.09%
Pensacola	United States	14	7	-46.89%

*Air pollution to two significant numbers

Table 6.3: The impact of (green) VC centres on urban air pollution

The model is OLS with city and year fixed effects with standard errors clustered at the city level. The dependent variable is the natural logarithm of the yearly average PM2.5 concentration at the city level. Independent variables are logged and lagged one year. In Models 5-7, the Cumulative Green Start-Ups (count) and Cumulative Green Start-Up Funding variables are orthogonalized with respect to the number of Cumulative VC-backed Startups. Hence, for these models the results can be interpreted as the effect of the excess cumulative green startups and funding on city-level air pollution. A similar orthogonalization process has been conducted for Cumulative VC/PE Funding, New Start-Up Funding and the New Number of Start-Ups with respect to the Cumulative number of VC-backed Startups to avoid multicollinearity concerns.

Dependent variable: Log(PM2.5)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log(Cumulative Green Start-Ups)	-0.493***	-0.159***	-0.111***	-0.098***	-0.045***	-0.049***	-0.021**
	(0.018)	(0.007)	(0.006)	(0.007)	(0.008)	(0.008)	(0.008)
Log(Cumulative Green Start-Up Funding)				-0.003***	-0.002***	-0.002***	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)
Log(Cumulative VC-backed Start-Ups)					-0.106***	-0.105***	-0.008
					(0.006)	(0.006)	(0.007)
Log(Cumulative VC/PE Funding)						-0.002***	0.000
						(0.000)	(0.000)
Log(New Start-Up Funding)						0.001***	-0.000
						(0.000)	(0.000)
Log(New Number of Start-Ups)						0.007***	-0.002
						(0.002)	(0.002)
Log(GDP per Capita)							0.050***
							(0.006)
Log(Total Labour Force)							0.006*
							(0.003)
Log(Unemployment Rate)							0.011**
							(0.005)
Constant	3.703***	3.670***	3.665***	3.666***	3.680***	3.680***	2.538***
	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.065)
Observations	128,340	128,340	128,340	128,340	128,340	128,340	15,760
No. of Cities	12,834	12,834	12,834	12,834	12,834	12,834	1,576
City Fixed Effects	NO	YES	YES	YES	YES	YES	YES
Year Fixed Effects	NO	NO	YES	YES	YES	YES	YES
R-squared	0.0894	0.9900	0.9920	0.9921	0.9921	0.9921	0.9927

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6.4: Mundlak model - the impact of green entrepreneurship on urban air pollution

Dependent Variable: log Air Pollution (PM2.5)	(8)		(9)		(10)	
	Within City Variation	Between City Variation	Within City Variation	Between City Variation	Within City Variation	Between City Variation
Log(Cumulative Green Start-Ups)	-0.111***	-0.390***	-0.047***	-0.301***	-0.022***	-0.052*
	(0.006)	(0.019)	(0.008)	(0.019)	(0.008)	(0.030)
Log(Cumulative VC-backed Start-Ups)				-0.095***	0.001	-0.019
				(0.007)	(0.009)	(0.021)
Log(GDP per Capita)					0.049***	-0.343***
					(0.006)	(0.016)
Log(Total Labour Force)					0.006**	0.225***
					(0.003)	(0.012)
Log(Unemployment Rate)					0.011**	-0.272***
					(0.005)	(0.020)
Constant	3.687***		3.693***		3.433***	
	(0.006)		(0.006)		(0.230)	
Loglikelihood	114044		114406		15279	
Observations	128,340		128,340		15,760	
Number of groups (Cities)	12,834		12,834		1,576	

Cluster (city) robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. OLS log-log regression.

Table 6.5: Sub-sectoral analysis

Dependent variable: Log(PM2.5)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	Materials	Agriculture	Air Pollution	Biofuels	Biomass	Eeff	Storage	Fuel cells	Geothermal
Log(Cumulative Green Sub-Sector Start-Ups)	-0.025**	0.010	-0.025	-0.017	0.005	-0.043***	-0.007	-0.013	0.049
	(0.010)	(0.007)	(0.017)	(0.015)	(0.026)	(0.009)	(0.012)	(0.018)	(0.057)
Observations	15,760	15,760	15,760	15,760	15,760	15,760	15,760	15,760	15,760
No. of Cities	1,576	1,576	1,576	1,576	1,576	1,576	1,576	1,576	1,576
City Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Total Cumulative Start-Up No. and Funding	YES	YES	YES	YES	YES	YES	YES	YES	YES
Total New Start-Up No. and Funding	YES	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.9927	0.9927	0.9927	0.9927	0.9926	0.9927	0.9926	0.9926	0.9927

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Dependent variable: Log(PM2.5)	(20)	(21)	(22)	(23)	(24	(25)	(26)	(27)	(28)
	Hydro	Nuclear	Misc.	Recycling	Smart Grid	Solar	Transportation	Wastewater	Wind
Log(Cumulative Green Sub-Sector Start-Ups)	-0.009	-0.003	-0.008	-0.011	-0.029**	0.009	-0.013	-0.017	-0.040**
	(0.023)	(0.021)	(0.006)	(0.011)	(0.012)	(0.014)	(0.008)	(0.014)	(0.016)
Observations	15,760	15,760	15,760	15,760	15,760	15,760	15,760	15,760	15,760
No. of Cities	1,576	1,576	1,576	1,576	1,576	1,576	1,576	1,576	1,576
City Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Total Cumulative Start-Up No. and Funding	YES	YES	YES	YES	YES	YES	YES	YES	YES
Total New Start-Up No. and Funding	YES	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.9926	0.9926	0.9927	0.9926	0.9927	0.9926	0.9927	0.9927	0.9927

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Model is OLS with city and year fixed effects with standard errors clustered at the city level. The dependent variable is the natural logarithm of the yearly average PM2.5 concentration at the city level. Independent variables are logged and lagged one year. An orthogonalization process has been conducted for Cumulative VC/PE Funding, New Start-Up Funding and the New Number of Start-Ups with respect to the Cumulative number of VC-backed Startups to avoid multicollinearity concerns.

Table 6.6: Reverse causality minimisation procedure (Godfrey et al., 2020)

Dependent variable: Log(PM2.5)	(29)	(30)
Granger Orthog Cumulative Green Start-ups	-0.015**	-0.013*
	(0.007)	(0.007)
Granger Orthog Cumulative Total Start-ups	0.055***	0.054***
	(0.008)	(0.008)
Observations	102,672	102,672
No. of Cities	12,834	12,834
City Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
Total Cumulative Start-Up Funding	NO	YES
Total New Start-Up No. and Funding	NO	YES
R-squared	0.9927	0.9927

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6.7: Relationship between air pollution, legislation & GDP per capita

Dependent variable: Log(PM2.5)	(31)	(32)
Granger Orthog Cumulative Green Start-ups	-0.017**	-0.017**
	(0.008)	(0.008)
Granger Orthog Cumulative Total Start-ups	-0.002	-0.003
	(0.007)	(0.007)
Log(GDP per Capita)	0.580***	0.496***
	(0.057)	(0.053)
Log(GDP per Capita) # Log(GDP per Capita)	-0.029***	-0.026***
	(0.003)	(0.003)
Log(Country Air Pollution Legislation)		-0.083***
		(0.007)
Constant	0.271	0.818***
	(0.268)	(0.252)
Observations	15,760	15,760
No. of Cities	1,576	1,576
City Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
R-squared	0.9928	0.9930

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6.8: Difference-in-differences specification

Dependent variable: Log(PM2.5)	(33) World	(34) Africa	(35) Asia	(36) Latin America	(37) Europe
Treatment x Post	-0.029*	-0.083**	-0.023	-0.072***	0.016
	(0.016)	(0.035)	(0.018)	(0.021)	(0.013)
Constant	2.586***	3.404***	3.567***	2.783***	2.552***
	(0.007)	(0.006)	(0.008)	(0.007)	(0.006)
Observations	4,998	219	182	366	3,691
No. of Cities	341	34	16	41	220
City Fixed Effects	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES
R-squared	0.9980	0.9788	0.9983	0.9906	0.9877

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7. Conclusion

7.1 Summary

One of our main motivations in this research was to understand how finance, debt markets, and entrepreneurship interact with issues of public interest. Despite the growing feeling of distrust within the general populace towards financial markets, we saw a market nudging local authorities and start-ups towards sustainability. We focused on smaller players, counties, cities, and start-ups, as these are usually perceived as more vulnerable. For example, some companies may want to move to pollution havens, or places with less regulations. Thus, any small authority would always be at risk of its economic prosperity if it had stricter regulations than did its neighbours, especially considering that these industries bring along many jobs and provide a great stimulus to the local economy. The best example of this endeavour for more jobs is Amazon making cities bid for its second headquarter, wherein cities participated in race to the bottom (Florida, 2018). Counties and cities want to better regulate their environment, deal with threats, including lobbyists, activists, and economic challenges, without including outside pressures from the state or the federal authorities. Thus, start-ups might be nimbler in reacting to these challenges.

This is where out contribution makes a difference. We began our thesis by having a general conversation about pollutions and the institutions in the US before focusing on chemical pollution. We then showed how start-ups are filling the niche of fighting against local pollution issues. In our literature review, we explained the intricacies of the US system. We explained and analysed the central role of local governments in managing local economies, policies, and even infrastructure. We also explained the current state of pollution in the country, especially as a country that is still industrialised. We also showed how different players interacted with the current state of pollution in the country.

From there, we discussed our methodology. Unlike previous work on municipal bonds, we built our datasets from public information, which included the bonds themselves. We explained how we read 2.5 million bond contracts to allocate them to the geography of their issuers and mapped all TRI factories and all start-ups in the Preqin and Cleantech Dataset. We also justified the methodology we chose to implement from the options the environmental justice literature gave us. We also discussed the methodology we used to assess the toxicity of the chemicals and their impact. Then we converted all our values into LD50 and developed a new metric from the EPA Tri-Chip database, which we defined as the impact coefficient. We also created a combination of these metrics, which we realised in later chapters, to provide clearer insight into the market's behaviour.

In Chapter 4, which included our first study, we discussed the toxicity and impact of chemicals released into the water table on the municipal issuances. Both showed a clear impact on municipal bonds issued by counties and that counties with higher levels of pollution pay a higher yield than do counties with lower levels.

To confirm the causality between the two metrics, we used a set of state laws known as green chemistry legislations. These laws add restrictive measures on the types of chemicals that can be used in the states and essentially outlaw the most extreme chemicals. This provided us with an ideal experimental design, in which we can compare the impact of these laws on the issuance yield of the bonds in those states. To work around the staggered regression, we ran them state by state, which showed similar results. This provided clear evidence of a link between the level of water pollution and the yield at the issuance of municipal bonds.

In Chapter 5, we focused on chemical accidents. Unlike normal chemical emissions that can be controlled and prepared for, chemical accidents are random. We provided, to our knowledge, the first academic study analysing the impact of chemical accidents and malfunctions on the economic prosperity of municipalities. In this study, we focused on how cities must burden themselves with the costs of these chemical accidents. We also identified that the most impacted cities tend to be smaller villages with less than 2,000 people. The other group of most impacted cities tend to be the largest cities, whose density complicates such accidents.

To show the link between the impact of pollution and the economy, we analysed state laws. In many states, there are laws designed to protect populations exposed to chemical toxins from adverse medical effects. These are called medical monitoring laws. By using a staggered difference-in-differences regression, we showed that after their first accident, the increase in issuance yield of cities within medical monitoring states is smaller than it is in other states. We show this relationship even further by showing that corporates in medical monitoring states see an increase in their issuance yields after their first accidents.

In the last study chapter, we focused on the intersection between entrepreneurship and urban sustainability. This paper no longer focuses on only the United States; instead, we focus on a global dataset of 13,000 cities. We show that the cumulative number of start-ups working on sustainability issues results in lowering the average level of particulate matter. We then analyse the start-up sectors that have the biggest influence on air quality.

We find that energy efficiency, materials, smart girds, and wind energy are the biggest contributors in improving air quality. Other sectors that should have a greater impact do not achieve their intended goals. Most notably, the start-ups focused on air pollution did not have an impact on air pollution and did not improve air quality. We also run tests to work around the issues of reverse causality, and we do so by running a reverse causality minimisation and a difference in differences using air quality legislations from around the world.

7.2. Limitation and Future Works

Like all research, our studies had limitations. The first major limitation was that, despite our justification, we built our research on methodologies we developed or brought from different fields. Thus, it may be challenging for these methodologies to be accepted into mainstream finance literature.

Our mapping methodology used point coordinates, which meant that we had to convert addresses to coordinates. This would work when the addresses are done centrally by the EPA. However, for some of this thesis, we had to geocode the addresses ourselves, and this problem was more pronounced when geocoding addresses in countries that use different alphabets.

The greatest limitation of this research, aside from the mapping, was attributing the bonds to their respective geographies. As explained earlier, this involved me, the PhD applicant, manually reading and processing 2.5 million bond issuance contracts that had to be downloaded from the MSRB database. During this process, we found many mistakes within the database, with mislabelled or missing contracts, in which case we had to use our experience and knowledge to allocate the issuance.

In this process, there was the compounding effect of two sources of uncertainty: uncertainty from the data and human error. As for the human error, we could not control for this due to the sheer scale of the work; however, we performed regular and random data checks.

The errors in the database were out of our control. These errors at times included missing variables that were otherwise available in the literature, such as state taxable. At other times, they simply stemmed from the MSRB database mislabelling an issuance by a different name to that of the issuer. When noticed, we corrected for this; however, we cannot claim to have corrected all errors.

Another major data limitation appeared with the change in administration in the United States in 2020. With the arrival of the Biden administration, many of the processes surrounding the EPA and other pollution data providers became much more streamlined and accessible. Thus, we went back and corrected many of the issues, and some of our assumptions may have changed during that period.

The last major limitation is simply a limitation of skill and physical capacity. At the beginning of this research, many of the skills needed to complete the project had to be developed. I, the PhD researcher, had to learn to code in GIS and in python, with no coding background. I learned both; however, this may have dictated some of the processes I implemented in managing the data. As for the physical limitations, some of these datasets were 10s of gigabytes in size, requiring us to favour efficiency over accuracy.

To us, this thesis was simply the beginning of further research. While working on the last chapter, we already started our plans to look at the interaction between green municipal bonds and green start-ups in the US. This research would be interesting, as it would allow us to understand the signalling effects of municipal bonds.

We have also started conversations about creating a more holistic pollution index rather than focusing on particle matter or chemical emissions. Using a combination of datasets and some advanced mathematics could enable creating greenhouse gases emissions for specific factories and companies that could go back to the beginning of the century or further.

Despite the limitations listed here and the future work proposed, we still argue that the work done here is a substantial contribution to a growing field of financial literature. Each of these chapters represents a small advance in understanding complex interactions between sustainability, pollution, emissions, and municipal bonds and green entrepreneurship – a field of study that we see think truly impacts people lives.

References For Introduction

Andrew, B. (2008). Market failure, government failure and externalities in climate change mitigation: The case for a carbon tax. *Public Administration and Development*, 393-401.

Al-Hilali, M. T.-u.-D., & Khan, M. M. (1998). *The Noble Qur'an Translation.* Madinah, KSA: King Fahd Complex for the printing of the holy Qur'an.

Carmody, T. (2016, February 26). *How the Flint River got so toxic.* Retrieved from www.theverge.com: https://www.theverge.com/2016/2/26/11117022/flint-michigan-water-crisis-lead-pollution-history

Fatemi, A. M., & Fooladi, I. J. (2013). Sustainable finance: A new paradigm. *Global Finance Journal*, 101-113.

Hsu, P.-H., Li, K., & Tsou, C.-Y. (2022). The Pollution Premium. *Journal of Finance*, Forthcoming.

Matsumura, E. M., Prakash, R., & Vera-Munoz, S. C. (2013). Firm-Value Effects of Carbon Emissions and Carbon Disclosures. *The Accounting Review*, 695–724.

References for the literature Review

Anderton, D., Anderson, A., Oakes, J., & Fraser, M. (1994). Environmental equity: the demographics of dumping. *Demography*, 229–248 .

Ang, A., Green, R. C., Longstaff, F. A., & Xing, Y. (2017). Advance Refundings of Municipal Bonds. *The Journal of Finance*, 1645-1682.

Anton Nahman, G. A. (2005). The Environmental Kuznets Curve: A Litterature Survey. *South African Journal of Economics*, 105-120.

Aronson, J. R., & Hilley, J. L. (1986). *Financing State and Local Governments: Fourth Edition.* Washington DC: Brookings Institute Press.

Been, V. (1995). Analyzing evidence of environmental justice. *Journal of Land Use Envrionmental Law*, 1-36.

Bhattarai, M., & Hammig, M. (2001). Institutions and the Environmental Kuznets Curve for deforestation: A Cross-country Analysis for Latin America, Africa, and Asia. *World Development* , 995–1010.

Bhattarai, M., & Hammig., M. (2004). Governance, Economic Policy, and the Environmental Kuznets Curve for Natural Tropical Forests. *Environmental and Development Economics*.

Bisaro, A. (2013, October 28). *Little Ice Age Spurs Mongol Invasion*. Retrieved from climatechange.medill.northwestern.edu: https://climatechange.medill.northwestern.edu/2015/02/09/little-ice-age-spurs-mongol-invasion/

Bolin, B., Matranga, E., Hackett, E. J., Sadalla, E. K., Pijawka, K. D., Brewer, D., & Sicotte, D. (2000). Environmental equity in a sunbelt city: the spatial distribution of toxic hazards in Phoenix, Arizona. *Global Environmental Change Part B: Environmental Hazards*, 11-24.

Bouchrika, I. (2022). *101 American School Statistics: 2021/2022 Data, Trends & Predictions.* Research.com.

Bowen, W., Salling, M., Haynes, K., & Cyran, E. (1995). Towards environmental justice: spatial equity in Ohio and Cleveland. *Annals of the American Association of Geographers*, 641–663.

Briffault, R. (1990). Our Localism: Part I: The Structure of Local Government Law. *Columbia Law Review*, 1-115.

Briffault, R. (1996). The Local Government Boundary Problem in Metropolitan Areas. *Stanford Law Review*, 1115-1171.

Briffault, R. (2003). The Disfavored Constitution: State Fiscal Limits and State Constitutional Law. *Rutgers Law Review*, 907-957.

Briffault, R. (2008). The central place of States and Local Governments in American Federalism. In S. G. Feldstein, & F. J. Fabozzi, *The Handbook of Municipal Bonds* (pp. 3 - 24). Honoken, New Jersey: John Wiley & Sons, Inc.

Brooks, N., & Sethi, R. (1997). The distribution of pollution: community characteristics and exposure to air toxics. *Journal of Environmental Economics and Management*, 233-250.

Brunel, C. (2017). Pollution Offshoring and Emission Reductions in EU and US Manufacturing EU and US Manufacturing . *Environmental and Resource Economics*.

Bullard, R. D., Mohai, P., Saha, R., & Wright, B. (2007). *Toxic Wastes and Race at Twenty 1987—2007.* Cleveland: United Church of Christ.

Burke, L. (1993). *Environmental Equity in Los Angeles. NCGIA technical report.* Santa Barbara: National Center for Geographic Information and Analysis.

Chapman, L., & Keller, A. (2016, Jan 19). *United Way estimates cost of helping children $100M.* Retrieved from WNEM.com: http://www.wnem.com/story/30995770/united-way-estimates-cost-of-helping-children-100m

Chakraborty, J., & Zandbergen, P. (2007). Children at risk: Measuring racial/ethnic disparities in potential exposure to air pollution at school and home. *Journal of Epidemiology and Community Health*, 1074–1079.

Chakraborty, J., Maantay, J. A., & Brender, J. D. (2011). Disproportionate Proximity to Environmental Health Hazards: Methods, Models, and Measurement. *American Journal of Public Health*, 27-36.

Charbonneau, H. R. (2008). An Overview of Investment Banking. In S. G. Feldstein, & F. J. Fabozzi, *The Handbook of Municipal Bonds* (pp. 25-42). Hoboken, New Jersey: John Wiley & Sons, Inc.

Clark, G. L. (1985). *Judges and the cities.* Chicago: University of Chicago Press.

Clements Worldwide. (2017). *The Most Litigious Countries in the World.* Washington, D.C.: academia.edu.

Cohen, B., & Munoz, P. (2015). Toward a Theory of Purpose-Driven Urban Entrepreneurship. *Organisation and the Environment*, 264-285.

Congressional Research Service. (2022). *Federal Workforce Statistics Sources: OPM and OMB .* Washington DC: Congressional Research Service.

Cooper, T. (2022, October 23). *Municipal Broadband 2022: Barriers Remain an Issue in 17 States*. Retrieved from broadbandnow.com: https://broadbandnow.com/report/municipal-broadband-roadblocks/

Cornell Law School. (2022, November 6). *Election*. Retrieved from Cornell Law School: https://www.law.cornell.edu/wex/elections

Cutter, S., & Solecki, W. D. (1996). Setting environmental justice in space and place: acute and chronic airborne toxic releases in the southeastern United States. *Urban Geography*, 380-399.

Cutter, S., Holm, D., & Clark, L. (1996). The role of geographic scale in monitoring environmental justice. *Risk Analysis*, 517–526 .

Daniels, G., & Friedman, S. (1999). Spatial inequality and the distribution of industrial toxic releases: evidence from the 1990 TRI. *Social Science Quarterly*, 244–262 .

Downey, L. (2006). Environmental racial inequality in Detroit. *Social Forces*, 771–796 .

EPA. (2022, June 30). *History of the Toxics Release Inventory (TRI) Program*. Retrieved from epa.gov: https://www.epa.gov/toxics-release-inventory-tri-program/history-toxics-release-inventory-tri-program

EPA. (2022, September 6). *Learn About Environmental Justice*. Retrieved from epa.gov: https://www.epa.gov/environmentaljustice/learn-about-environmental-justice

EPA. (2022, June 24). *The Origins of EPA*. Retrieved from epa.gov: https://www.epa.gov/history/origins-epa

EPA. (2022, July 13). *What is the Toxics Release Inventory?* Retrieved from epa.gov: https://www.epa.gov/toxics-release-inventory-tri-program/what-toxics-release-inventory

Feldstein, M. (1993). Government Spending and Budget Deficits in the 1980s: A Personal View. *National Bureau of Economic Research*, Working Paper No. 4324.

Fischer, P. J. (1983). Advance refunding and municipal bond market efficiency. *Journal of Economics and Business*, 11–20.

Fricker, R. D., & Hengartner, N. (2001). Environmental equity and the distribution of toxic release inventory and other environmentally undesirable sites in metropolitan NYC. *Environmental and Ecological Statistics*, 33-52.

Gilbert, N. (2019, February 14). *EPA blasted for failing to set drinking water limits for 'forever chemicals'*. Retrieved from science.org: https://www.science.org/content/article/epa-blasted-failing-set-drinking-water-limits-forever-chemicals

Goldman, B., & Fitton, L. (1994). *Toxic Wastes and Race Revisited: An Update of the 1987 Report on the Racial and Socioeconomic Characteristics of Communities with Hazardous Waste Sites.* Washington, DC: Center for Policy Alternatives.

Grossman, G. M., & Krueger, A. B. (1991). Environmental Impact of a North American Free Trade Agreement. *Working paper*.

Haynes, T. (Director). (2020). *Dark Waters* [Motion Picture].

Hird, J. (1993). Environmental policy and equity: the case of Superfund. *Journal of Policy Analysis and Management*, 323–343 .

Honma, T., & Suda, M. (1998). Correlation of lethal doses of industrial chemicals between oral or intraperitoneal administration and inhalation exposure. *Industrial Health*, 273-281.

Kalotay, A. J., & Abreo, L. (2010). Making the right call. *Credit*, 57–59.

Kalotay, A. J., & May, W. H. (1998). The timing of advance refunding of tax-exempt municipal bonds. *Municipal Finance Journal*, 1–15.

Kidwell, D. S., & Sorensen, E. H. (1983). Pricing of Municipal Bond Underwritings: It May Pay to Invest When Underwriters Don't. *Financial Analysts Journal*, 58-64.

Kriesel, W., Centner, T., & Keeler, A. (1996). Neighborhood exposure to toxic releases: are there racial inequities? . *Growth and Change*, 479–499.

Legal Aid Society of Northeastern New York. (2022, November 06). *The Differences between Federal, State, and Local Laws*. Retrieved from Lawhelp.org: https://www.lawhelp.org/resource/the-differences-between-federal-state-and-loc#:~:text=Federal%20laws%20apply%20to%20everyone,%2C%20town%2C%20township%20or%20village.

Lerner, S. (2022, August 5). *Massive Quantities of PFAs Waste Go Unreported to the EPA*. Retrieved from theintercept.com: https://theintercept.com/2022/08/05/pfas-waste-epa-afff-us-ecology/

Levinson, A. (2009). Offshoring pollution: Is the U.S. increasingly importing polluting goods? *Working paper*.

Lindmark, M. (2002). An EKC-Pattern in Historical Perspective: Carbon Dioxide Emissions, Technology, Fuel Prices, and Growth in Sweden 1870–1997. *Ecological Economics* , 333-347.

Maantay, J. (2007). Asthma and air pollution in the Bronx: methodological and data considerations in using GIS for environmental justice and health research. *Health Place*, 32-56.

Maciag, M. (2012, September 14). *Number of Local Governments by State*. Retrieved from governing.com: https://www.governing.com/archive/number-of-governments-by-state.html

Madison, J. (1788, January 26). The Federalist Paper 45: The Alleged Danger From the Powers of the Union to the State Governments Considered. *New York Packet*. Retrieved from The Federalist Papers : No. 45.

Magazzino, C., Porrini, D., Fusco, G., & Schneider, N. (2021). Investigating the link among ICT, electricity consumption, air pollution, and economic growth in EU countries. *Energy Sources, Part B: Economics, Planning, and Policy* , 976-998.

McMaster, R., Leitner, H., & Sheppard, E. (1997). GIS-based environmental equity and risk assessment: methodological problems and prospects. *Cartography and Geographic Information Science*, 172–189.

Mennis, J. (2002). Using geographic information systems to create and analyze statistical surfaces of population and risk for environmental justice analysis. *Social Science Quarterly*, 281–297.

Mennis, J. L., & Jordan, L. (2005). The distribution of environmental equity: exploring spatial non-stationarity in multivariate models of air toxic releases. *Annals of the American Association of Geographers*, 249–268.

Mohai, P., & Saha, R. (2006). Reassessing racial and socio-economic disparities in environmental justice research. *Demography*, 383–399.

Mohai, P., & Saha, R. (2006). Reassessing racial and socio-economic disparities in environmental justice research. *Demography*, 383–399 .

Mohai, P., Lantz, P., Morenoff, J., House, J., & Mero, R. (2009). Racial and socioeconomic disparities in residential proximity to polluting industrial facilities: evidence from the Americans’ Changing Lives Study. *American Journal of Public Health*, S649–S655.

Mohai, P., Pellow, D., & Roberts, J. T. (2009). Environmental Justice. *Annual Review of Environment and Resources*, 405-430.

Moore, R., Ricks, K., & Little, a. J. (2022). *Annual State and Local Government Finances Summary: 2020.* Washington: US Census Bureay.

Muller, N. Z., Mendelsohn, R., & Nordhaus, W. (2011). Environmental Accounting for Pollution in the United States Economy. *American Economic Review*, 1649–1675.

Munasinghe, M. (1999). Is Environmental Degradation an Inevitable Consequence of Economic Growth: Tunneling through the Environmental Kuznets Curve. *Ecological Economics* , 89–109.

Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, 468-482.

Perlin, S., Setzer, R., Creason, J., & Sexton, K. (1995). Distribution of industrial air emissions by income and race in the United States: an approach using the toxic release inventory. *Environmental Science & Technology*, 69–80.

Perota, J., Werner, C., Hoskinson, J., Pennolino, P., & Leddy, B. (Directors). (2016). *Special Districts: Last Week Tonight with John Oliver (HBO)* [Motion Picture].

Pollock, P., & Vittas, M. (1995). Who bears the burden of environmental pollution? Race, ethnicity, and environmental equity in Florida. *Social Science Quarterly*, 294–310.

Portney, P. R. (1990). Policy Watch Economics and the Clean Air Act. *Journal of Economic Perspectives*, 173-181.

Rein, L. (2011, October 7). *Civil War gave birth to much of modern federal government.* Retrieved from Washington Post:

https://www.washingtonpost.com/politics/civil-war-gave-birth-to-much-of-modern-federal-government/2011/09/22/gIQA43EFSL_story.html

Reynolds, L., & Briffault, R. (2022). *Cases and Materials on State and Local Government Law.* West Academic Publishing: St. Paul, MN.

Ringquist, E. (1997). Equity and the distribution of environmental risk: the case of TRI facilities. *Social Science Quarterly*, 811–829 .

Ritchie, H. (2019, October 01). *Who has contributed most to global CO2 emissions?* Retrieved from ourworldindata: https://ourworldindata.org/contributed-most-global-co2

Robert, D. M., & Spatt, C. S. (1993). A note on advance refunding of municipal debt. *Working paper*.

Rubin, D. F. (1993). Constitutional aid limitation provisions and the public purpose doctrine. *St. Louis University Public Law Review*, 143-148.

Schlosberg, D., & Collins, L. B. (2014). From environmental to climate justice: climate change and the discourse of environmental justice. *Climate Change*.

Securities Industry and Financial Markets Association. (2022, November 3). *US Municipal Bonds Statistics*. Retrieved from www.sifma.org: https://www.sifma.org/resources/research/us-municipal-bonds-statistics/#:~:text=Trading%20(as%20of%20October)%20%2413.8,%2C%20%2B0.2%25%20Y%2FY

Shrivastava, P., & Kennelly, J. J. (2013). Sustainability and Place-Based Enterprise. *Organisation and Environment*, 83-101.

Suda, M., Tsuruta, H., & Honma, T. (1999). The contribution of acute toxicity in animals to occupational exposure limits of chemical substances. *Industrial Health*, 22-27.

Suvarna, S. K., Layton, C., & Bancroft, J. D. (2019). *Bancroft's Theory and Practice of Histological Techniques.* Amsterdam : Elsevier .

Sze, J., & London, J. K. (2008). Environmental Justice at the Crossroads Julie . *Sociology Compass* , 1331-1354.

tax policy center. (2020, May). *What are the sources of revenue for local governments?* Retrieved from taxpolicycenter.org: https://www.taxpolicycenter.org/briefing-book/what-are-sources-revenue-local-governments

The Green Papers. (2020, November 5). *Official Name and Status History of the several States and U.S. Territories*. Retrieved from The Green Papers: https://www.thegreenpapers.com/slg/statehood.phtml

Tiefenbacher, J., & Hagelman, R. (1999). Environmental equity in urban Texas: race, income, and patterns of acute and chronic toxic air releases in metropolitan counties. *Urban Geography*, 516-533.

Torras, M., & Boyce., J. K. (1998). Income, Inequality, and Pollution: A Reassessment of the Environmental Kuznets Curve. *Ecological Economics* , 147-160.

U.S. Code, Congressional and Administrative News. (1970, July 9). *Reorganization Plan No. 3 of 1970*. Retrieved from archive.epa.gov: https://archive.epa.gov/epa/aboutepa/reorganization-plan-no-3-1970.html

U.S. Constitution art. I. (1787). *U.S. Constitution.* Philadelphia.

United Church of Christ Commission for Racial Justice Toxic Wastes and Race in the United States. (1987). *A National Report on the Racial and Socio-economic Characteristics of Communities with Hazardous Waste Sites.* New York: United Church of Christ.

United States Census Bureau. (1990). Local Census Statistical Areas Committees and Other Local Assistance . In U. S. Bureau, *Geographic Areas Reference Manual* (pp. 3_1-1_14). Washington: US Census Bureau.

United States Census Bureau. (1990). Places. In U. S. Bureau, *Geographic Areas Reference Manual* (pp. 9_1-9_33). Washington: US Census Bureau.

United States Census Bureau. (2012, August 30). *Census Bureau Reports There Are 89,004 Local Governments in the United States.* Retrieved from Census.gov: https://www.census.gov/newsroom/releases/archives/governments/cb12-161.html

United States Census Bureau. (2013, February 21). *U.S. Territory and Statehood Status by Decade, 1790-1960.* Retrieved from census.gov: https://www.census.gov/dataviz/visualizations/048/

United States Census Bureau. (2019, October 29). *Count of Governments Throughout the Years: 1942 to 2017.* Retrieved from census.gov: https://www.census.gov/library/visualizations/2019/econ/cog_infographic_2019_1.html

United States Census Bureau. (2021, October 8). *Urban Areas Facts*. Retrieved from census.gov: https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/ua-facts.html

Urban-Brookings Tax Policy Center. (2022, September 15). *State and Local Finance Data Exploring the Census of Governments*. Retrieved from taxpolicycenter.org: https://state-local-finance-data.taxpolicycenter.org/pages.cfm

Venter, Z. S., Aunan, K., Chowdhury, S., & Lelieveld, J. (2020). COVID-19 lockdowns cause global air pollution declines. *Earth, Atmospheric, and Planetary Sciences*, 18984-18990.

Victor, P. A. (1971). *Pollution Economy and Environment.* London: Routledge.

Wilson, S. M. (2010). Environmental Justice Movement: A Review of History, Research, and Public Health Issues. *Journal of Public Management & Social Policy* , 19-50.

Wong, A. (2022). *Environmental Justice.* Retrieved from astro.sunysb.edu: http://www.astro.sunysb.edu/fwalter/HON301/F21/AWong.pdf

Wood, W. H. (2008). Municipal Bond Refunding. In S. G. Feldstein, & F. J. Fabozzi, *The Handbook of Municipal Bonds* (pp. 235-246). Hoboken, New Jersey: John Wiley & Sons, inc.

Wood, W. H. (2008). Role of the Financial Advisor. In S. G. Feldstein, & F. J. Fabozzi, *The Handbook of Municipal Bonds* (pp. 43-50). Hoboken: Wiley.

Yandle, B., & Morriss, A. (2001). The Technologies of Property Rights: Choice Among Alternative Solutions to Tragedies of the Commons. *Ecology Law Quarterly* , 123-168.

Yandle, B., Bhattarai, M., & Vijayaraghavan, M. (2004). Environmental Kuznets Curves: A Review of Findings, Methods, and Policy Implications. *PERC Research Study*.

Zhou, B., & Li, X. (2021). The monitoring of chemical pesticides pollution on ecological environment by GIS. *Environmental Technology & Innovation*.

References for Methodology

Honma, T., & Suda, M. (1998). Correlation of lethal doses of industrial chemicals between oral or intraperitoneal administration and inhalation exposure. *Industrial Health*, 273-281.

Maciag, M. (2012, September 14). *Number of Local Governments by State*. Retrieved from Governing.com: https://www.governing.com/archive/number-of-governments-by-state.html

References for Chapter 4

Adelino, M., Cunha, I., & Ferreira, M. A. (2017). The Economic Effects of Public Financing: Evidence from Municipal Bond Ratings Recalibration. *The Review of Financial Studies*, 3223–3268.

Agrawal, A. K., & D. Kim. (2021). Municipal Bond Insurance and the U.S. Drinking Water Crisis. *Working Paper*.

Agrawal, A., & Hockerts, K. (2019a). Impact investing: review and research agenda. *Journal of Small Business and Entrepreneurship*, 1-29.

American Water Works Association. (2022, November 15). *U.S. Infrastructure Investment & Jobs Act: Resources for the Water Sector* . Retrieved from awwa.org: https://www.awwa.org/Resources-Tools/Resource-Topics/US-Infrastructure-Investment-Jobs-Act#:~:text=Water%20infrastructure%20financing%3A%20%2450%20million,2026%2C%20%243%20billion%20per%20year.

Audretsch, D. B., & Keilbach, M. (2007). The Theory of Knowledge Spillover Entrepreneurship. *Journal of Management Studies*, 1242-1254.

Baicker, K., Clemens, J., & Singhal, M. (2012). The Rise of the States: U.S. Fiscal Decentralization in the Postwar Period. *Journal of Public Economics*, 1079-1091.

Baker, A. C., Larcker, D. F., & Wang, C. C. (2021). How Much Should We Trust Staggered Difference-In-Differences Estimates?

Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). Financing the Response to Climate Change: The Pricing and Ownership of US Green Bonds. *Working Paper*.

Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2020). Financing the Response to Climate Change: The Pricing and Ownership of U.S. Green Bonds.

Biehl, C. F., Hoepner, A. G., & Liu, J. (2012). Social, Environmental, and Trust Issues in Business and Finance. *Socially responsible finance and investing*, 111–142.

Bilott, R. (2019). *Exposure: Poisoned Water, Corporate Greed, and One Lawyer's Twenty-Year Battle against DuPont.* Atria Publishing Group.

Briffault, R. (2008). The central place of States and Local Governments in American Federalism. In S. G. Feldstein, & F. J. Fabozzi, *The*

Handbook of Municipal Bonds (pp. 3 - 24). Honoken, New Jersey: John Wiley & Sons, Inc.

Brinkman, L., & Miller, S. A. (2021). Environmental impacts and environmental justice implications of supplementary cementitious materials for use in concrete. *Environmental Research: Infrastructure and Sustainability*.

Butler, A. W. (2008). Distance Still Matters: Evidence from Municipal Bond Underwriting. *The Review of Financial Studies*, 763–784.

Butler, A. W., Fauver, L., & Mortal, S. (2009). Corruption, Political Connections, and Municipal Finances. *The Review of Financial Studies*, 2873–2905.

California Legislative Information. (2022, November 16). *Chapter 6.6. Safe Drinking Water and Toxic Enforcement Act of 1986 .* Retrieved from leginfo.legislature.ca.gov: https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=HSC&division=20.&title=&part=&chapter=6.6.&article

Cantor, R., & Packer, F. (1997). Differences of opinion and selection bias in the credit rating industry. *J. Bank. Financ.*, 1395-1417.

Caramichael, J., & Rapp, A. C. (2022). The Green Corporate Bond Issuance Premium. *Working Paper*.

Chakraborty, J., Maantay, J. A., & Jean D. Brender. (2011). Disproportionate Proximity to Environmental Health Hazards: Methods, Models, and Measurement. *American Journal of Public H, 101*, S27–S36.

Christensen, P., Keiser, D., & Lade, G. (2019). Economic Effects of Environmental Crises: Evidence from Flint Michigan. *Working Paper*.

Cohen, B., & Muñoz, P. (2015). Toward a Theory of Purpose-Driven Urban Entrepreneurship. *Organization & Environment*, 264-285.

Cojoianu, T. F., Hoepner, A. G., & Lin, Y. (n.d.). Impact vs. ESG Investing in Private Markets.

congress.gov. (2016). *H.R.4479 - Families of Flint Act*. Retrieved November 15, 2022, from https://www.congress.gov/bill/114th-congress/house-bill/4479

Cornaggia, K. R., Hund, J., Nguyen, G., & Ye, Z. (2021). Opioid Crisis Effects on Municipal Finance. *The Review of Financial Studies*, 1-48.

Dagostino, R. (2018). The Impact of Bank Financing on Municipalities' Bond Issuance and the Real Economy. *Working Paper*.

Danagoulian, S., Grossman, D. S., & Slusky, D. (2020). Office Visits Preventing Emergency Room Visits: Evidence from the Flint Water Switch. *Working Paper*.

Dean, T. J., & McMullen, J. (2007). Toward a theory of sustainable entrepreneurship: reducing environmental degradation through entrepreneurial action. *J. Bus. Ventur*, 50-76.

entrepreneurship, T. k. (2009). Zoltan J. Acs; Pontus Braunerhjelm; David B. Audretsch; Bo Carlsson . *Small Business Economics volume*, 15-30.

epa.gov. (2022, November 15). *Information about Public Water Systems*. Retrieved from epa.gov: https://www.epa.gov/dwreginfo/information-about-public-water-systems#:~:text=There%20are%20over%20148%2C000%20public%20water%20systems%20in%20the%20United%20States.

Evans, S., Campbell, C., & Naidenko, O. V. (2019). Cumulative risk analysis of carcinogenic contaminants in United States drinking water. *Heliyon*.

Ge, W., & Li, M. (2015). Corporate social responsibility and the cost of corporate bonds . *Journal of Accounting Public Policy*, 597-624.

Goldsmith-Pinkham, P., Gustafson, M. T., Lewis, R. C., & Schwert, M. (2020). Sea Level Rise Exposure and Municipal Bond Yields. *Working Paper*.

Gorton, N., & Pinkovskiy, M. (2021). Credit Access and Mobility during the Flint Water Crisis. *Working Paper*.

Govinfo.gov. (2016). *162 Cong. Rec. H695 - FLINT WATER CRISIS*. Retrieved November 15th, 2022, from https://www.govinfo.gov/app/details/CREC-2016-02-10/CREC-2016-02-10-pt1-PgH695-3

Green, D., & Loualiche, E. (2021). State and Local Government Employment in the COVID-19 Crisis. *Journal of Public Economics*, 193.

Gussman, J., & Plumb, J. (Directors). (2014). *Return of the River* [Motion Picture].

Haynes, T. (Director). (2020). *Dark Waters* [Motion Picture].

Honma, T., & Suda, M. (1998). Correlation of Lethal Doses of Industrial Chemicals between Oral or Intraperitoneal Administration and Inhalation Exposure. *Industrial Health* , 273-281.

Hosea, L. (Director). (2019). *Thirst for Justice* [Motion Picture].

Hsu, P.-H., Li, K., & Tsou, C.-Y. (2022). The Pollution Premium. *Journal of Finance, Forthcoming*.

Huang, D., & Kumar, A. (2022). Uncharted Waters: Pollution and Municipal Finance. *Working Paper*.

Jerch, R., Kahn, M. E., & Lin, G. C. (2020). Local Public Finance Dynamics and Hurricane Shocks. *Working Paper*.

Jha, A., Karolyi, S. A., & Muller, N. Z. (2020). Polluting Public Funds: The Effect of Environmental Regulation on Municipal Bonds. *Working Paper*.

Lee, R., & Cavoski, A. (2022). *Climate change governance and environmental justice.* Birmingham: University of Birmingham.

legislature Michigan. (1967, November 2). *Chemical Agents Act 119 of 1967.* Retrieved from legislature.mi.gov: https://www.legislature.mi.gov/documents/mcl/pdf/mcl-Act-119-of-1967.pdf

Malen, J., & Marcus, A. (2017). Promoting clean energy technology entrepreneurship: the role of external context. *Energy Policy*, 7–15.

Mason, C., & Brown, R. (2013). Creating good public policy to support high-growth firms. *Small Bus. Econ.*, 211-225.

Millar, S. A. (2015, February 27). *Green Chemistry – The State of the States.* Retrieved from khlaw.com: https://www.khlaw.com/insights/green-chemistry-state-states

Millar, S. A. (2019, August 29). *Green Chemistry 2018–2019: A Review of the Year That Was and Predictions for the Remainder of 2019.* Retrieved from https://www.natlawreview.com/: https://www.natlawreview.com/article/green-chemistry-2018-2019-review-year-was-and-predictions-remainder-2019

Moore, M. (Director). (2018). *Fahrenheit 11/9* [Motion Picture].

Muehlenbachs, L., Spiller, E., & Timmins, C. (2015). The Housing Market Impacts of Shale Gas Development. *American Economic Review*, 3633–59.

news.sky.com. (2021, April 7). *Florida residents evacuated over threat of toxic flood told it's safe to go home despite lingering concerns*. Retrieved from news.sky.com: https://news.sky.com/story/hundreds-allowed-home-after-toxic-flash-flood-fears-at-former-phosphate-plant-site-12268345

Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, 468-482.

Palucka, T. (2015). *DOING THE IMPOSSIBLE*. Retrieved from AmericanHeritage.com: http://web.archive.org/web/20081203124718/http://www.americanheritage.com/articles/magazine/it/

Reade, A., & Yiliqi. (2021, October 21). *New EPA Data: Huge Amounts of PFAS Underreported and Burned.* Retrieved from nrdc.org: https://www.nrdc.org/experts/yiliqi/new-epa-data-huge-amounts-pfas-underreported-and-burned-0

Sarni, W., Clark, A., & Burnett, V. (Directors). (2019). *Flint: The Poisoning Of An American City* [Motion Picture].

Shrivastava, P., & Kennelly, J. J. (2013). Sustainability and Place-Based Enterprise. *Organization & Environment*, 83-101.

United States Court of Appeals for the Ninth Circuit. (2019, November 11). *17-72260 - Safer Chem, Healthy Families, et al v. USEPA, et al.* Retrieved from govinfo.gov: https://www.govinfo.gov/app/details/USCOURTS-ca9-17-72260/summary

Vedula, S., York, J. G., & Corbett, A. C. (2019). Through the Looking-Glass: The Impact of Regional Institutional Logics and Knowledge Pool Characteristics on Opportunity Recognition and Market Entry. *Journal of Management Studies*, 1414-1451.

Yi, H. (Working Paper). Finance, Public Goods, and Migration. *2020*.

York, J. G., & Lenox, M. J. (2014). Exploring the sociocultural determinants of de novo versus de alio entry in emerging industries. *Strategic Management Journal*, 1930–1951.

York, J., & Venkataraman, S. (2010). The entrepreneur-environment nexus: uncertainty, innovation, and allocation. *J. Bus Ventur*, 449-463.

Zietsma, C., Ruebottom, T., & Shantz, A. S. (2018). Unobtrusive Maintenance: Temporal Complexity, Latent Category Control and the Stalled Emergence of the Cleantech Sector. *Journal of Management Studies*, 1242-1277.

References for Chapter 5

Agrawal, A., & Hockerts, K. (2019a). Impact investing: review and research agenda. *Journal of Small Business and Entrepreneurship*, 1-29.

Associated Press. (2021, April 3). *Florida emergency as phosphate plant pond leak threatens radioactive flood*. Retrieved from theguardian.com: https://www.theguardian.com/us-news/2021/apr/03/florida-emergency-piney-point-phosphate-plant-pond-leak-radioactive-flood-ron-desantis

Audretsch, D. B., & Keilbach, M. (2007). The Theory of Knowledge Spillover Entrepreneurship. *Journal of Management Studies*, 1242-1254.

Baker, A. C., Larcker, D. F., & Wang, C. C. (2021). How Much Should We Trust Staggered Difference-In-Differences Estimates? . *Working Paper* , 21-112.

Baker, M. P., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). Financing the Response to Climate Change: The Pricing and Ownership of U.S. Green Bonds. *Working Paper*.

bbc.com. (2021, April 5). *Piney Point: Emergency crews try to plug Florida toxic wastewater leak*. Retrieved from bbc.com: https://www.bbc.com/news/world-us-canada-56629013

Beck, J. M. (2009, April 2009). *Medical Monitoring – Another 50-State Survey*. Retrieved from druganddevicelawblog.com: https://www.druganddevicelawblog.com/2009/04/medical-monitoring-another-50-state.html

Beeler, M. F., & Sappenfield, R. (1987). Medical monitoring. What is it, how can it be improved? *American Journal of Clinical Pathology*, 285-8.

Behrens, M. A., & Appel, C. E. (2020). American Law Institute Proposes Controversial Medical Monitoring Rule in Final Part of Torts Restatement.

Bernstein, A., Gustafson, M., & Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics*, 253–272.

Biehl, C. F., Hoepner, A. G., & Liu, J. (2012). Social, Environmental, and Trust Issues in Business and Finance. *Socially responsible finance and investing*, 111–142.

Cantor, R., & Packer, F. (1997). Differences of opinion and selection bias in the credit rating industry. *Journal of Banking & Finance*, 1395-1417.

CBS47/ FOX30. (2022, November 07). *Fire at Brunswick chemical plant prompts evacuations*. Retrieved from actionnewsjax.com: https://www.actionnewsjax.com/news/local/fire-brunswick-chemical-plant-prompts-evacuations/3BIK37NZEVGOPHW2SE2JWR3OKU/

Cochran, E. (2002). Chemical Risk Dara Remanins dangerously available to public. *Legal Backgrounder*.

Cohen, B., & Muñoz, P. (2015). Toward a Theory of Purpose-Driven Urban Entrepreneurship. *Organization & Environment*, 264-285.

Cojoianu, T. F., Hoepner, A. G., & Lin, Y. (n.d.). Impact vs. ESG Investing in Private Markets.

Congressional Research Service. (2006, December 15). *Chemical Facility Security*. Retrieved from everycrsreport.com: https://www.everycrsreport.com/files/20061215_RL31530_3ea2860942b408ea1b6a2def8b837b3a8c70f195.html#ifn123

Dahl, R. (2004). Does Secrecy Equal Security? . *Limiting Access to Environmental Information*, Environmental Health Perspectives.

Danagoulian, S., Grossman, D. S., & Slusky, D. (2020). Office Visits Preventing Emergency Room Visits: Evidence from the Flint Water Switch. *Working Paper*.

Davis, A. (2002, May 30). *New Alarms Heat Up Debate On Publicizing Chemical Risks*. Retrieved from wsj.com: https://www.wsj.com/articles/SB1022720722479969000

Dean, T. J., & McMullen, J. (2007). Toward a theory of sustainable entrepreneurship: reducing environmental degradation through entrepreneurial action. *J. Bus. Ventur*, 50-76.

Eilperin, J. (2019, November 21). *Trump administration scales back safety rules adopted after deadly chemical explosion*. Retrieved from washingtonpost.com: https://www.washingtonpost.com/climate-environment/2019/11/21/trump-reverses-safety-rules-adopted-after-deadly-chemical-explosion/

entrepreneurship, T. k. (2009). Zoltan J. Acs; Pontus Braunerhjelm; David B. Audretsch; Bo Carlsson . *Small Business Economics volume*, 15-30.

Gibbons, B. (2022, September 13). *EPA will restore an Obama-era chemical disaster safety rule halted by Trump Administration*. Retrieved from Oilandgaswatch.org: https://news.oilandgaswatch.org/post/epa-will-restore-an-obama-era-chemical-disaster-safety-rule-but-advocates-say-it-doesnt-go-far-enough

Goldsmith-Pinkham, P., Gustafson, M., Lewis, R., & Schwert, M. (2021). Sea level rise exposure and municipal bond yields. *Working Paper*.

Hsu, P.-H., Li, K., & Tsou, C.-y. (2022). The Pollution Premium. *Working Paper*.

J.Willey, R. (2017). West Fertilizer Company fire and explosion: A summary of the U.S. Chemical Safety and Hazard Investigation Board report. *Journal of Loss Prevention in the Process Industries*, 132-138.

Jerch, R., Kahn, M. E., & Lin, G. C. (2020). Local public finance dynamics and hurricane shocks. *National Bureau of Economic Research*, Technical report.

Malen, J., & Marcus, A. (2017). Promoting clean energy technology entrepreneurship: the role of external context. *Energy Policy*, 7–15.

Mason, C., & Brown, R. (2013). Creating good public policy to support high-growth firms. *Small Bus. Econ.*, 211-225.

Muehlenbachs, L., Spiller, E., & C. Timmins. (2015). The Housing Market Impacts of Shale Gas Development. *American Economic Review*, 3633–59.

Murfin, J., & Spiegel, M. (2020). Is the risk of sea level rise capitalized in residential real estate? *Review of Financial Studies*, 1217–1255.

Nguyen, D., S. Ougena, S. Q., & Sila, V. (2021). Climate change risk and the cost of mortgage credit. *Working Paper*.

Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, 468-482.

Palucka, T. (2015). *DOING THE IMPOSSIBLE*. Retrieved from AmericanHeritage.com: http://web.archive.org/web/20081203124718/http://www.americanheritage.com/articles/magazine/it/

Shrivastava, P., & Kennelly, J. J. (2013). Sustainability and Place-Based Enterprise. *Organization & Environment*, 83-101.

Slavitt, E. M., Cote, G. D., & Hannah, G. (2003, December 1). *National Security vs. Public Disclosure: The War on Terrorism's Implications Upon Federal Emergency Planning and Right to Know Laws*. Retrieved from fedsoc.org: https://fedsoc.org/commentary/publications/national-security-vs-public-disclosure-the-war-on-terrorism-s-implications-upon-federal-emergency-planning-and-right-to-know-laws

Swanson, D., & Dunklin, R. (2013). *West Fertilizer was insured for only $1 million, a fraction of estimated losses.* Dallas: The Dallas Morning News.

The Associated Press. (2022, November 7). *Neighborhoods evacuated near burning Georgia chemical plant*. Retrieved from wfla.com: https://www.wfla.com/news/national/explosions-fire-prompt-evacuations-at-florida-chemical-plant/

United States Government Accountability Office. (2004). *Environmental Disclosure: SEC Should Explore Ways to Improve Tracking and Transparency of Information.* Washington DC: United States Government Accountability Office.

Vedula, S., York, J. G., & Corbett, A. C. (2019). Through the Looking-Glass: The Impact of Regional Institutional Logics and Knowledge Pool Characteristics on Opportunity Recognition and Market Entry. *Journal of Management Studies*, 1414-1451.

York, J. G., & Lenox, M. J. (2014). Exploring the sociocultural determinants of de novo versus de alio entry in emerging industries. *Strategic Management Journal*, 1930–1951.

York, J., & Venkataraman, S. (2010). The entrepreneur-environment nexus: uncertainty, innovation, and allocation. *J. Bus Ventur*, 449-463.

Zietsma, C., Ruebottom, T., & Shantz, A. S. (2018). Unobtrusive Maintenance: Temporal Complexity, Latent Category Control and the Stalled Emergence of the Cleantech Sector. *Journal of Management Studies*, 1242-1277.

References for Chapter 6

Acs, Z.J., Audretsch, D.B., Braunerhjelm, P., Carlsson, B., 2009. Knowledge spillover theory of entrepreneurship. Small Bus Econ 32, 15–30. https://doi.org/10.1007/s11187-008-9157-3

Agrawal, A., Hockerts, K., 2019. Impact investing: review and research agenda. J. Small Bus. Entrep. 0, 1–29. https://doi.org/10.1080/08276331.2018.1551457

Anderson, A.R., 1998. Cultivating the Garden of Eden: Environmental entrepreneuring. J. Organ. Chang. Manag. 11, 135–144. https://doi.org/10.1108/09534819810212124

Audretsch, D.B., Feldman, M.P., 1996. R&D Spillovers and the Geography of Innovation and Production. Am. Econ. Rev.

Audretsch, D.B., Keilbach, M., 2007. The theory of knowledge spillover entrepreneurship. J. Manag. Stud. 44, 1242–1254. https://doi.org/10.1111/j.1467-6486.2007.00722.x

Barber, B.M., Morse, A., Yasuda, A., 2021. Impact investing. J. financ. econ. 139, 162–185.

Baumol, W.J., 1996. Entrepreneurship: Productive, unproductive, and destructive. J. Bus. Ventur. 11, 3–22.

Bell, A., Fairbrother, M., Jones, K., 2019. Fixed and random effects models: making an informed choice. Qual. Quant. 53, 1051–1074. https://doi.org/10.1007/s11135-018-0802-x

Benedikter, R., Giordano, J., 2011. The Outer and the Inner Transformation of the Global Social Sphere through Technology: The State of Two Fields in Transition. New Glob. Stud. https://doi.org/10.2202/1940-0004.1129

Brown, L.A., 1975. The Market and Infrastructure Context of Adoption: A Spatial Perspective on the Diffusion of Innovation. Econ. Geogr. 51, 185. https://doi.org/10.2307/143117

Bruton, G.D., Ahlstrom, D., Li, H.L., 2010. Institutional theory and entrepreneurship: Where are we now and where do we need to move in the future? Entrep. Theory Pract. https://doi.org/10.1111/j.1540-6520.2010.00390.x

Cainelli, G., De Marchi, V., Grandinetti, R., 2015. Does the development of environmental innovation require different resources? Evidence from Spanish manufacturing firms. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2015.02.008

Chen, W., Tan, J., 2009. Understanding transnational entrepreneurship through a network lens: Theoretical and methodological considerations. Entrep. theory Pract. 33, 1079–1091.

Clark, G.L., 2012. From Corporatism to Public Utilities: Workplace Pensions in the 21st Century. Geogr. Res. 50, 31–46. https://doi.org/10.1111/j.1745-5871.2011.00701.x

Cohen, B., Muñoz, P., 2015. Toward a theory of purpose-driven urban entrepreneurship. Organ. Environ. 28, 264–285.

Cohen, B., Winn, M.I., 2007. Market imperfections, opportunity and sustainable entrepreneurship. J. Bus. Ventur. 22, 29–49. https://doi.org/10.1016/j.jbusvent.2004.12.001

Cojoianu, T., Clark, G.L., Hoepner, A.G.F., Pažitka, V., Wójcik, D., 2020a. Fin vs. tech: are trust and knowledge creation key ingredients in fintech start-up emergence and financing? Small Bus. Econ. https://doi.org/10.1007/s11187-020-00367-3

Cojoianu, T., Clark, G.L., Hoepner, A.G.F., Veneri, P., Wójcik, D., 2020b. Entrepreneurs for a low carbon world: How environmental knowledge and policy shape the creation and financing of green start-ups. Res. Policy 49. https://doi.org/10.1016/j.respol.2020.103988

Cojoianu, T., Hoepner, A., Lin, Y., 2021. Who are Impact Investors?, in: Academy of Management Proceedings. Academy of Management

Briarcliff Manor, NY 10510, p. 15007.

Colombelli, A., Quatraro, F., 2017. Green start-ups and local knowledge spillovers from clean and dirty technologies. Small Bus. Econ. 1–20. https://doi.org/10.1007/s11187-017-9934-y

Currie, J., Zivin, J.G., Mullins, J., Neidell, M., 2014. What do we know about short- and long-term effects of early-life exposure to pollution? Annu. Rev. Resour. Econ. 6, 217–247. https://doi.org/10.1146/annurev-resource-100913-012610

Dean, T.J., McMullen, J.S., 2007. Toward a theory of sustainable entrepreneurship: Reducing environmental degradation through entrepreneurial action. J. Bus. Ventur. 22, 50–76. https://doi.org/10.1016/j.jbusvent.2005.09.003

Demirel, P., Li, Q.C., Rentocchini, F., Tamvada, J.P., 2019. Born to be green: new insights into the economics and management of green entrepreneurship. Small Bus. Econ. 52, 759–771. https://doi.org/10.1007/s11187-017-9933-z

Dieperink, H., Nijkamp, P., 1987. Multiple Criteria Location Model for Innovative Firms in a Communication Network. Econ. Geogr. 63, 66–73.

Dijkstra, L., Poelman, H., Veneri, P., 2019. The EU-OECD definition of a functional urban area.

Doblinger, C., Surana, K., Anadon, L.D., 2019. Governments as partners: The role of alliances in U.S. cleantech startup innovation. Res. Policy. https://doi.org/10.1016/j.respol.2019.02.006

Feldman, M.P., Ozcan, S., Reichstein, T., 2019. Falling not far from the tree: Entrepreneurs and organizational heritage. Organ. Sci. https://doi.org/10.1287/orsc.2018.1222

Georgallis, P., Dowell, G., Durand, R., 2019. Shine on Me: Industry Coherence and Policy Support for Emerging Industries. Adm. Sci. Q. 64, 503–541. https://doi.org/10.1177/0001839218771550

Ghisetti, C., 2018. Smart Cities, Innovation and Sustainability: Which Role for Cities in Fostering “Green” Entrepreneurship?, in: Leal-Millan, A., Peris-Ortiz, M., Leal-Rodriguez, A. (Eds.), Sustainability in Innovation and Entrepreneurship: Policies and Practices for a World with Finite Resources. Springer. https://doi.org/10.1007/978-3-319-57318-2_1

Godfrey, C., Hoepner, A.G.F., Lin, M.-T., Poon, S.-H., 2020. Women on Boards and Corporate Scandals: Evidence From a Granger Style Reverse Causality Minimisation Procedure, SSRN Electronic Journal. Available at: https://ssrn.com/abstract=3522205.

Hsieh, C., Nickerson, J.A., Zenger, T.R., 2007. Opportunity discovery, problem solving and a theory of the entrepreneurial firm. J. Manag. Stud. 44, 1255–1277. https://doi.org/10.1111/j.1467-6486.2007.00725.x

Isaak, R., 2016. The making of the ecopreneur, in: Making Ecopreneurs. Routledge, pp. 63–78.

Malen, J., Marcus, A.A., 2017. Promoting clean energy technology entrepreneurship: The role of external context. Energy Policy 102, 7–15. https://doi.org/10.1016/j.enpol.2016.11.045

Martin, R., Sunley, P., 1998. Slow convergence? The new endogenous growth theory and regional development. Econ. Geogr. 74, 201–227. https://doi.org/10.3166/ges.7.129-154

Meek, W.R., Pacheco, D.F., York, J.G., 2010. The impact of social norms on entrepreneurial action: Evidence from the environmental entrepreneurship context. J. Bus. Ventur. https://doi.org/10.1016/j.jbusvent.2009.09.007

Moeen, M., Agarwal, R., 2017. Incubation of an industry: Heterogeneous knowledge bases and modes of value capture. Strateg. Manag. J. https://doi.org/10.1002/smj.2511

Moroz, P.W., Branzei, O., Parker, S.C., Gamble, E.N., 2018. Imprinting with purpose: Prosocial opportunities and B Corp certification. J. Bus. Ventur. https://doi.org/10.1016/j.jbusvent.2018.01.003

Mundlak, Y., 1978. On the pooling of time series and cross section data. Econom. J. Econom. Soc. 69–85.

OECD, 2010. Taxation, innovation and the environment, Taxation, Innovation and the Environment. Paris: OECD. https://doi.org/10.1787/9789264087637-en

Parker, S.C., Gamble, E.N., Moroz, P.W., Branzei, O., 2019. The Impact of B Lab Certification on Firm Growth. Acad. Manag. Discov. https://doi.org/10.5465/amd.2017.0068

Qian, H., Acs, Z.J., 2013. An absorptive capacity theory of knowledge spillover entrepreneurship. Small Bus. Econ. 40, 185–197. https://doi.org/10.1007/s11187-011-9368-x

Rennings, K., 2000. Redefining innovation - Eco-innovation research and the contribution from ecological economics. Ecol. Econ. https://doi.org/10.1016/S0921-8009(99)00112-3

Russo, M. V, 2001. Institutions, exchange relations, and the emergence of new fields: Regulatory policies and independent power production in America, 1978–1992. Adm. Sci. Q. 46, 57–86.

Schroeder, H., Burch, S., Rayner, S., 2013. Novel multisector networks and entrepreneurship in urban climate governance. Environ. Plan. C Gov. Policy 31, 761–768.

Schunck, R., Perales, F., 2017. Within- and between-cluster effects in generalized linear mixed models: A discussion of approaches and the xthybrid command. Stata J. https://doi.org/10.1177/1536867x1701700106

Scott, W.R., 1995. Institutions and Organizations: Foundations for Organizational Science, America.

Shane, S., Venkataraman, S., 2000. The Promise of Entrepreneurship as a Field of Research. Acad. Manag. Rev. 25, 217–226.

Shepherd, D.A., 2019. Researching the dark side, downside, and destructive side of entrepreneurship: It is the compassionate thing to do! Acad. Manag. Discov. 5, 217–220.

Vedula, S., Doblinger, C., Pacheco, D., York, J., Bacq, S., Russo, M., Dean, T., 2021. Entrepreneurship for the Public Good: A Review, Critique, and Path Forward for Social and Environmental Entrepreneurship Research. Acad. Manag. Ann.

Vedula, S., York, J.G., Corbett, A.C., 2018. Through the Looking-Glass: The Impact of Regional Institutional Logics and Knowledge Pool Characteristics on Opportunity Recognition and Market Entry. J. Manag. Stud.

Wooldridge, J.M., 2010. Econometric analysis of cross section and panel data. MIT press.

York, J.G., Lenox, M.J., 2014. Exploring the sociocultural determinants of de novo versus de alio entry in emerging industries. Strateg. Manag. J. 35, 1930–1951. https://doi.org/10.1002/smj.2187

York, J.G., O’Neil, I., Sarasvathy, S.D., 2016. Exploring Environmental Entrepreneurship: Identity Coupling, Venture Goals, and Stakeholder Incentives. J. Manag. Stud. 53, 695–737. https://doi.org/10.1111/joms.12198

York, J.G., Venkataraman, S., 2010. The entrepreneur-environment nexus: Uncertainty, innovation, and allocation. J. Bus. Ventur. 25, 449–463. https://doi.org/10.1016/j.jbusvent.2009.07.007

Yu, Z., Gibbs, D., 2020. Unravelling the role of green entrepreneurs in urban sustainability transitions: A case study of China’s Solar City. Urban Stud. 57, 2901–2917.

Zalakeviciute, R., Alexandrino, K., Mejia, D., Bastidas, M.G., Oleas, N.H., Gabela, D., Chau, P.N., Bonilla-Bedoya, S., Diaz, V., Rybarczyk, Y., 2021. The effect of national protest in Ecuador on PM pollution. Sci. Rep. 11, 1–12. https://doi.org/10.1038/s41598-021-96868-6

Zhang, Xin, Chen, X., Zhang, Xiaobo, 2018. The impact of exposure to air pollution on cognitive performance. Proc. Natl. Acad. Sci. U. S. A. 115, 9193–9197. https://doi.org/10.1073/pnas.1809474115

Zheng, S., Wang, J., Sun, C., Zhang, X., Kahn, M.E., 2019. Air pollution lowers Chinese urbanites' expressed happiness on social media. Nat. Hum. Behav. 3, 237–243. https://doi.org/10.1038/s41562-018-0521-2

Zivin, J.G., Neidell, M., 2012. The impact of pollution on worker productivity. Am. Econ. Rev. 102, 3652–3673. https://doi.org/10.1257/aer.102.7.3652

Appendix A: Mapping Algorithm