NBER WORKING PAPER SERIES

IMPORTING THE OPIOID CRISIS? INTERNATIONAL TRADE AND FENTANYL OVERDOSES

Timothy J. Moore
William W. Olney
Benjamin Hansen

Working Paper 31885
http://www.nber.org/papers/w31885

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
November 2023, Revised July 2024

We thank Abby Alpert, Jillian Carr, Jon Davis, Bill Evans, Manasi Deshpande, David Hummels, Zubin Jelvah, Bob Kaestner, Ethan Lieber, Jens Ludwig, Steve Machin, Ed Rubin, Dan Sacks, Molly Schnell, Kosali Simon, and Jonathan Zhang for helpful comments, as well as conference and seminar participants at the Chicago/LSE Conference on the Economics of Crime and Justice, Collegio Carlo Alberto, Columbia University, Cornell University, Elon University, Florida Applied Micro Virtual Seminar, FREIT Empirical Trade Online Seminar, George Washington University, H2K Workshop in International Economics, NBER Summer Institute Economics of Crime Meeting, NBER Health Economics Spring Meeting, Melbourne Trade Workshop, Mid-Midwest Applied Microeconomics Conference, Monash University, San Diego State University, Stony Brook University, University of Chicago, University of Cologne, University of Colorado at Boulder, University of Hawaii, University of Maryland at College Park, University of Missouri, University of New Hampshire, University of Texas at El Paso, Vanderbilt University, Williams College, and the Workshop on the Economics of Risky Behavior. Moore gratefully acknowledges financial support from an Australian Research Council Discovery Early Career Research Award (DE170100608). The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

Importing the Opioid Crisis? International Trade and Fentanyl Overdoses
Timothy J. Moore, William W. Olney, and Benjamin Hansen
NBER Working Paper No. 31885
November 2023, Revised July 2024
JEL No. F1,F6,I1,K4

ABSTRACT

The U.S. opioid crisis is now driven by fentanyl, a powerful synthetic opioid that currently accounts for 90% of all opioid deaths. Fentanyl is smuggled from abroad, with little evidence of how this happens. We find a positive relationship between state-level imports and drug overdoses, which is consistent with fentanyl smuggling occurring via legal trade flows. This relationship accounts for 14,000-20,000 deaths per year, and is not explained by geographic differences in "deaths of despair," general demand for opioids, or import competition. Our results suggest that fentanyl smuggling via imports is pervasive and a key determinant of recent opioid problems.

Timothy J. Moore
Department of Economics
Purdue University
403 W. State Street
West Lafayette, IN 47907
and NBER
moore839@purdue.edu

William W. Olney
Department of Economics
Williams College
24 Hopkins Hall Dr
Williamstown, ma 01267
wwo1@williams.edu

Benjamin Hansen
Department of Economics
1285 University of Oregon
Eugene, OR 97403
and NBER
bchansen@uoregon.edu

1 Introduction

We are experiencing the worst drug overdose epidemic in U.S. history, with approximately 110,000 overdose deaths in 2022. Opioids account for around 84,000 of those deaths, driving a sixfold increase in drug overdose deaths since 2000. Many more Americans now die each year from opioid overdoses than from gunshots, traffic accidents, homicides, or liver disease.[1] The opioid crisis has also increased social problems, including family dislocation, unemployment, and infectious disease rates (e.g., Powell et al. 2019; Buckles et al. 2022; Mukherjee et al. 2023).

The U.S. opioid crisis has evolved in three phases. This is apparent in Figure 1, which shows fatal overdoses due to different opioids from 1999 to 2022. In the first phase, the introduction and aggressive marketing of OxyContin and other powerful prescription opioids led to a tripling of prescription opioid deaths in the 2000s, to around 11,000 deaths by 2010 (Alpert et al. 2022; Arteaga and Barone 2023). While policy and market responses around 2010 halted this rise, they stimulated demand for heroin, a powerful illicit opioid long available in the U.S. (Alpert et al. 2018; Evans et al. 2019). This second phase was characterized by a quadrupling of heroin deaths between 2010 and 2015, and heroin becoming the opioid with the highest death rate. Then fentanyl – a synthetic opioid over 50 times more potent than heroin – emerged as both a cheap adulterant and a substitute to heroin (Pardo et al. 2019). The third phase of the opioid crisis has involved the dramatic rise of fentanyl overdose deaths, with a 29-fold increase between 2012 and 2022 and around 340,000 fentanyl-related deaths over this period. There were 76,000 fentanyl deaths in 2022 alone, representing 90% of all opioid overdose deaths (Ahmad et al. 2023). Fentanyl overdoses are now the leading cause of death for Americans aged 18–49 years.

Prominent studies document the spatial persistence of opioid problems (e.g., Alpert et al. 2018; Evans et al. 2019; Alpert et al. 2022). However, fentanyl has changed the geography of the opioid crisis (Zoorob 2019). This is apparent in Figure 2, which shows states' opioid overdose rates four years before and after fentanyl deaths began rising in 2013. The highest opioid overdose rates are initially in the Appalachian region and Southwest, before shifting towards the Midwest and Northeast. The other panels of Figure 2 show that these changes are due to fentanyl.[2] This suggests that factors related to fentanyl supply are now driving the opioid crisis.

[1] Authors' calculations using the Centers for Disease Control and Prevention (CDC) Multiple Cause of Death Files described in Section 3, and CDC overdose data (Ahmad et al. 2023). Annual deaths from these other causes range from 26,000 (homicides) to 57,000 (liver disease). These data are also used to create Figures 1 and 2.

[2] Non-fentanyl opioid overdoses are still highest in Appalachia and the Southwest; the 50-state Spearman rank correlation between 2009 and 2017 is 0.65. In contrast, the equivalent correlation for fentanyl overdoses is 0.13.

Illicit fentanyl is produced abroad. The Drug Enforcement Administration (DEA) believes it is often smuggled into the U.S. across the Southwest border or sent directly from China to consumers in the mail (DEA 2019; 2021). However, the geographic concentration of fentanyl deaths in the Northeast and Midwest suggests there are other channels. In this paper, we examine whether legal trade facilitates fentanyl smuggling by estimating the state-level relationship between international imports and fentanyl overdose rates.[3] This empirical approach is informed by existing evidence that drug problems disproportionately occur near key smuggling locations.[4]

To do this, we use substantial variation in imports across states. For example, the value of imports per resident in the five highest-importing states is more than seven times larger than in the five lowest-importing states, and neighboring states often have large differences in imports. Importantly, research suggests that import patterns reflect longstanding comparative advantages, agglomeration, and broad economic characteristics, rather than factors strongly linked to opioid problems (Wolf 2000; Hillberry and Hummels 2008; Dvorkin and Shell 2016).

Using CDC mortality data and U.S. Census import data for 2008-2020, we descriptively show that states with above- and below-median imports have similar drug overdose trends in the first five years of the sample period (2008-2012). Their drug overdose rates diverge sharply thereafter; by 2018, drug overdose deaths rates are 41% higher in the states with above-median import levels than in the below-median states. These differences persist through 2020.

Our regression estimates confirm that there is a positive relationship between states' imports and drug overdose death rates from 2013. To reduce endogeneity concerns, we use 2008 import values, as they predate the rise of fentanyl by several years. Over the 2017-2020 period, we estimate that 10% more imports per resident is associated with a 4.4% increase in the opioid death rate and a 7.5% increase in fentanyl death rate. This translates to about 14,000-20,000 deaths per year. There is a similar relationship between imports and the amount of fentanyl seized by local police, which is a complementary measure of drug market activity.[5]

Appendix Figure A1 shows further breakdowns by opioid type. Figure A2 shows there is more spatial persistence in opioid overdoses over an earlier time period of similar length (2001-2009) than between 2009 and 2017.

[3]All of our data are available at the state level, which has the benefit of being the relevant geographic unit of many opioid-related policies (e.g., drug laws; prescription drug monitoring programs; and naloxone access).

[4]A positive relationship between smuggling locations and drug problems only requires that there are positive costs of transporting fentanyl within the U.S. Distributing drugs involves the risk of arrest by law enforcement, and of theft and violence by other parties. These are minimized by relying on personal connections, resulting in a "cottage industry" structure (Bichler et al. 2017). This explains documented relationships between smuggling locations and illicit drug problems in a variety of settings (Evans et al. 2016, Evans et al. 2019, Moore et al. 2005).

[5]The seizure data come from state and local forensic laboratories, which carefully measure fentanyl. Moreover, the number of fentanyl seizures are not affected by changes in state policies that may affect the relationship

Further results suggest that the relationship between legal imports and fentanyl problems is not driven by other factors. First, we show that import patterns are unrelated to other causes of death, including non-drug suicides and alcoholic liver disease, which are "deaths of despair" that occur in similar places to drug overdoses and are thought to have common determinants (Case and Deaton 2015; 2020). Second, we control for additional state characteristics that potentially affect the demand or supply of fentanyl, including (i) import competition from China and elsewhere, which has adversely affected local labor markets (Autor et al. 2013) and been linked to drug overdoses (Pierce and Schott 2020); (ii) the presence of "triplicate" pharmaceutical regulations in the 1990s, which affected the marketing of OxyContin and subsequent opioid problems (Alpert et al. 2022); (iii) the introduction of modern prescription drug monitoring programs (Buchmueller and Carey 2018); (iv) the value of exports, an alternate measure of trade activity that should not facilitate smuggling; (v) the amount of fentanyl used legally in medical procedures, which may be diverted from healthcare (Walters 2018); (vi) geographic differences in heroin and how easily they can be mixed with fentanyl; and (vii) states' proximity to the Mexican and Canadian borders and their border activity, which may make fentanyl smuggling easier (Pardo et al. 2019). None of these factors meaningfully affect the nature of the relationship between legal imports and fentanyl overdose rates.

We focus on specific import characteristics to understand how legal trade is being used to smuggle fentanyl. Results show that both the overall volume of imports and specific import characteristics, such as country of origin, mode of transport, and product type, are associated with fentanyl problems. U.S. government agencies often focus on fentanyl smuggling from China and Mexico (Government Accountability Office (GAO) 2018; DEA 2021; Stein et al. 2023). Perhaps, as a result of this attention, we find that imports from these two countries are only weakly related to fentanyl overdoses. Instead, our results indicate that the use of imports to smuggle fentanyl is more diffuse and pervasive than currently appreciated. These findings also suggest that smugglers account for the endogeneity of enforcement when deciding how to smuggle fentanyl into the U.S., and that broader data-driven screening efforts may save lives.[6] To that end, we demonstrate how a machine-learning approach that allows for interactions in import characteristics can further help to illuminate smuggling patterns and set interdiction priorities.

between consumption and fatal overdoses (e.g., naloxone access).

[6]Consistent with rational models of crime (Becker 1968; Ehrlich 1973), there is evidence of strategic behavior and learning by criminals in many settings, including to avoid detection of drug trafficking (Dell 2015); car theft (Di Tella and Schargrodsky 2004); speeding (Eeckhout et al. 2010); and drunk driving (Banerjee et al. 2019).

We contribute to a growing literature that focuses on understanding and combating the opioid crisis.[7] However, a recent review of economic studies on the opioid crisis that covered approximately 150 papers identified only two papers studying fentanyl (Maclean et al. 2022). In one, Miller (2020) examines dark-web illicit fentanyl prices, while in the other, Powell and Pacula (2021) show that the 2010 abuse-deterrent reformulation of OxyContin increased fentanyl overdose deaths.[8] We provide novel insights into this understudied market.

We also contribute to understanding the distributional implications of trade. Recent evidence shows that import competition from China has adversely affected U.S. manufacturing and workers in particular labor markets (Autor et al. 2013; Pierce and Schott 2016). This has led to worse physical and mental health outcomes in these areas, including more drug overdoses (Charles et al. 2019; Pierce and Schott 2020). Rather than focusing on how *import competition* affects overdoses via opioid demand, our results indicate that *imports* increase opioid problems by providing fentanyl smuggling opportunities. Ultimately, we show that smuggling via imports is playing an important role in shaping the fentanyl crisis and generating mortality costs that represent a meaningful fraction of the welfare gains from trade.[9]

There is research examining how legal trade aids illicit activities. Historically, most documented smuggling was related to evading tariffs and duties (e.g., Bhagwati 1964; Fisman and Wei 2004), although research has also examined how trade is used to smuggle illicit goods (Fisman and Wei 2009), including illicit drugs (Russo 2014; Freylejer and Orr 2023).[10] Several factors have been shown to influence the returns to smuggling, including shipping costs (Moyle 2014); international networks (Rotunno and Vézina 2013), and local corruption levels (Fisman and Wei 2009). Across these settings, theory consistently predicts smuggling is easier with higher trade flows (Pitt, 1981; Norton, 1988). In line with this research, we find that U.S. imports are being used to smuggle sizeable amounts of a potent illicit drug.

[7]For example, recent papers provide insights into the role of marketing OxyContin (Alpert et al. 2022; Arteaga and Barone 2023); the consequences of its abuse-deterrent reformulation (Alpert et al. 2018; Evans et al. 2019); physician behavior (Schnell 2022) and training (Schnell and Currie 2018); emergency room practices (Eichmeyer and Zhang 2022); prescription drug monitoring programs (Buchmueller and Carey 2018; Balestra et al. 2021); prescribing rules (Sacks et al. 2021); and local economic conditions (Hollingsworth et al. 2017; Charles et al. 2019).

[8]Information on the fentanyl market is sparse, generally coming from law enforcement reports (e.g., DEA 2019; 2021); journalistic accounts (Westhoff 2019); and analysis of broad indicators (e.g., Pardo et al. 2019).

[9]At a value of statistical life of $10 million (Banzhaf 2022; Kniesner and Viscusi 2019), a back-of-the-envelope calculation suggests the mortality consequences of 14,000-20,000 deaths per year are valued at $140-200 billion. This is on the order of 20% of the welfare gains from trade (Costinot and Rodriguez-Clare, 2018).

[10]Russo (2014) and Freylejer and Orr (2023) find evidence consistent with cocaine and methamphetamine being smuggled via imports. Several other papers study drug trafficking, including how gangs use sea and land (Dell 2015; Mejia and Restrepo 2016; Hidalgo et al. 2022) and how ethnic networks aid smuggling (McCully, 2023).

Finally, we add to the growing field of forensic economics. Research in this field, which includes most of the papers on trade and smuggling cited above, uses a combination of theory and observational data to uncover hidden behavior (Zitzewitz 2012). Seizing illicit drugs inherently depends on where law enforcement agencies choose to search. By using well-measured administrative data available for all of the U.S., we show how statistical inferences provide insights into illicit drug smuggling that are different to those emphasized publicly by law enforcement.

Our findings point to the potential benefits of better screening imports. Policy makers are aware of the vulnerability of imports, with a 2019 White House advisory to the shipping industry requesting they protect their supply chains against fentanyl smuggling.[11] However, it focused on smuggling from China and Mexico, while our results show that a variety of import flows are related to fentanyl deaths. This indicates that more resources should be devoted to general customs screening efforts. For example, our estimates imply that moderating the relationship between imports and fentanyl overdoses by even 20% could save around 2,800-4,000 lives per year and be valued at around $28-40 billion (Banzhaf 2022). These gains are large, especially considering that the entire U.S. Customs and Border Protection (CBP) budget is around $15 billion for 2023, with a minority related to screening imports.[12]

Our findings may also be useful for targeting drug policy resources. States with high levels of imports per resident have had more fentanyl problems than elsewhere. This has likely increased the demand for drug treatment, policing, medical care, and family support. The rationale for assisting these residents is analogous to the longstanding recognition that workers and communities negatively affected by trade deserve extra support (Baicker and Rehavi 2004). At a minimum, understanding the role of new supply-side factors in changing the distribution of opioid problems can help to better address this large and growing public health crisis.

2 Background

2.1 Fentanyl

Fentanyl is a potent painkiller discovered in 1959 by Paul Janssen, a Belgian chemist. It is 50-100 times more powerful than morphine, and uses relatively inexpensive chemical precursors. It was approved to be used as an anesthetic in Europe in 1963 and in the U.S. in 1968, and has consistently been used in major surgeries since. Fentanyl analogs, which use a similar chemical

[11] trumpwhitehouse.archives.gov/wp-content/uploads/2019/08/Fentanyl-Advisory-Movement-Tab-C.pdf.
[12] See https://www.dhs.gov/dhs-budget.

structure to fentanyl and mimic its pharmacological effects, were developed soon after.[13] Since the 1990s, fentanyl and fentanyl analogs have been used in transdermal patches or lozenges to treat chronic pain, typically for advanced cancer patients. They have also been used by veterinarians as a large-animal anesthetic (Stanley 2014; Pardo et al. 2019).

Fentanyl stiffens the muscles that control breathing, increasing the risks of respiratory failure and death. Respiratory failure occurs in a similar way to other opioids, although the potency of fentanyl heightens these risks. Medical fentanyl was misused early in the opioid crisis, and there were 1,000-3,000 fentanyl overdose deaths each year between 2002 and 2012 (Stanley 2014). However, the medical use of fentanyl has decreased markedly in recent years (Stein et al. 2023).

2.2 Illicitly manufactured fentanyl

The recent rise in fentanyl overdoses is attributed to illicitly manufactured fentanyl. Since the 1970s, there have been documented cases of illicit fentanyl being distributed in the U.S. These were local instances that were typically traced back to a highly skilled, domestically based chemist working for an organized crime organization (Pardo et al. 2019). However, in the last decade, there has been a surge in the supply of illicit fentanyl. The increase in fentanyl overdose deaths shown in Figure 1 highlights its widespread availability in the U.S.[14]

Illicit fentanyl is produced overseas, primarily in China. Pardo et al. (2019) identify seven reasons for the surge in fentanyl supply. First, new "cookbook" methods made it easier to synthesize fentanyl and its analogs. There has been a diffusion of these methods, which use widely accessible equipment and chemicals. Second, the new techniques made it possible for minimally trained technicians to make fentanyl. This change from "chemists" to "cooks" substantially expanded who could make fentanyl. Third, analogs have broadened the methods and ingredients used to make fentanyl-like drugs, making regulation more difficult. Fourth, there has been a lack of regulatory control of ingredients to make fentanyl, many of which can be used to produce legitimate pharmaceuticals (Felbab-Brown 2022). Fifth, internet and dark web sales have expanded distribution networks. Sixth, the growth of e-commerce and inbound packages made it easier and cheaper to smuggle fentanyl. Seventh, there was a large stock of existing opioid users that created demand for fentanyl. Apart from pre-existing opioid demand, these reasons are likely to be exogenous to the characteristics of particular U.S. states or regions.

[13] There are now hundreds of fentanyl analogs; common ones include sufentanil, alfentanil, and carfentanil.

[14] As an alternative indicator, Pardo et al. (2019) note that CBP fentanyl seizures went from a bulk weight of one kilogram in 2013 to one metric ton in 2018, a thousand-fold increase over a five-year period.

China has the second-largest pharmaceutical industry – after the U.S. – and there is cheap access to key ingredients, equipment, and technicians. The Chinese government was slow to ban fentanyl precursors and analogs, so supply developed in a quasi-legal environment. Even after recent bans, there are concerns that China lacks the capacity to enforce them (Felbab-Brown 2022). There is also believed to be a growing diversification of illicit fentanyl production, with the DEA highlighting production in India and Mexico (with Chinese producers providing precursors to Mexican gangs) (DEA 2021). There is little evidence of production in the U.S., perhaps because the two key precursors for fentanyl became controlled substances by 2008, well ahead of similar actions by the United Nations in 2017 and China in 2018 (Pardo et al. 2019).

2.3 Illicit fentanyl trafficking and distribution

U.S. government agencies emphasize smuggling directly from China using mail and packages, and gangs smuggling fentanyl across the Mexican border through legal ports of entry and over land. For example, the DEA's *2019 National Drug Threat Assessment* (DEA 2019) states:

> The two primary sources of the fentanyl are Mexico and China, where drug traffickers produce fentanyl and other synthetic opioids in clandestine operations. Fentanyl is smuggled into the United States across the SWB [Southwest Border] as well as through international mail and express consignment shipping services, primarily in powder and counterfeit pill form...(p.9)

The largest number of fentanyl seizures do occur at the Southwest Border, and current White House diplomacy and funding requests related to fentanyl trafficking are focused on Mexican gangs and security at the Southwest Border (Pardo et al. 2019; CBP 2024).

However, there is a great deal of uncertainty about how fentanyl is smuggled into the U.S. Its potency means that commercial quantities can be concealed inside many different goods. For example, law enforcement has seized fentanyl hidden in imports of pharmaceuticals, cosmetics, computer keyboards, ovens, coffee makers, and industrial equipment (DEA 2019; CBP 2023). Fentanyl has also been seized in goods coming from many countries other than China and Mexico, including Belgium, Canada, the Dominican Republic, Estonia, Fiji and Taiwan (Australian Federal Police 2022; CBP 2023). Moreover, many other countries face their own challenges around stopping fentanyl smuggling.[15]

There are puzzling differences between the location of major fentanyl seizures and where fentanyl problems occur. The DEA and CBP seize large amounts of fentanyl, mostly at the

[15] As examples, Mexican gangs and Chinese traffickers have travelled to Europe to establish smuggling ventures, and illicit fentanyl labs have been discovered in Europe (Felbab-Brown 2022). Sweden was slow to regulate fentanyl analogs, resulting in legal online markets (Moeller and Svensson 2021). Australian authorities have discovered large shipments of fentanyl in imports, including in imports from Canada (Australian Federal Police 2022).

Southwest Border (Pardo et al. 2019; DEA 2021).[16] Yet, as shown in Figure 2, fentanyl deaths are highest in the Midwest and Northeast.[17] Given that drug problems are more likely to occur near smuggling locations, this suggests that authorities currently miss a substantial amount of fentanyl smuggling.[18] Moreover, opioid demand was high in the Southwest prior to the fentanyl surge, making demand-side factors unlikely to account for these patterns. Instead, it suggests that fentanyl seizures may be highly endogenous to enforcement efforts, and that fentanyl smuggling into the Midwest and Northeast may be more common than currently appreciated.

2.4 Import security, customs screening, and drug detection

CBP is responsible for monitoring and regulating goods entering the U.S. They are tasked with facilitating the flow of goods; collecting customs revenues and enforcing trade laws; and preventing the entry of harmful and illegal items. CBP deals with the inherent tensions between these goals by collecting information about cargo ahead of its arrival in order to evaluate potential trade and security risks, and then focusing enforcement efforts on imports deemed to be high risk. Most information is collected electronically, and CBP has programs that expedite customs processes for frequent importers deemed trustworthy or low risk (McNicholas 2016).

Containers have security seals affixed at the point of loading and removed at its final destination. There are strict policies and protocols, and seals generally include GPS tracking, unique identifiers, and other security features to prevent tampering (McNicholas 2016). Containers that arrive at port and are then moved inland retain their seals through to where the container is unpacked (known as the port of unlading) (McNicholas 2016).[19]

Customs screening occurs in several ways. High-risk shipping containers are often screened before entering the U.S. using large-scale X-ray and gamma ray machines, as well as radiation detection devices.[20] Similar screening devices operate at U.S. ports of entry, including rail and

[16]The DEA seized 79 million pills and a total of 13,176 kg. (29,048 lb.) of impure fentanyl in 2023 (DEA 2024).

[17]The DEA understands these patterns; it includes such figures in its documents (e.g., DEA 2019; 2021). Also note that local police seizures of fentanyl, which we use in the paper, are also highest in the Midwest and Northeast.

[18]Criminology and ethnographic research consistently finds drug trafficking within the U.S. to largely be a "cottage industry" that involves small, connected groups of people; large, hierarchically-organized distribution networks are rare (Bichler et al. 2017). Economics research has documented a proximity between drug problems and known smuggling locations. For instance, crack cocaine arrived first in states close to key smuggling locations (Evans et al. 2016); the proximity to Florida's "pill mills" affected the size of oxycodone problems (Evans et al. 2019); and heroin prices are lowest near key smuggling locations in Australia (Moore et al. 2005).

[19]For details, see `www.cbp.gov/sites/default/files/documents/rc_security_profile_overview_3.pdf`.

[20]Since the September 11 terrorist attacks, the U.S. has developed bilateral agreements other nations to place CBP officers at foreign ports and screen shipping containers before they are placed on vessels destined for the United States. This program, known as the "Container Security Initiative" involves 35 countries and 61 ports

truck customs facilities, and for air cargo at departing airports. Physical searches of U.S. imports also occur at both imports' ports of departure and arrival, and sometimes include dogs and field testing for drugs, as well sending samples for lab testing. In recent years, the U.S. Postal Service has been required to transmit data on international mail shipments to CBP and there has been more scanning of international mail and packages coming into the U.S. (GAO 2018; 2022).

While fentanyl and its analogs are found using these methods, they have limitations. X-rays and other screening devices cannot see through some packaging types; many chemical screening devices do not detect fentanyl at low purity levels; drug detection depends on a library of "drug signatures" that may miss novel analogs; and both field and lab testing for drugs is limited (GAO 2018). In addition, while CBP has centralized intelligence officials that use their seizure data to inform their drug interdiction efforts, the seizure data has been of poor quality and reviews highlight the lack of systemic approaches to allocating resources or evaluating outcomes (GAO 2018; 2022). To our knowledge, there is no empirical evidence on fentanyl detection probabilities in U.S. imports, and a general lack of information on the effectiveness of customs screening.

3 Data

3.1 Mortality data

Our data are from the National Vital Statistics System's Multiple Cause of Death files, which include all deaths in the U.S. We use a restricted-access version for 1999-2020 that identifies each decedent's state of residence. We follow Centers for Disease Control and Prevention (CDC) coding to identify and categorize drug overdose deaths (Ahmad et al., 2023).[21] This allows us to identify specific opioids: heroin has its own drug identification code, while "natural opioid analgesics" is mainly oxycodone and "synthetic opioid analgesics other than methadone" is almost entirely fentanyl and its analogs (Slavova et al., 2019). We also use the same data to create state-level counts of other causes of death for our placebo analyses.[22]

Coroners or medical examiners generally determine the cause of death and complete death

that collectively account for approximately 80% of containerized imports into the U.S.

[21]Deaths are coded using International Classification of Disease, 10th Revision (ICD-10). Drug overdoses use underlying cause of death codes X40–X44, X60–64, X85, or Y10–Y14. Drug identification codes identify the presence of any opioids (T40.0-T40.4, T40.6) and specific opioids: heroin (T40.1); oxycodone and other natural opioid analgesics (T40.2); and fentanyl and other synthetic opioid analgesics (T40.4).

[22]ICD-10 underlying-cause-of-death codes are used to identify deaths from heart disease (I00-I09, I11, I13, I20-I51); lung cancer (C33-C34); motor vehicle accidents (V02–V04, V09.2, V12–V14, V19, V20–V80, V81.1, V82.1, V83–V87, V89.2); non-drug suicide (U03, X60-X84, Y87.0 and no drug identification codes); and alcohol cirrhosis (K70). These groupings match CDC classifications; see `https://wonder.cdc.gov/ucd-icd10-expanded.html`.

certificates. There are inconsistent approaches to drug testing and completing death certificates, leading to opioid overdoses being under-reported and misclassified (Slavova et al. 2019, Drake and Ruhm 2023). Given these concerns, we will report broad measure of drug overdoses and consider the potential role of misreporting when interpreting the results based on specific opioids.

3.2 Trade data

Our trade data are from the U.S. Census' Trade Online portal.[23] These are primarily compiled from documents legally required to be filed with U.S. Customs and Border Protection for imports, exports, warehouse withdrawals, and activities in Foreign Trade Zones.

We use annual data on imports for 2008-2020 based on the "state of destination" code, which identifies imports' intended final destination based on the documentation filed upon entry to the U.S. This code, which does not include the District of Columbia, is available from 2008. The value of imports to each state is reported by country of origin; product category (which is categorized using the North American Industry Classification System (NAICS)); and mode of transport (air transport, sea transport, and other modes).[24] International mail and packages are included, although they are not assigned a method of transportation (neither are imports coming via rail or road from Canada and Mexico). Information on imports valued at less than $2,000 does not have to be filed, although the Census imputes these from sources including automated electronic filings made by importers and package data provided by courier companies. Weight is only reported for imports designated as coming via air or sea.[25]

Our primary measure is the real value of all imports except oil and gas, which are generally imported using specialized ships and pipelines, rather than in shipping containers or packages.[26] We use other measures in robustness exercises, and information on the origin, method of transport, and type of product to examine heterogeneous effects and understand smuggling routes. We also use state-level data on the real value of exports in placebo analyses.[27]

[23] Available at `https://usatrade.census.gov/`.

[24] The value of goods imported is the amount appraised by U.S. Customs and Border Protection, which is generally the price paid or payable when sold (excluding import duties, freight, insurance, and other charges incurred in bringing the merchandise to the U.S.). We use U.S. Bureau of Economic Analysis Imports of Goods price series to convert values to 2022 dollars (available at: `https://fred.stlouisfed.org/series/A255RD3Q086SBEA`).

[25] The weight of mail and packages is not included even if they are arrive by air or sea. Weight, which is measured in kilograms, is gross and includes "the weight of moisture content, wrappings, crates, boxes, and containers (other than cargo vans and similar substantial outer containers)." For more information about these and other data characteristics, see *The Guide to the U.S. International Trade Statistical Program* (`https://www.census.gov/foreign-trade/guide/sec2.html`). Note that imports' final destination is not available at a sub-state level.

[26] Oil and gas imports (NAICS 211) represent 12% of the value of imports. We also provide estimates using a measure that includes oil and gas imports.

[27] We convert to 2022 dollars using the U.S. Bureau of Economic Analysis Exports of Goods price series (available

3.3 Forensic law enforcement data from drug seizures

The DEA's National Forensic Laboratory Information System (NFLIS) provides a compilation of data on drugs seized by police that are sent to the forensic laboratories for testing. Laboratories provide the data voluntarily to the NFLIS. It currently includes data from 50 state systems and 109 local or municipal laboratories, and is estimated to cover more than 98% of drug cases submitted to U.S. forensic laboratories (Pitts et al. 2023).

We use this annual state-level seizure data from the NFLIS annual reports to complement our mortality data.[28] The number of drug reports in a state represents the number of times that drug has been identified in cases submitted to forensic laboratories in the NFLIS. When multiple drugs are identified, the case contributes to the reports for each drug; therefore, the number of drug reports exceeds the number of cases submitted for forensic analysis. There is no information on drug combinations (e.g., the number of times a substance contained both fentanyl and heroin). We use data for 2010-2020, as data in NFLIS reports have been statistically adjusted to take account of reporting and sampling issues since 2010 (Pitts et al. 2023). We focus on annual state-level counts of fentanyl, fentanyl analogs, heroin, and oxycodone.

These data are not necessarily representative of the number of drugs in a state or even the number of drugs seized by police, as they depend on policing operations and whether a seizure was tested by a forensic laboratory. Many seizures are not sent to laboratories and some seizures sent are not tested, for reasons such as charges being dismissed; a defendant pleading guilty; or no defendant being identified (Pitts et al., 2023). Despite these limitations, these data provide a complementary measure of drug activity at the state level.[29]

3.4 Other data

We use several data sets to create annual state-level demographic and economic variables for the 2008-2020 period. Population data from Census Population Estimates are used to construct per-capita rates for several variables, including drug overdoses, imports, and police drug seizures.[30] We use the American Community Survey to calculate annual state population shares by sex, race/ethnicity, and age (Ruggles et al. 2023). We also use labor force participation and

at: `https://fred.stlouisfed.org/series/A253RD3Q086SBEA`).

[28]Available at: `https://www.nflis.deadiversion.usdoj.gov/`

[29]Criminal justice data from sources like the Uniform Crime Reporting Program and National Incident-Based Reporting System are not useful for our purposes, as they provide little information about specific drugs and have inconsistent geographic coverage.

[30]We use the compilation by the National Cancer Institute's Surveillance, Epidemiology and End Results (SEER) program `https://seer.cancer.gov/popdata/`.

unemployment rates from the Bureau of Labor Statistics' Local Area Unemployment Statistics, and real Gross Domestic Product from the Bureau of Economic Analysis.[31].

Other data sets are used to measure four time-varying state-level factors that may affect the demand or supply of fentanyl during our sample period. First, we use state-level data on the legal supply of fentanyl from the DEA's Automation of Reports and Consolidated Orders System (ARCOS).[32] Second, we use information from the RAND/USC Schaeffer OPTIC database on the enactment of prescription drug monitoring programs, which are centralized prescription databases that have been shown to affect opioid problems (e.g, Buchmueller and Carey 2018).[33] Third, to examine the role that the "China shock" may play in influencing our results, we measure import competition using the common approach of calculating a state's exposure to national industry-level imports in a given year based on their share of industry employment in a pre-sample year (Autor et al. 2013).[34] Finally, to account for drug smuggling via border crossings, we use annual statistics from the Bureau of Transportation Statistics on inbound border crossings by state and year at the U.S.-Canada and U.S.-Mexico borders.[35]

3.5 Summary statistics

Combining of these data sources results in a balanced panel of 50 states. All of the variables are available annually throughout the 2008-2020 period, except for police drug seizure rates from the NFLIS, which begin in 2010. Summary statistics for the key mortality, trade and seizure variables are provided in Appendix Table A1.

All of the key drug overdose and import measures have positive values throughout the sample period. We will use the natural log of both our outcome variables and import measures in our regressions, which deals with the positive skewness present in these data and allows us to interpret our estimates as elasticities. The positive values mean that no adjustments are required to deal with zero values, which is important given that methods to deal with zero values can

[31]The BLS data can be found at https://www.bls.gov/lau/data.htm and the BEA data can be found at https://www.bea.gov/data/gdp/gdp-state

[32]Manufacturers and distributors are required to report fentanyl transactions in grams. We use ARCOS annual reports, available at `https://www.deadiversion.usdoj.gov/arcos/`. ARCOS data have been used extensively in economic research (e.g. Alpert et al. 2022; Arteaga and Barone 2023)

[33]Available at: `https://www.rand.org/health-care/centers/optic/resources/datasets.html`.

[34]The national 6-digit NAICS industry import data comes from the U.S. Census via Peter Schott's webpage (Schott 2008), and the pre-sample state industry employment shares are calculated for 2000 using data from the County Business Patterns dataset produced by the U.S. Census (available at: `https://www.census.gov/programs-surveys/cbp/data/datasets.html`.)

[35]We focus on total border crossings, which occur by car, bus, train, or on foot: `https://www.bts.gov/browse-statistical-products-and-data/border-crossing-data/border-crossingentry-data`.

materially affect regression estimates (Mullahy and Norton 2022, Chen and Roth 2023).[36]

4 Descriptive evidence on imports and overdoses

In this section, we describe state-level import patterns and identify how they relate to fentanyl overdose deaths. First, we review the distribution of imports across states and show it has been stable over time. Then, to establish a link between imports and fentanyl overdose deaths in the raw data, we compare drug overdoses trends for states with relatively high and low levels of per-capita imports during our sample period. We show that their overdose trends are remarkably similar before the rise of fentanyl and markedly different thereafter. This introduces the key features of the data that motivate our empirical approach in the next section.

4.1 The distribution of imports

We begin by documenting state differences in import levels. Table 1 shows the average annual value of imports per resident over the 2008-2020 period. There is substantial cross-state variation in imports: the states with the five highest value of imports per capita (New Jersey, Michigan, Tennessee, California and Kentucky) have values more than seven times larger than the five states with the lowest values (South Dakota, Wyoming, New Mexico, Montana and Hawaii). There are also sizeable differences in import levels between neighboring states. For example, the average annual value of imports per capita for New Jersey ($11.5K) is roughly double that of New York ($6.0K), while the value for Michigan ($10.5K) is nearly triple that for Wisconsin ($3.8K). Other examples of broadly similar pairs of states with meaningful differences in the value of imports per capita are Tennessee ($9.5K) and Alabama ($3.6K); North Dakota ($3.9K) and South Dakota ($1.1K); New Hampshire ($7.2K) and Maine ($2.8K); Maryland ($4.2K) and Virginia ($2.7K); and Washington ($5.2K) and Oregon ($3.8K). These comparisons highlight the uneven distribution of imports across states.

Existing evidence provides insight into the likely reasons for these differences, including distance from potential trading partners and the quality of transportation infrastructure (e.g., Duranton et al. 2014, Donaldson 2018). Trade across states and provinces is partly explained by these factors, together with local industrial composition and the shipping of intermediate goods (Wolf 2000; Hillberry and Hummels 2008). Dvorkin and Shell (2016) argue that proximity to

[36] Zero values are present for specific drug overdose rates other than fentanyl and in the police seizure rates. We make adjustments to deal with these values, and use these estimates to assess the robustness of our findings rather than to identify effect sizes.

trading partners and industrial specialization explain state differences in international imports, which in turn is often driven by state's natural endowments, agglomeration, and the persistence of historical shocks.[37] The important point for our analysis is that state-level variation in imports is unlikely to be driven by unobserved time-varying factors correlated with opioid problems.

Imports patterns do appear to reflect historical patterns and longstanding comparative advantages. For instance, the largest category of imports into Michigan is Transportation Equipment (NAICS 336), consistent with the strong automotive industry present since the founding of companies like Ford and General Motors more than a century ago. Indiana's largest category of import is Chemical Manufacturing (NAICS 325), which is driven by pharmaceutical ingredients for companies like Eli Lilly and Company, founded in 1876, and Roche, which set up their North American headquarters there in 1964. In California and Massachusetts, the top imported goods are Computer and Electronic Products (NAICS 334), a sector that has benefited fromclose relationships between technology industries and top universities in those states.

Furthermore, we find that state differences in imports are relatively stable throughout our sample period, which is consistent with long-term factors driving import flows. The 50-state Spearman rank correlation of per-capita imports in 2008 and 2020 is 0.90. Eight of the 10 states with the highest value of imports per capita in 2008 are in the top 10 in 2020, and nine of the 10 states with the lowest value of imports per capita in 2008 are in the bottom 10 in 2020. This stability can be seen in Figure A3, which shows states' imports in quartiles for the continental U.S. in 2008 and 2020. While there are trade-related shocks over this period — including the Great Recession, tariff increases by the Trump Administration, and Covid-19 supply chain issues — none have led to marked changes in the distribution of imports at the state level.[38]

To the extent that import flows are stable and determined by states' long-standing industrial composition, imports are unlikely to be related to other potential determinants of drug problems. To further ensure that this is the case, we use state-level import data from before the rise of fentanyl to address concerns that import flows could respond endogenously to opioid demand. Furthermore, we account for other factors known to have affected the opioid crisis and we examine the relationship between imports and other health outcomes.

[37]For reviews of this literature, see Redding and Rossi-Hansberg (2017) and Redding (2022).

[38]For reviews of research on these shocks, see Bems et al. (2013), Fajgelbaum and Khandelwal (2022) and Baldwin and Freeman (2022). While studies cited therein do find that these shocks affect the volume and composition of imports, the impacts were not sufficiently large or geographically focused to generate noticeably different trade patterns at the state level, which limits our ability to utilize these shocks in our analysis. In robustness analysis, we do use a shift-share measure of imports driven by industry-level shocks.

4.2 Drug overdoses and import patterns

Key features of the opioid crisis have already been highlighted in Figures 1 and 2. Figure 1 shows that fentanyl deaths start to increase in 2013 and quickly become the dominant opioid associated with overdose deaths. Figure 2 shows that the spatial distribution of opioid overdose deaths changed due to the rise of fentanyl, withopioid overdose deaths becoming concentrated in the Midwest and Northeast. Together, these figures show that there was a sharp increase in fentanyl supply that did not simply reflect preexisting opioid demand.

We relate drug overdose rates to import patterns by dividing states into two equal groups based on their average annual value of imports over the 2008-2020 period. "High-importing" states have average annual imports above the median value of $3.86K per resident, while "low-importing" states have average annual imports below it. States are ordered by this measure in Table 1: the high-importing group covers New Jersey to North Dakota, while the low-importing group covers Wisconsin to South Dakota.[39]

In Figure 3, we plot the average annual fatal drug overdose rates per 100,000 residents for these two groups. Panel A shows the rates for all drug overdose deaths. The groups have similar rates and trends in the first five years of our sample period (2008-2012). While low-importing states have the higher rate in each year, on average the rate in high-importing states is only 9% smaller. Moreover, the differences are very stable: the rate in high-importing states is exactly 9% lower in three of these five years, and 7% and 11% lower in the other two years. This suggests that drug overdose deaths in high- and low-importing states were shaped by similar forces during the period immediately before the rise of fentanyl.

The two groups of states have starkly different trends from 2013 onward. The gap between the low- and high-importing groups reverses between 2012 and 2013, with high-importing states having 2% higher drug overdose death rates than low-importing states in 2013. This difference rapidly widens, and by 2017 the average drug overdose death rate in high-importing states is 37% higher than in low-importing states. Both groups of states experienced an increase in drug overdose deaths in every year of this period, but the 89% increase in drug overdose deaths in high-importing states dwarfs the 29% increase in low-importing states. The sizeable gap persists through to the end of our sample period; the relative difference is largest in 2018 (at 41%), while

[39] Later we use the 2008 value of imports per capita as our preferred measure. Note that the groups are almost identical if we split them based on the median value of imports in 2008: the only change is that Maryland switches from the high group to low one, while the reverse happens to Oregon.

the absolute difference was largest in 2020 (at 7.6 drug overdose deaths per 100,000 residents).

If the average gap between low-importing and high-importing states during 2008 and 2012 had persisted throughout the sample period, high-importing states would have had around 19,000 fewer deaths annually over the 2017-2020 period.[40] This calculation ignores many factors we will address in our regression-based analysis, such as low-importing states also being treated by imports — just less intensively than high-importing states — and the potential role of other determinants of drug overdoses. Despite this, the compelling nature of these raw trends provides a sense of the scale of drug overdose deaths that may be connected to import flows.

Figure 3 also shows the groups' drug overdose deaths due opioids versus non-opioids (in Panel B) and due to fentanyl versus non-fentanyl opioids (in Panel C). In combination, these panels show that the differences in drug overdoses between high- and low-importing states after 2012 is entirely driven by fentanyl overdoses. We also plot fentanyl police seizure rates in high- and low-importing states, finding a qualitatively similar pattern (Appendix Figure A4).[41]

Finally, given that recent drug overdose rates are highest in the Midwest and Northeast, we show a local association between imports and overdoses. We do so by presenting overdose death rates for pairs of neighboring states with different import flows. In Appendix Figure A5, we show drug overdose rates for New Jersey/New York; Michigan/Wisconsin; Tennessee/Alabama; and Maryland/Virginia. On average, the first state in each pair has an average value of imports per resident that is 120% larger than the second state. In each case, the higher-importing state has a higher drug overdose death rate than the lower-importing state in recent years.

Overall, the descriptive evidence points to a connection between imports and fentanyl deaths. There is nothing to indicate that state patterns in imports are correlated with other potential determinants of drug problems. Indeed, states with different import flows have similar trends in drug overdose deaths before fentanyl was a problem. Thus, there is a suggestive link between imports and fentanyl overdoses in the raw data that we now examine more formally.

[40]The average is 19,053 deaths. We use the average difference in levels for 2008-2012, and scale the implied differences in the 2017-2020 rates by annual population numbers. High-importing states are more populous than low-importing states, accounting for 69% of the national population over this period. If we do the same counterfactual exercise based on the relative differences being constant (i.e., high-importing states having a 9% lower drug overdose rate than low-importing states throughout), then deaths in high-importing states would be 20,137 lower each year over the 2017-2020 period.

[41]Seizure rates are near zero in both groups until 2014, when a gap between the two groups immediately opens up. The gap grows through 2017 as fentanyl seizure increase substantially, and then decreases slightly due to seizure rates flattening in high-importing states.

5 Empirical approach

In this section, we describe our approach to estimating the relationship between states' legal imports and drug overdose deaths. The background information in Section 2 and descriptive evidence in Section 4 informs this approach in several ways.

First, a global supply shock in illicit fentanyl began around 2013 and potentially affected all U.S. states at around the same time. We infer its timing and magnitude from well-measured mortality data and credible sources, but otherwise take it as given (i.e., we do not seek to explain the reasons for the supply shock). We focus on drug overdose deaths as an important and widely available measure of illicit drug problems, while using forensic drug reports from local police seizures as a complementary measure of drug market activity.

Second, we expect that the flow of legal imports affected states' sensitivity to this shock by facilitating fentanyl smuggling. This is informed by supply-chain warnings from the federal government; fentanyl being found in imports during customs and drug interdiction operations; and our own descriptive evidence. We primarily measure legal import activity using states' value of imports per resident in 2008, which is the start of our sample period. This precedes the surge in fentanyl supply by several years, and avoids reverse causality issues associated with fentanyl smuggling influencing trade patterns. We are initially agnostic about the role of import characteristics — such as source countries, product types, and mode of transport — as there is little definitive evidence on how exactly fentanyl smuggling is occurring.

Third, we rely on import differences across states being unrelated to time-varying factors that may otherwise affect the demand or supply of fentanyl. We pay particular attention to the potential influence of regional differences, as import activity is highest in the Midwest and Northeast and any regional factors driving the recent increase in overdose deaths may appear to be related to import patterns. We account for this by flexibly controlling for regional time trends, and also by considering whether our results are driven by a particular set of states. We further test this assumption by examining the relationship between imports and other outcomes, and by assessing whether the import-overdose relationship is affected by adding measures related to potential determinants of drug problems.

Our primary estimating equation is:

$$lnY_{st} = \alpha_s + \gamma_{st} + \sum_{t=2009}^{2020} \beta_t lnImports_{s2008} \times \mathbf{1}(Year = t) + \mathbf{X}_{st}\theta + \epsilon_{st} \quad (1)$$

where Y_{st} represents the number of deaths per 100,000 residents in state s and year t. $Imports_{s2008}$ is the value of imports per resident into state s in 2008. This is interacted with year indicator variables for 2009 through 2020 to produce our key coefficients of interest, β_t, which provide the estimated elasticity of drug overdose deaths to imports in each year relative to 2008.

We include state fixed effects (α_s) to account for permanent state differences in overdose outcomes. We add region-by-year fixed effects (γ_{st}) to account for specific time trends in each region defined by the Census Bureau (Midwest, Northeast, South and West). The vector of time-varying state-level covariates ($\mathbf{X}_{st}$) includes state population shares by sex, age (0-24, 25-44, 45-64, 65+ years), and race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other); log of GDP per resident; unemployment and labor force participation rates, and the natural log of population. We allow for an arbitrary correlation in errors (ϵ_{st}) at the state level.

This regression produces 12 coefficients of interest, which are annual elasticity estimates for 2009 through 2020 (relative to 2008). We also summarize these estimates by averaging the coefficients over three time periods: 2009 to 2012; 2013 to 2016; and 2017 to 2020. These are natural groupings: the first period precedes the national increase in fentanyl supply; the second period covers its early rise; and the third period is when fentanyl is the clearly dominant drug in the opioid crisis. Standard errors for these estimates are calculated using the delta method.

We extend our empirical approach to explore the robustness of our findings and the extent to which confounding factors affect them. Possible smuggling routes are explored later by using information on imports' country of origin, mode of transportation, and industry. We also complement this analysis with a machine-learning approach.

6 Results

6.1 Imports and drug overdose deaths

In this section, we present estimates of the relationship between the 2008 value of imports and drug overdose deaths using equation 1. The annual elasticity estimates, which are given by the β_t coefficients, are plotted in Figure 4. The four-year averages of these estimates for the

2009-2012, 2013-2016 and 2017-2020 periods are summarized in Table 2.

We first present estimates for all drug overdose in Figure 4A. Early in the sample period, from 2009 to 2012, the elasticity estimates are 0.03 or smaller in absolute magnitude and not statistically significant at conventional levels. From 2013, the estimates are consistently positive and increase in magnitude, becoming statistically significant at the 5% level from 2015. They peak at 0.25 in 2018. In Table 2, the average coefficients (standard errors) in the four-year groups are -0.01 (0.04) for 2009-2012; 0.10 (0.05) for 2013-2016; and 0.22 (0.07) for 2017-2020.

We next present estimates for all opioid overdoses in Figure 4B and for fentanyl overdoses in Figure 4C. The results are qualitatively similar to those for all drug overdoses: the estimated elasticities before 2013 are small and not statistically different from zero, then positive and increasing in magnitude from 2013. The annual estimates are statistically significant at the 5% level for opioid deaths from 2013 and for fentanyl deaths from 2015. Summary estimates in Table 2 imply that a 10% higher value of imports per resident in 2008 is associated with a 4.4% higher opioid death rate and a 7.5% higher fentanyl death rate over the 2017-2020 period.

We present estimates for non-opioid drug overdose deaths in Figure 4D. There is no meaningful relationship between imports and non-opioid overdose deaths. While the estimates become negative towards the end of the sample period, indicating that there may be some crowdout as the positive relationship between imports and fentanyl overdoses grows, the magnitudes are small and not statistically significant at the 5% level.

These regression results are in line with the descriptive evidence. There is a large and statistically significant relationship between imports and drug overdose deaths that develops after the rise of fentanyl in 2013 and is strongest for fentanyl overdoses.

To understand the importance of our regression controls, we present results for all drug overdoses, all opioid overdoses and fentanyl overdoses using parsimonious versions of equation 1 (see Appendix Table A2). Removing state fixed effects has little impact on the estimates, as does removing the time-varying demographic and economic controls.[42] Removing the region-by-year fixed effects increases the 2017-2020 elasticity estimates by 11-41%. This is not surprising, as region-by-year fixed effects absorb substantial amounts of the variation in both drug overdoses and imports.[43] Thus, our use of within-region variation may result in conservative estimates of

[42]This is informative. Some of our controls are potentially endogenous, as studies do find that the opioid crisis has affected employment and other economic outcomes (e.g., Mukherjee et al. 2023).

[43]Conditional on state and year fixed effects, region-by-year effects account for 36% of the remaining variation

the true relationship between imports and drug overdoses.

We get qualitatively similar results using alternative measures of imports (see Appendix Figure A6). First, we use the 2008 value of imports inclusive of oil and gas imports. The estimates are slightly smaller in magnitude, consistent with oil and gas imports not facilitating smuggling.[44] Second, we use the average weight of non-oil-and-gas imports per resident in 2008, where weight is measured in kilograms. Recall that this measure does not include imports sent via mail or courier packages, or land imports from Canada and Mexico. Even with the different coverage and underlying variation, this measure has a positive and generally statistically significant relationship with drug overdose death rates after 2013. Third, we use our main measure of imports but unscaled for population, which could be the more accurate measure if potential smuggling opportunities and detection risks do not depend on local population numbers. It generates qualitatively similar results, with a more rapid rise in the elasticity estimates starting in 2014. Fourth, we use a shift-share measure of imports. This is based on states' industry shares of 2008 imports and national industry changes in imports through 2020, where industry is defined at the NAICS 3-digit level. This produces almost identical results to the main estimates. The results are also similar using annual import values instead of the 2008 values, which is the final measure of imports that we use. Overall, the overdose-import relationship is robust to how imports are measured.

We also assess if the imports-overdose relationship is driven by specific states or regions by estimating equation 1 after dropping each Census region in turn (see Appendix Figure A7 and Table A3). The relationship between imports and fentanyl overdoses is robust to these sample changes. The average elasticities over the 2017-2020 period, which are all statistically significant at the 1% level, are 0.75 without the Northeast; 0.77 without the Midwest; 0.67 without the South; and 0.81 without the West. These results suggest a quite general relationship between imports and fentanyl overdoses across the entire U.S.

Our estimates imply that a large number of overdose deaths are associated with states' legal imports. If we scale the 2017-2020 elasticity estimates in Table 2 by the underlying mortality rates and population numbers over this period, the point estimates imply that this relationship can account for an annual average of 14,073 drug overdose deaths, 16,777 opioid overdose deaths,

in drug overdose deaths. Region fixed effects also account for 27% of state-level differences in the 2008 value of imports per capita.

[44] We could consider oil and gas imports as a placebo measure, except that some states have no oil and gas imports in some years. We later use the value of exports in placebo regressions, along with other related measures.

and 16,645 fentanyl deaths. Without the region-by-year fixed effects, the effect sizes over the 2017-2020 period are between 17,609 and 19,811 deaths.[45] The consistency of these results points to fentanyl driving a sizeable empirical relationship between imports and drug overdoses that accounts for on the order of 14,000-20,000 deaths per year by the end of our sample period.

6.2 Imports and police drug seizures

We complement our drug overdose results with an analysis examining the relationship between imports and police drug seizures. Fentanyl is well measured in seizure data, as counts are based on forensic results, regardless of whether or not police thought the drug was present when they sent it for testing. This alternate outcome addresses concerns that our mortality findings could be influenced by time-varying differences across states in drug attribution or policies that affect overdose risks (e.g., naloxone access). Another useful feature of seizure rates is that they do not depend on potency, whereas overdose risks are higher for fentanyl than for other opioids.

We present results for the relationship between 2008 imports and fentanyl seizures in Figure 5. We use a modified version of equation 1 with 2010 as the reference year, as these data start in 2010. A limitation of the fentanyl seizure data is that 4.2% of the observations are zeroes, which we deal with by adding 0.01 to all observations before taking the log of seizure rates.[46]

These results are qualitatively similar to those for drug overdose deaths. The elasticities average 0.20 for 2011 and 2012, before increasing in magnitude beginning in 2013 and becoming statistically significant at the 5% level. The elasticities average 0.89 for the 2013-2016 period and 1.28 for the 2017-2020 period. The estimates are almost identical when we combine fentanyl and fentanyl analogs, which increase seizure rates by around 60%.[47] Despite inherent differences in terms of how overdose deaths and police seizures are measured, the similarity of these estimates provides strong empirical support for imports facilitating fentanyl smuggling.

[45] A sense of the scale can also be obtained by formalizing the comparison in Figure 3 between high- and low-imports states in a difference-in-differences model. We use drug overdose deaths per 100,000 population as the outcome; interact year indicator variable with an identifier for high-importing states (with 2008 as the reference year); and include state fixed effects and the same covariates in equation 1 (with standard errors clustered at the state level). The estimated difference for 2017-2020 is a statistically significant 5.44 deaths per 100,000 population. This represents 12,367 deaths per year. If we take all but the lowest-importing state as partially treated, then the implied relationship between drug deaths and imports suggests that it can account for 17,416 deaths per year.

[46] We chose 0.01 as it is around the minimum seizure rate when values are positive. Understanding the robustness of these estimates is important, as methods to address zero values can affect the estimates (Mullahy and Norton 2022, Chen and Roth 2023). In Appendix Table A4, we also show that the results are similar with and without this correction using a sample of 40 states with positive seizure rates throughout the sample period.

[47] Fentanyl analogs contribute to fentanyl overdose deaths, as they are included in the T40.4 drug identification code in ICD-10. We do not analyze fentanyl analogs on their own, as 47% of observations would be zero.

6.3 Imports and opioids other than fentanyl

We now use the mortality and seizure data to generate results for oxycodone and heroin. While the existing results suggest that fentanyl drives the relationship between imports and opioid overdoses, assessing these outcomes provides insights into fentanyl-related spillovers and whether broader changes in opioid demand could explain our results.

We use two mortality measures: one using all overdoses where the specific opioid is reported, and a narrower one using overdoses where the specific opioid is the *only* opioid.[48] We also use the police seizure rates of each drug.[49] For these three measures, we plot the annual elasticity estimates for fentanyl, heroin and oxycodone in Appendix Figure A8.[50] In the first row, we show that the results using overdoses where *only* fentanyl was reported (panel B) generates similar findings to the fentanyl results shown previously (re-shown in panels A and C).

Heroin and oxycodone outcomes have relatively weaker relationships to the 2008 value of imports. The heroin outcomes have imprecise inverted-U relationships to imports that peak at around 0.3-0.4 in 2013 and then decline to zero or negative values by 2020. Overdoses with any oxycodone have a positive, increasing and statistically significant relationship to imports from 2015 to 2020 that averages 0.39 over the 2017-2020 period. The estimates for overdoses with only oxycodone reported are similar in terms of their pattern and precision, although they are slightly smaller in magnitude. In contrast to these results, there is no apparent relationship between imports and oxycodone seizures.

These estimates are in line with fentanyl-related spillovers. The heroin estimates are consistent with it initially being a complement to fentanyl, before becoming a substitute (Pardo et al., 2019). The positive relationship between imports and oxycodone overdoses – but not seizures – could be due to addicted individuals consuming multiple opioids or the misreporting of opioid deaths (Slavova et al. 2019, Drake and Ruhm 2023). Importantly, the fentanyl outcomes have the strongest and clearest relationship to imports, and the timing of all of these responses align with the surge in fentanyl supply.

[48] When multiple drugs are reported, no attribution is made about which drugs contributed to the death, as the drug identification codes in the data are separate to the "underlying cause of death" code. Neither resolves the misclassification concerns discussed in Section 3.

[49] These include all seizures where a specific opioid is present; this is the only measure we have from the NFLIS.

[50] Given that some zeroes are present, for each outcome we add 0.01 to each rate before taking the natural log of it. This is near the minimum when values are positive, and the fentanyl mortality results are similar with this adjustment. We do not use these results to scale effect sizes (Mullahy and Norton 2022, Chen and Roth 2023).

7 Assessing alternate explanations

We have documented a robust and economically meaningful positive relationship between state-level imports per resident and fentanyl overdose death rates since 2013, which is also present between imports and fentanyl seizure rates. It is robust to our choice of regression controls, how we measure imports, and dropping specific states or Census regions. Moreover, we have shown that states with different levels of imports experienced similar trends in drug overdoses prior to 2013, and that import patterns do not strongly influence non-fentanyl drug overdose deaths.

In this section, we further rule out other explanations for our findings by providing two types of additional evidence. First, we show that import patterns are not correlated with more general determinants of mortality by estimating the relationship between imports and non-drug causes of death. Second, we show the results are robust to adding state characteristics to our regression that could potentially affect fentanyl overdose rates. We consider four factors likely to be most closely related to the demand for fentanyl in Section 7.2, and then four other factors potentially related to the supply of illicit fentanyl in Section 7.3.

7.1 Placebo tests using other causes of death

We conduct a variety of placebo tests by replacing drug overdoses with other causes of death. The rest of equation 1 is unchanged. These results help us assess whether import patterns are correlated with more general determinants of mortality.

Deaths of despair. Considerable attention has been given to the declining life expectancy of middle-aged Americans due to large increases in drug overdoses, suicides, and deaths due to alcoholic liver disease (Case and Deaton 2015). While the reasons behind rising "deaths of despair" are not well understood, they occur in similar places and are thought to have common determinants (Currie and Schwandt 2021, Case and Deaton 2022, Ruhm 2022).

If imports are facilitating drug smuggling, then state-level imports should not be related to non-drug suicides or alcoholic liver deaths. We present annual elasticity results in Figures 6A and 6B, which show that there is no meaningful empirical relationship between imports and either of these causes of death.[51]

Other causes of death related to population health. We also use, as placebo outcomes, all

[51]For non-drug suicide, there are statistically significant estimates of around -0.05 in both 2019 and 2020. This may reflect drug suicides recently crowding out non-drug suicides, although it is small relative to the drug-overdose estimates.

non-drug deaths, lung cancer deaths, heart disease deaths, and traffic fatalities. Along with drug overdose deaths, these types of deaths have been linked to common economic phenomena, including poverty rates (e.g., Gordon and Sommers 2016); graduating in a recession (e.g., Schwandt and Von Wachter 2023); and short-term changes in economic activity (e.g., Evans and Moore 2012).

We present the regression estimates for these causes of death in Figures 6C-6F. None of these mortality rates have a statistically significant relationship with imports during our sample period. Moreover, the precise estimates for these common causes of death result in 95% confidence intervals that generally rule out elasticities greater than 0.05 in absolute magnitude.

7.2 Determinants of opioid demand

We now consider the role of several factors that may affect opioid demand and thus fentanyl overdoses. For each, we add a variable to the right-hand side of equation 1 and separately interact it with the year indicator variables. In Figure 7, we show the estimated relationship between imports and fentanyl overdoses conditional on the additional controls (left column), alongside the time-varying relationship between the additional state characteristic and fentanyl overdoses (right column).[52] These estimates are summarized in Appendix Table A5.

Import competition. Import competition, particularly from China, has adversely affected local labor markets (Autor et al. 2013; Pierce and Schott 2016). It has also been linked to an increase in drug overdose deaths and other "deaths of despair" (Charles et al. 2019; Pierce and Schott 2020). We already control for labor market conditions in equation 1, and there is little reason to expect that import competition affects fentanyl overdoses but not other deaths of despair. Nonetheless, we now further assess whether import competition affects our results.

We follow the literature and measure import competition by calculating states' exposure to national industry-level imports in a given year based on their share of industry employment in a pre-sample year. Specifically, we use state's industry employment shares in the year 2008 and national 6-digit NAICS industry imports to calculate import competition in the following way:

$$ImpComp_{st} = \sum_{n} \left(\frac{empl_{sn2008}}{empl_{n2008}} * imports_{nt} \right) \tag{2}$$

Where s represents the state, t the year, and n the industry. This measures how national

[52] Ideally, we would condition on all of these variables at the same time. However, we have limited degrees of freedom, as we have 650 observations and equation 1 already includes 122 parameters.

imports affect some states more than others based on production patterns in 2008. We add import competition to equation 1 and separately interact it with the year indicator variables in order to measure the impact of import competition on fentanyl overdoses over time.

In Figures 7A and 7B, we present estimates of the separate relationships that imports and import competition have with fentanyl overdoses. The imports coefficients are little changed, with average elasticity estimates for the 2013-2016 period of 0.37 and for the 2017-2020 period of 0.72. The relationship between import competition and fentanyl overdoses is insignificant throughout the sample period.

It is not surprising that our import competition results differ from Pierce and Schott (2020), who find that import competition increases deaths of despair. We study a more recent period, when the labor market effects of import competition have dissipated (Bloom et al., 2019). In any case, to the extent that import competition affects opioid demand, it is distinct from the relationship between imports and fentanyl overdoses that we document.

The long-term effects of OxyContin marketing. Alpert et al. (2022) identify California, Idaho, Illinois, New York, and Texas as "triplicate" states that were subject to less intense marketing of OxyContin in the 1990s than "non-triplicate" states. In triplicate states, doctors prescribing OxyContin would use triplicate forms that allowed the state to monitor prescribing irregularities. Relative to triplicate states, non-triplicate states have had higher opioid overdoses rates, longer unemployment spells, and more children not living with their parents as the opioid crisis has worsened (Alpert et al. 2022; Buckles et al. 2022; Mukherjee et al. 2023).

We assess whether non-triplicate status affects the imports-overdose relationship using an identifier for non-triplicate states that is interacted with the year identifiers and added to equation 1. We present the results in Figures 7C and 7D. The elasticity estimates for imports are similar, with average elasticity estimates for 2013-2016 of 0.34 and for 2017-2020 of 0.83. The estimated relationship between non-triplicate status and fentanyl overdoses is positive and increasing in magnitude over time, albeit generally imprecisely. These results show that, even though a long-term determinant of opioid demand affects the recent distribution of fentanyl overdoses, it does not change the relationship between imports and fentanyl overdoses.

Prescription drug monitoring programs (PDMP). State PDMP are modern, computer-based versions of "triplicate" programs, allowing authorities to identify over-prescribing and prescription opioids being diverted into the black market. Some researchers have found their introduction affects opioid problems (e.g., Buchmueller and Carey 2018; Balestra et al. 2021).

We create a variable identifying the presence of a PDMP in a given state and year based on the date a PDMP law was enacted, and interact it with the year indicator variables. These results are presented in Figures 7E and 7F. The relationship between imports and fentanyl overdoses is little changed, and the coefficients measuring the relationship between PDMP and fentanyl overdoses are small and not statistically different from zero.

Exports as a placebo measure of trade and economic activity. Economic activity and trade openness may influence the demand for illicit drugs. We have already examined the relationship of several causes of death that are potentially sensitive to local economic conditions, finding they have no empirical relationship to imports. We now add exports to our analysis, which could affect economic activity but should not facilitate fentanyl smuggling.

We add the log of the annual value of exports per resident to equation 1 and interact it with the year indicators. These are presented in Figures 7G and 7H. The relationship between imports and fentanyl overdoses is slightly stronger and similarly precise to the main results, while exports have a weak and imprecise relationship with fentanyl overdoses.

7.3 Alternate determinants of fentanyl supply

We next examine the role of factors potentially related to illicit fentanyl supply. As in the previous section, we generally do so by adding a variable to the right-hand side of equation 1 and separately interacting it with the year indicator variables. We also explore the role of land-border smuggling by changing the sample. All of these results are presented in Figure 8 and summarized in Appendix Table A5.

Diversion of legal fentanyl. The U.S. Department of Justice believes some legal fentanyl is diverted from healthcare facilities, albeit on a small scale (Walters, 2018). We check if this explains our results by adding information on the amount of legal fentanyl sent annually to each state, which we convert to grams per state resident. The log of this variable is added to equation 1 and interacted with the year identifiers, allowing imports and legal fentanyl to have separate time-varying effects on fentanyl overdoses.

The results are presented in Figures 8A and 8B. The relationship between imports and fentanyl overdoses remains similar after accounting for the possible diversion of legal fentanyl from healthcare settings. The coefficients identifying the relationship between legal fentanyl and fentanyl overdoses are generally negative, although never at statistically significant levels.

The role of heroin types east and west of the Mississippi River. Traditionally, different types of heroin have been available east and west of the Mississippi River, with white-powder heroin prevalent to its east and black-tar heroin to its west. It is easier to mix fentanyl with white-powder heroin, which is important when illicit fentanyl is used to adulterate or supplement heroin (Pardo et al. 2019; DEA 2021). This difference may have made it more attractive to supply fentanyl to states east of the Mississippi River, and is potentially a reason for those states experiencing an earlier and larger increase in fentanyl deaths (Zoorob 2019).

We already account for time-varying differences across Census regions. However, to further explore whether geographic differences in the heroin market affect the relationship between imports and fentanyl overdoses, we add an identifier for states east of the Mississippi River and interact it with the year identifiers.[53] The results are presented in Figures 8C and 8D. The relationship between imports and fentanyl overdoses is only slightly attenuated, with an average elasticity of 0.65 over the 2017-2020 period that remains statistically significant at the 1% level. States east of the Mississippi River have higher fentanyl overdose rates than states to the west after 2013. The relative differences peak in 2017 at 107% higher, before declining to 64% by 2020. The 2015-2018 estimates are statistically significant at the 5% level.

The geographic differences in heroin types explain at most a small part of the relationship between imports and drug overdoses. Moreover, as with the Census region controls, flexibly controlling for these differences reduces the state-level variation in both imports and drug overdoses, possibly attenuating the true relationship between imports and drug overdoses.

Smuggling across U.S. land borders. We next consider whether we are inadvertently attributing the impact of smuggling across the Canadian and Mexican borders to legal imports. Fentanyl and other illegal drugs are sometimes carried across the border (e.g., Pardo et al. 2019; DEA 2021), and border states also generally have more legal trade than other states.

We account for this using state-year data on inbound entrants at the U.S.-Canada and U.S.-Mexico borders. We focus on total entrants, whether by car, bus, train, or on foot. In equation 1, we add the log of average border entrants per resident and interact it with the year indicators. The 36 non-border states are retained by adding 0.01 to all observations before taking the log of this variable.[54] The results are presented in Figures 8E and 8F. Controlling for border crossings

[53] We follow the norm by classifying Louisiana and Minnesota – the two states that the Mississippi River passes through – as to the west ((Zoorob, 2019)).

[54] This is the only variable in this section that has any zero values and requires such an adjustment.

into the U.S. does not affect the relationship between imports and fentanyl overdoses.

We also show results in Figure 8G using the original equation 1 and the 36 states without a border with Canada or Mexico. For this sample, the average elasticity between imports and fentanyl overdoses over the 2017-2020 period is 0.83, which is statistically significant at the 1% level. The similarity of these results to those for the full sample suggests that the relationship between imports and fentanyl overdoses is distinct from any role border crossings have in facilitating drug smuggling.

7.4 Summary

In this section, we have considered the relationship between legal imports and six non-drug-related causes of death; the effects of adding seven state-specific factors that may affect the relationship between imports and fentanyl overdoses; and a sample restriction that drops border states. All of this additional evidence points to imports aiding the smuggling of fentanyl in recent years, rather than our estimates being driven by changes in population health or other determinants of fentanyl demand and supply.

8 The role of import characteristics

More imports, regardless of type, can decrease the probability of detection and facilitate drug smuggling (Pitt, 1981). However, we may be able to identify possible smuggling routes by examining if particular types of imports are more strongly associated with fentanyl overdoses. We start by focusing on the country of origin of the imported good, and examine whether this is related to fentanyl deaths. We then consider the mode of transport, with the idea that smuggling opportunities or screening processes may differ with imports coming via sea, air, land, or mail. Finally, we look at product types, based on the industry of the imported good.

We supplement this empirical approach with a machine-learning analysis. In addition to being directly informative about the heterogeneous effects of drug smuggling, this illustrates how objectively measured administrative trade and mortality data can be used to inform priorities for customs and law enforcement agencies.

8.1 Country/region of origin

Law enforcement agencies often emphasize that fentanyl is smuggled directly from China, or via Mexico (e.g., DEA 2019; 2021). However, as discussed in Section 2, there is substantial uncertainty about this. To explore the role of the origin of different imports, we decompose imports into six different origin locations: Canada; Mexico; Asia; Latin America (Central and South America); Europe; and the rest of the world (Africa/Oceania).[55]

In addition to including the main 2008 import variable, we also add the log of the 2008 import *shares* from each country/region and interact them separately with the year indicators. This specification allows overall import volumes to have a distinct role from imports coming from particular locations. We report average elasticity estimates over the usual four-year periods in Appendix Table A6. There is still a positive relationship between the overall value of imports and fentanyl overdoses that develops after 2013, with a statistically significant estimate of 0.68 over the 2017-2020 period. Country/region import shares also play a role, with positive and statistically significant estimates for Latin American import shares that average 0.452 over the 2017-2020 period. Some other country/region estimates are positive, although they are not statistically significant at conventional levels.[56]

These results provide new insights into the role of imports' country of origin. There is little evidence that imports from China or Mexico are driving the results; instead, smuggling via imports is driven by overall volumes and shares from elsewhere. Perhaps the focus on China and Mexico results in other routes being used to avoid scrutiny. These findings indicate that drug smuggling is more diverse than current policy discussions suggest.

8.2 Mode of transport

Is fentanyl smuggling more strongly associated with some modes of transportation than others? To investigate this possibility, we examine whether there are heterogeneous effects of imports coming via four modes: sea, air, land/mail from Canada and Mexico, and mail from elsewhere.[57]

We estimate the relationship between these different modes of transport and drug overdoses by making similar changes to equation 1. We add the 2008 import *shares* for each mode of

[55] There is a high correlation of 0.992 between the 2008 value of Chinese and non-Chinese Asian imports that likely results from entrepôts and other close trade linkages among countries within the region (Ganapati et al. 2023). To avoid multicollinearity, we do not separate Chinese and non-Chinese Asian exports, although our estimates are similar if we just use Chinese imports by themselves. We combine Africa and Oceania in the analysis, as together they account for less than 2% of the total value of U.S. imports.

[56] The importance of Latin American imports is confirmed using a second specification that does not account for overall import volumes, but allows the 2008 value of imports from each origin to have a direct association with fentanyl drug overdoses. The results are summarized in Appendix Table A7. The only statistically significant estimate is a positive one for Latin American imports over the 2017-2020 period.

[57] As discussed in Section 3, sea and air transport are the only modes explicitly identified in the Census import data, and mail packages are not assigned a mode of transport. We define land/mail imports from Canada and Mexico as the difference between their total imports and sea-plus-air imports. We define mail packages from elsewhere as the difference between total imports and sea-plus-air imports for all other countries.

transport and their interactions with the year indicators, and summarize the results in Appendix Table A6. Overall import volumes remain important, with an elasticity estimate for 2017-2020 of 0.756. There are no other statistically significant estimates, although the elasticity of fentanyl overdoses to the 2008 share of sea imports over the 2017-2020 period is potentially meaningful, at around 0.25. Furthermore, in a second specification allowing the 2008 value of imports for each mode to have a direct association with fentanyl drug overdoses, sea imports develop a positive and statistically significant relationship to fentanyl overdoses.[58] Sea imports account for nearly half of imports, so it is difficult to separate their role from the influence of overall volume. Interestingly, the estimates for mail packages are small, and the confidence intervals rule out elasticities larger than 0.2. Despite popular concerns, this finding indicates that smuggling via mail packages is not driving our results.

8.3 Industry

Features of imported goods may make some products more conducive to drug smuggling than others (i.e. packaging, size, volume, weight, cavities). Lacking evidence on which features and products provide the best smuggling opportunities, we instead analyze the role of six NAICS industry categories that represent sizeable shares of 2008 imports: computer and electronic product manufacturing (16.2% of imports); transportation equipment manufacturing (14.2%); chemical manufacturing, which includes pharmaceuticals (11.9%); primary metal manufacturing (8.8%); machinery manufacturing (4.9%); and agriculture, forestry, fishing and hunting (3.1%). These industries account for 59% of imports used in our analysis (i.e., excluding oil and gas imports).

We include these industry shares in equation 1 in a similar way and present the results in Appendix Table A6. The impact of overall volumes is slightly weaker than in the heterogeneity analysis thus far, with an average elasticity over the 2017-2020 period of 0.567. For the same period, the share of agriculture, forestry, fishing and hunting products has a statistically significant point estimate of 0.20, while there is also a statistically significant estimate of 0.17 for the share of primary metal manufacturing. Chemical manufacturing imports also have a positive relationship with fentanyl overdoses that becomes statistically significant over the 2017-2020 period in a specification where we use industry values instead of industry shares.[59] These results

[58]See Appendix Table A7. For the 2017-2020 period, the coefficient (standard error) for sea imports is 0.503 (0.197), while the point estimates for the other three modes are smaller than 0.1.

[59]See Appendix Table A7. The 2008 values of agriculture, forestry, fishing and hunting products and primary

are consistent with anecdotal evidence that fentanyl is smuggled in products like fish and meat, and often disguised as legal pharmaceuticals.

8.4 Machine learning approach

Formulating specific hypotheses around how particular import characteristics influence fentanyl overdoses is challenging due to the inherently secretive nature of smuggling. Moreover, in the absence of these hypotheses, it is difficult to use detailed breakdowns of imports given the available data. Thus, we now use a flexible "machine learning" approach to understand the role of import characteristics in more detail (Mullainathan and Spiess, 2016).[60]

We use the Least Absolute Shrinkage and Selection Operator (LASSO), which introduces a penalty term in a least-squares model to reduce overfitting. LASSO is a natural method for our situation, as we have disaggregated shares of import flows based on country/region, mode of transport, and industry.[61] We use LASSO models that include the same controls as equation 1, which are partialled out by the LASSO estimation procedure. We select the lambda penalty parameter based on cross-validation, and report both LASSO and post-OLS estimates.

We first re-examine the relationship between imports' country/region of origin and fentanyl overdoses. We use the same country/region groups, except that we now separate Africa and Oceania. The variables that LASSO can select include the overall value of imports per capita and the country/region shares, all of which are separately interacted with identifiers for 2013-2016 and 2017-2020. The results are presented in Appendix Table A8.

Consistent with our previous findings, the LASSO estimates suggest that overall import volumes have the strongest relationships with fentanyl deaths in both time periods. For 2013-2016, LASSO also selects the share of Asian imports, which is negatively related to fentanyl deaths. For 2017-2020, three share variables are selected: positive estimates for Latin America and Africa, and a negative one for Canada. Of all of the shares selected, Latin American import shares for 2017-2020 have the strongest estimated relationship with fentanyl overdoses. These results are similar to the OLS analysis.

We perform similar re-examinations for import shares by mode of transport and industry

metal manufacturing products are also positive and statistically significant for the 2017-2020 period.

[60]Davis and Heller (2020) use results from a youth employment program to highlight machine learning's strengths in testing for heterogeneous effects by avoiding over-fitting concerns, while Bhatt et al. (2023) show it can be useful for identifying high-risk candidates for a gun violence intervention. Our approach is similar to Zou (2021), who used LASSO to select industry and regulatory controls to predict air pollution gap hot-spots.

[61]Regression trees or causal forest models like those used by Davis and Heller (2020) are better suited to selecting heterogeneous effects in interactive models.

type. These are done in a similar way to the analysis of country/region of origin, and also presented in Appendix Table A8. No variables are selected in the mode-of-transport LASSO model, highlighting the weak relationships between specific modes and fentanyl overdoses. In the industry analysis, overall import value is selected for both periods, along with electronic manufacturing for 2013-2016, and primary metal manufacturing, agriculture, forestry, fishing and hunting, and chemical manufacturing for 2017-2020. Again, the selected industry shares are consistent with the statistically significant results from the previous analysis.

The LASSO model is especially useful for studying more specific import characteristics. Given policy often focuses on where imports are coming from, we present results for the separate interactions between imports' country/region of origin and the other import characteristics. Specifically, our first approach interacts the country/region groups with the transport modes. The variables that LASSO can select include the overall value of imports per capita and the country/region-by-mode shares, all of which are separately interacted with identifiers for 2013-2016 and 2017-2020. These results are also presented in Appendix Table A8.

For the origin-by-mode analysis, LASSO selects no variables in the 2013-2016 period and the overall value of imports and five specific import types for the 2017-2020 period. Four have a positive relationship with fentanyl overdoses, which in order of magnitude are: sea imports from Latin America; air imports from Africa; sea imports from Africa; and sea imports from Mexico. The share of air imports from Canada has a negative relationship with fentanyl overdoses.

For the origin-by-industry analysis, 2013-2016 shares for three different Oceanian product types are selected. However, the shares and these estimated elasticities are small. For 2017-2020, overall imports and six import types are selected. All have positive estimates: Asian transportation equipment manufacturing, African transportation equipment manufacturing, European chemical manufacturing, European primary metal manufacturing, Oceanian agriculture, forestry, fishing and hunting, and Oceanian primary metal manufacturing.

These additional results are informative. For example, the positive relationship between Latin American import shares and fentanyl overdoses appears to be driven by sea imports, but not by any specific type of products. On the other hand, the results for primary metal manufacturing and chemical manufacturing are most closely linked to imports from Europe. Some of these results are consistent with traffickers evading enforcement efforts. For example, law enforcement are paying attention to the Southwest Border and flights from Mexico, and the results indicate that smugglers may be using sea imports from Mexico in response. Differences in the number of variables selected in the two models highlight how authorities could vary penalty thresholds depending on their capacity to target specific imports.[62]

Overall, these machine-learning results reinforce our earlier findings and show that fentanyl smuggling is more pervasive and diversified than previously realized. Furthermore, this analysis provides a methodological contribution by illustrating how policy makers could use this objective data-driven approach to provide insights into the inherently secretive nature of drug smuggling.

9 Discussion and conclusion

The opioid epidemic has evolved into an illicit drug crisis. While there were were approximately 27,000 drug overdose deaths involving fentanyl from 1999-2012, there were a staggering 338,590 of these deaths from 2013-2022.[63] We provide new insights into the smuggling of illicit fentanyl, which is driving the most recent and deadliest phase of the opioid crisis. Using high-quality administrative data, we document that a positive relationship between states' legal imports and the number of fentanyl overdoses that starts around 2013. A qualitatively similar relationship is present between legal imports and local police seizures of fentanyl.

The link between imports and fentanyl problems is not driven by other possible explanations, such as the general demand for opioids; import competition; the long-lasting effects of OxyContin marketing; the presence of prescription drug monitoring programs; Mexican or Canadian border crossings; or general levels of trade openness and economic activity. It is difficult to think of an explanation apart from legal imports facilitating illicit fentanyl smuggling, especially given the rapid development of this relationship and the lack of any connection between imports and other causes of death.

Our estimates indicate that fentanyl smuggled via legal imports killed approximately 14,000-20,000 Americans per year over the 2017-2020 period. This represents on the order of 30-40% of all opioid deaths over these years. We combine estimates from the literature for the value of statistical life and the gains from trade associated with U.S. imports to assess fentanyl smuggling as a new external cost of trade. A value of statistical life (VSL) of $10 million implies the

[62]The negative estimates are also informative. For example, understanding the potential role of supply-chain security and customs screening in making air imports from Canada relatively unattractive to smugglers may help to reduce smuggling via other goods.

[63]This is substantially more than the aggregate of heroin (158,183) or oxycodone (226,298) spanning the entire 24 years from 1999-2022.

mortality consequences of 14,000-20,000 deaths per year are valued at $140-200 billion.[64] This suggests that the mortality costs of import-induced fentanyl deaths represent on the order of 20% of the gains from trade, based on estimates that the gains are 2-8% of GDP (Costinot and Rodriguez-Clare 2018). Even if the gains from trade are at the top end of the range in Costinot and Rodriguez-Clare (2018) and overdose deaths are at the bottom of our range, the mortality costs would still represent around 8% of the gains from trade.[65]

The more policy-relevant comparison is in relation to the resources devoted to screening imports for illicit drugs and other contraband. The value of our mortality effects is many times higher than the entire U.S. Customs and Border Protection budget of around $15 billion for 2023, a small share of which is related to screening imports.[66] Moreover, policy initiatives and law enforcement operations appear to be focused on China and Mexico, missing the contributions of overall import volumes and imports from other regions.[67] Our findings reinforce calls for better data and performance evaluation in order to improve U.S. drug policy responses to the opioid crisis (GAO 2022; Stein et al. 2023). At a minimum, our results point to the potential benefits of a more systematic (or even randomized) customs screening process, echoing prior research on deterrence (Eeckhout et al., 2010; Banerjee et al., 2019).

Our results could also be used to target demand-side interventions. For instance, funding for drug treatment facilities and personnel could be expanded in states more exposed to fentanyl via international trade. Implicitly, this would assist those adversely effected by globalization, which in this case are individuals whose substance abuse and mortality risks have been increased by trade-related fentanyl smuggling.

There are several limitations to this study. First, drug smuggling is inherently secretive, so we do not know exactly how imports are used to smuggle fentanyl and how fentanyl is distributed locally. It is possible that there are positive spillovers across states, although they

[64]Kniesner and Viscusi (2019) review and update VSL estimates to around $10 million in 2017 dollars, or $11.9 million in 2022 based on CPI-U values. Banzhaf (2022) reviews meta-analyses of VSL studies and arrives at a central estimate of $8.0 million per life in 2019 dollars, or $9.2 million in 2022 dollars. The U.S. Department of Health and Human Services are currently using a central estimate of VSL of $11.4 million in 2020 dollars, or $12.9 million in 2022 dollars (`https://aspe.hhs.gov/reports/updating-vsl-estimates`).

[65]There are also non-mortality consequences (e.g., Powell et al. 2019; Buckles et al. 2022; Mukherjee et al. 2023), which are even more difficult to value. The White House Council of Economic Advisers estimated that non-mortality costs accounted for 15% of total opioid-related costs in 2017, while another study estimated they were nearly half in that same year (Florence et al. 2021).

[66]See `https://www.dhs.gov/dhs-budget`.

[67]E.g., the *National Drug Control Strategy* only mentions maritime port security in terms of working with the Mexican Government to limit the Mexican gangs' effectiveness (Office of National Drug Control Policy 2022).

should attenuate our estimates. Second, we lack clear exogenous variation in imports across states, although we use imports from before the rise of fentanyl and find similar results using changes induced by national industry-level variation. Moreover, any alternate explanation would have to account for high-importing states shifting from having a drug overdose rate that is 9% lower than low-importing states in 2012 to one that is 41% higher only six years later. Third, we (and all researchers) lack representative data on fentanyl prices and purities, a longstanding concern when it comes to illicit drugs that makes it difficult to understand market dynamics (Manski et al. 2001). Finally, we do not provide direct evidence that increased or better targeted screening reduces the illicit supply of fentanyl, although there have been drug interdiction successes targeting similar activities in other contexts that have raised prices and reduced drug problems (Moore and Pacula 2020).

Nevertheless, our paper provides crucial insights into the supply of this destructive drug, and provide a novel hypothesis for the new geography of opioid overdoses. We highlight an under-appreciated opportunity to reduce illicit fentanyl smuggling that may save many lives. More broadly, we provide a clear example of how better data and data analysis can help shape policy responses to limit the tragic consequences of the opioid crisis.

References

Ahmad, F. B., Cisewski, J. A., Rossen, L. M., and Sutton, P. Provisional drug overdose death counts. Hyattsville, MD: National Center for Health Statistics. 2023.

Alpert, A., Powell, D., and Pacula, R. L. Supply-side drug policy in the presence of substitutes: Evidence from the introduction of abuse-deterrent opioids. *American Economic Journal: Economic Policy*, 10(4):1–35, 2018.

Alpert, A., Evans, W. N., Lieber, E. M., and Powell, D. Origins of the opioid crisis and its enduring impacts. *Quarterly Journal of Economics*, 137(2):1139–1179, 2022.

Arteaga, C. and Barone, V. A manufactured tragedy: The origins and deep ripples of the opioid epidemic. *Working paper*, 2023.

Australian Federal Police. Fentanyl warning following Australia's largest detection of deadly opioid, Aug. 22, 2022. URL `https://www.afp.gov.au/news-centre`.

Autor, D. H., Dorn, D., and Hanson, G. H. The China syndrome: Local labor market effects of import competition in the United States. *American Economic Review*, 103(6):2121–68, 2013.

Baicker, K. and Rehavi, M. M. Policy watch: Trade Adjustment Assistance. *Journal of Economic Perspectives*, 18(2):239–256, 2004.

Baldwin, R. and Freeman, R. Risks and global supply chains: What we know and what we need to know. *Annual Review of Economics*, 14:153–180, 2022.

Balestra, S., Liebert, H., Maestas, N., and Sherry, T. B. Behavioral responses to supply-side drug policy during the opioid epidemic. *NBER Working Paper 29596*, 2021.

Banerjee, A., Duflo, E., Keniston, D., and Singh, N. The efficient deployment of police resources: Theory and new evidence from a randomized drunk driving crackdown in India. *NBER Working Paper 26224*, 2019.

Banzhaf, H. S. The value of a statistical life: A meta-analysis of meta-analyses. *Journal of Benefit-Cost Analysis*, 13(2):182–197, 2022.

Becker, G. S. Crime and punishment: An economic approach. *Journal of Political Economy*, 76 (2):169–217, 1968.

Bems, R., Johnson, R. C., and Yi, K.-M. The great trade collapse. *Annual Review of Economics*, 5(1):375–400, 2013.

Bhagwati, J. N. On the underinvoicing of imports. *Bulletin of the Oxford University Institute of Economics & Statistics*, 27(4):389–397, 1964.

Bhatt, M., Heller, S., Kapustin, M., Bertrand, M., and Blattman, C. Predicting and preventing gun violence: An experimental evaluation of READI Chicago. *NBER Working Paper 30852*, 2023.

Bichler, G., Malm, A., and Cooper, T. Drug supply networks: A systematic review of the organizational structure of illicit drug trade. *Crime Science*, 6:1–23, 2017.

Bloom, N., Handley, K., Kurman, A., and Luck, P. The impact of Chinese trade on U.S. employment: The good, the bad, and the debatable. *Stanford Working Paper*, 2019.

Buchmueller, T. C. and Carey, C. The effect of prescription drug monitoring programs on opioid utilization in Medicare. *American Economic Journal: Economic Policy*, 10(1):77–112, 2018.

Buckles, K., Evans, W. N., and Lieber, E. M. The drug crisis and the living arrangements of children. *Journal of Health Economics*, page 102723, 2022.

Case, A. and Deaton, A. Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. *PNAS*, 112(49):15078–83, 2015.

Case, A. and Deaton, A. The great divide: Education, despair, and death. *Annual Review of Economics*, 14:1–21, 2022.

CBP. 22 Pill Presses, 257 Pill Press Parts; Fentanyl, and Xylazine: Cincinnati CBP Targets Deadly Imports, Oct. 30, 2023. URL `www.cbp.gov/newsroom/media-releases/all`.

CBP. CBP Announces Next Phase in Fight Targeting Criminals Funneling Fentanyl into American Communities, April 10, 2024. URL www.cbp.gov/newsroom/media-releases/all.

Charles, K. K., Hurst, E., and Schwartz, M. The transformation of manufacturing and the decline in US employment. *NBER Macroeconomics Annual*, 33(1):307–372, 2019.

Chen, J. and Roth, J. Logs with zeros? Some problems and solutions. *Quarterly Journal of Economics, forthcoming*, 2023.

Costinot, A. and Rodriguez-Clare, A. The U.S. gains from trade: Valuation using demand for foreign factor services. *Journal of Economic Perspectives*, 32(2):3–24, 2018.

Currie, J. and Schwandt, H. The opioid epidemic was not caused by economic distress but by factors that could be more rapidly addressed. *ANNALS of the American Academy of Political and Social Science*, 695(1):276–291, 2021.

Davis, J. and Heller, S. Rethinking the benefits of youth employment programs: The heterogeneous effects of summer jobs. *Review of Economics and Statistics*, 102(4):664–677, 2020.

DEA. DEA National Drug Threat Assessment. *Drug Enforcement Administration*, 2019.

DEA. DEA National Drug Threat Assessment. *Drug Enforcement Administration*, 2021.

DEA. DEA National Drug Threat Assessment. *Drug Enforcement Administration*, 2024.

Dell, M. Trafficking networks and the Mexican drug war. *American Economic Review*, 105(6): 1738–1779, 2015.

Di Tella, R. and Schargrodsky, E. Do police reduce crime? Estimates using the allocation of police forces after a terrorist attack. *American Economic Review*, 94(1):115–133, 2004.

Donaldson, D. Railroads of the Raj: Estimating the impact of transportation infrastructure. *American Economic Review*, 108(4-5):899–934, 2018.

Drake, K. M. and Ruhm, C. J. Estimating drug involvement in fatal overdoses with incomplete information. *American Journal of Preventive Medicine*, 2023.

Duranton, G., Morrow, P. M., and Turner, M. A. Roads and trade: Evidence from the U.S. *Review of Economic Studies*, 81(2):681–724, 2014.

Dvorkin, M. and Shell, H. A regional look at US international trade. *Review*, 98(1):17–39, 2016.

Eeckhout, J., Persico, N., and Todd, P. E. A theory of optimal random crackdowns. *American Economic Review*, 100(3):1104–1135, 2010.

Ehrlich, I. Participation in illegitimate activities: A theoretical and empirical investigation. *Journal of Political Economy*, 81(3):521–565, 1973.

Eichmeyer, S. and Zhang, J. Pathways into opioid dependence: Evidence from practice variation in emergency departments. *American Economic Journal: Applied*, 14(4):271–300, 2022.

Evans, W. N. and Moore, T. J. Liquidity, economic activity, and mortality. *Review of Economics and Statistics*, 94(2):400–418, 2012.

Evans, W. N., Garthwaite, C., and Moore, T. J. The white/black educational gap, stalled progress, and the long-term consequences of the emergence of crack cocaine markets. *Review of Economics and Statistics*, 98(5):832–847, 2016.

Evans, W. N., Lieber, E. M., and Power, P. How the reformulation of OxyContin ignited the heroin epidemic. *Review of Economics and Statistics*, 101(1):1–15, 2019.

Fajgelbaum, P. D. and Khandelwal, A. K. The economic impacts of the U.S.–China trade war. *Annual Review of Economics*, 14:205–228, 2022.

Felbab-Brown, V. *China and synthetic drugs control: Fentanyl, methamphetamines, and precursors*. Brookings Institution, 2022.

Fisman, R. and Wei, S.-J. Tax rates and tax evasion: Evidence from "missing imports" in China. *Journal of Political Economy*, 112(2):471–496, 2004.

Fisman, R. and Wei, S.-J. The smuggling of art, and the art of smuggling: Uncovering the illicit trade in cultural property and antiques. *American Economic Journal: Applied Economics*, 1 (3):82–96, 2009.

Florence, C., Luo, F., and Rice, K. The economic burden of opioid use disorder and fatal opioid

overdose in the United States, 2017. *Drug and Alcohol Dependence*, 218:108350, 2021.
Freylejer, L. and Orr, S. Import substitution in illicit methamphetamine markets. *Journal of International Economics*, 140, 2023.
Ganapati, S., Wong, W. F., and Ziv, O. Entrepôt: Hubs, scale, and trade costs. *American Economic Journal: Macroeconomics, forthcoming*, 2023.
GAO. *Illicit opioids: While greater attention given to combating synthetic opioids, agencies need to better assess their efforts, (GAO-18-205).* U.S. Government Accountability Office, 2018.
GAO. *Office of National Drug Control Policy met some strategy requirements but needs a performance evaluation plan.* U.S. Government Accountability Office, 2022.
Gordon, S. H. and Sommers, B. D. Recessions, poverty, and mortality in the United States: 1993–2012. *American Journal of Health Economics*, 2(4):489–510, 2016.
Hidalgo, E., Hornung, E., and Selaya, P. NAFTA and drug-related violence in Mexico. *CEPR Discussion Paper 17608*, 2022.
Hillberry, R. and Hummels, D. Trade responses to geographic frictions: A decomposition using micro-data. *European Economic Review*, 52(3):527–550, 2008.
Hollingsworth, A., Ruhm, C. J., and Simon, K. Macroeconomic conditions and opioid abuse. *Journal of Health Economics*, 56:222–33, 2017.
Kniesner, T. J. and Viscusi, W. K. The value of a statistical life. *Oxford Research Encyclopedia of Economics and Finance*, (19-15), 2019.
Maclean, J. C., Mallatt, J., Ruhm, C. J., and Simon, K. The opioid crisis, health, healthcare, and crime: A review of quasi-experimental economic studies. *Annals of the American Academy of Political and Social Science*, 703(1):15–49, 2022.
Manski, C. F., Pepper, J., and Petrie, C. *Informing America's policy on illegal drugs: What we don't know keeps hurting us.* National Research Council, 2001.
McCully, B. A. Immigrants, legal status, and illegal trade. *Working Paper*, 2023.
McNicholas, M. *Maritime security: An introduction.* Butterworth-Heinemann, 2016.
Mejia, D. and Restrepo, P. The economics of the war on illegal drug production and trafficking. *Journal of Economic Behavior and Organization*, 126:255–275, 2016.
Miller, J. N. The War on Drugs 2.0: Darknet fentanyl's rise and the effects of regulatory and law enforcement action. *Contemporary Economic Policy*, 38(2):246–257, 2020.
Moeller, K. and Svensson, B. Shop until you drop: Valuing fentanyl analogs on a Swedish internet forum. *Journal of Drug Issues*, 51(1):181–195, 2021.
Moore, T., Caulkins, J., Ritter, A., Dietze, P., Monagle, S., and Pruden, J. Heroin markets in Australia: Current understandings and future possibilities. *DPMP Monograph*, 2005.
Moore, T. J. and Pacula, R. L. *Causes and Consequences of Illicit Drug Epidemics*, pages 1–37. Springer International Publishing, Cham, 2020.
Moyle, B. The raw and the carved: Shipping costs and ivory smuggling. *Ecological Economics*, 107:259–265, 2014.
Mukherjee, A., Sacks, D. W., and Yoo, H. The effects of the opioid crisis on employment: Evidence from labor market flows. *Journal of Human Resources, forthcoming*, 2023.
Mullahy, J. and Norton, E. C. Why transform Y? A critical assessment of dependent-variable transformations in regression models for skewed and sometimes-zero outcomes. *NBER Working Paper 30735*, 2022.
Mullainathan, S. and Spiess, J. Machine learning: An applied econometric approach. *Journal of Economic Perspectives*, 31(2):87–106, 2016.
Norton, D. A. On the economic theory of smuggling. *Economica*, 55(217):107–118, 1988.
Office of National Drug Control Policy, Washington, D. *National Drug Control Strategy.* Office of National Drug Control Policy, 2022.
Pardo, B., Taylor, J., Caulkins, J. P., Kilmer, B., Reuter, P., and Stein, B. D. The future of

fentanyl and other synthetic opioids. *RAND*, 2019.

Pierce, J. R. and Schott, P. K. The surprisingly swift decline of U.S. manufacturing employment. *American Economic Review*, 106(7):1632–62, 2016.

Pierce, J. R. and Schott, P. K. Trade liberalization and mortality: Evidence from U.S counties. *American Economic Review: Insights*, 2(1):47–64, 2020.

Pitt, M. Smuggling and price disparity. *Journal of International Economics*, 11(4):447–58, 1981.

Pitts, W. J., Heller, D., Smiley-McDonald, H., Weimer, B., Grabenauer, M., Bollinger, K., Ropero-Miller, J., and Pressley, D. Understanding research methods, limitations, and applications of drug data collected by the National Forensic Laboratory Information System (NFLIS-Drug). *Journal of Forensic Sciences*, 2023.

Powell, D., Alpert, A., and Pacula, R. L. Transitioning epidemic: How the opioid crisis is driving the rise in Hepatitis C. *Health Affairs*, 38(2):287–294, 2019.

Redding, S. J. Trade and geography. *Handbook of International Economics*, 5:147–217, 2022.

Redding, S. J. and Rossi-Hansberg, E. Quantitative spatial economics. *Annual Review of Economics*, 9:21–58, 2017.

Rotunno, L. and Vézina, P. L. Chinese networks and tariff evasion. *World Economy*, pages 143–164, 2013.

Ruggles, S., Flood, S., Sobek, M., Brockman, D., Cooper, G., Richards, S., and Schouweiler, M. IPUMS USA: Version 13.0 [dataset]. *Minneapolis, MN: IPUMS*, 13:D013, 2023.

Ruhm, C. J. Living and dying in America: An essay on deaths of despair and the future of capitalism. *Journal of Economic Literature*, 60(4):1159–1187, 2022.

Russo, F. F. Cocaine: The complementarity between legal and illegal trade. *The World Economy*, 37(9):1290–1314, 2014.

Sacks, D. W., Hollingsworth, A., Nguyen, T., and Simon, K. Can policy affect initiation of addictive substance use? Evidence from opioid prescribing. *Journal of Health Economics*, 76: 102397, 2021.

Schnell, M. Physician behavior in the presence of a secondary market: The case of prescription opioids. *Working Paper*, 2022.

Schnell, M. and Currie, J. Addressing the opioid epidemic: Is there a role for physician education? *American Journal of Health Economics*, 4(3):383–410, 2018.

Schott, P. K. The relative sophistication of Chinese exports. *Economic Policy*, 53:5–49, 2008.

Schwandt, H. and Von Wachter, T. M. Socio-economic decline and death: The life-cycle impacts of recessions for labor market entrants. *NBER Working Paper 26638*, 2023.

Slavova, S., Delcher, C., Buchanich, J. M., Bunn, T. L., Goldberger, B. A., and Costich, J. F. Methodological complexities in quantifying rates of fatal opioid-related overdose. *Current Epidemiology Reports*, 6:263–274, 2019.

Stanley, T. H. The fentanyl story. *The Journal of Pain*, 15(12):1215–1226, 2014.

Stein, B. D., Kilmer, B., Taylor, J., and Vaiana, M. E. e. *America's opioid ecosystem*. RAND Corporation, 2023.

Walters, K. Fentanyl trafficking trends in the United States. *United States Department of Justice*, 66:55–57, 2018.

Westhoff, B. Fentanyl, Inc.: How rogue chemists are creating the deadliest wave of the opioid epidemic. *Atlantic Monthly Press*, 2019.

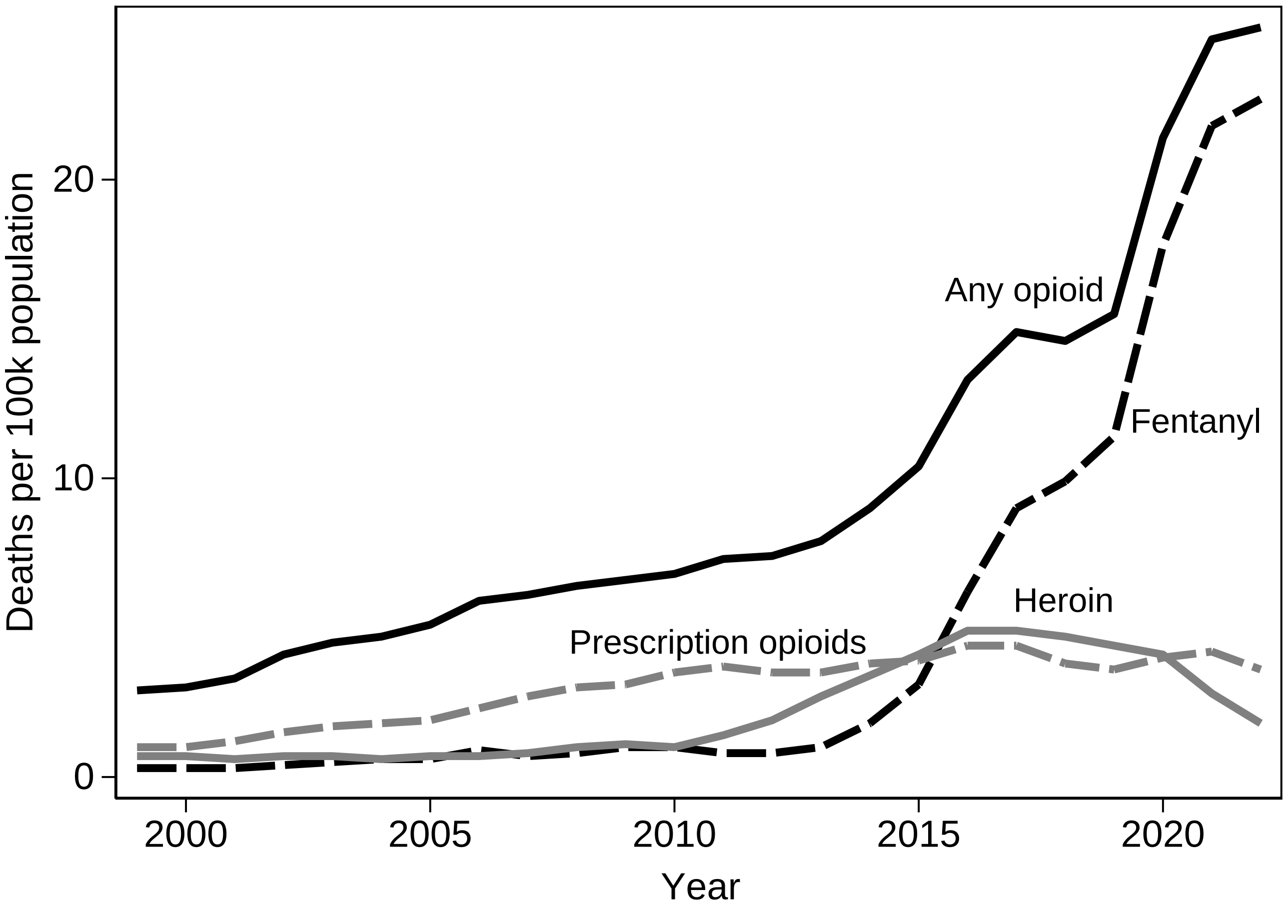
Wolf, H. Intranational home bias in trade. *Review of Economics and Statistics*, 82:555–63, 2000.

Zitzewitz, E. Forensic economics. *Journal of Economic Literature*, 50(3):731–769, 2012.

Zoorob, M. Fentanyl shock: The changing geography of overdose in the United States. *International Journal of Drug Policy*, 70:40–46, 2019.

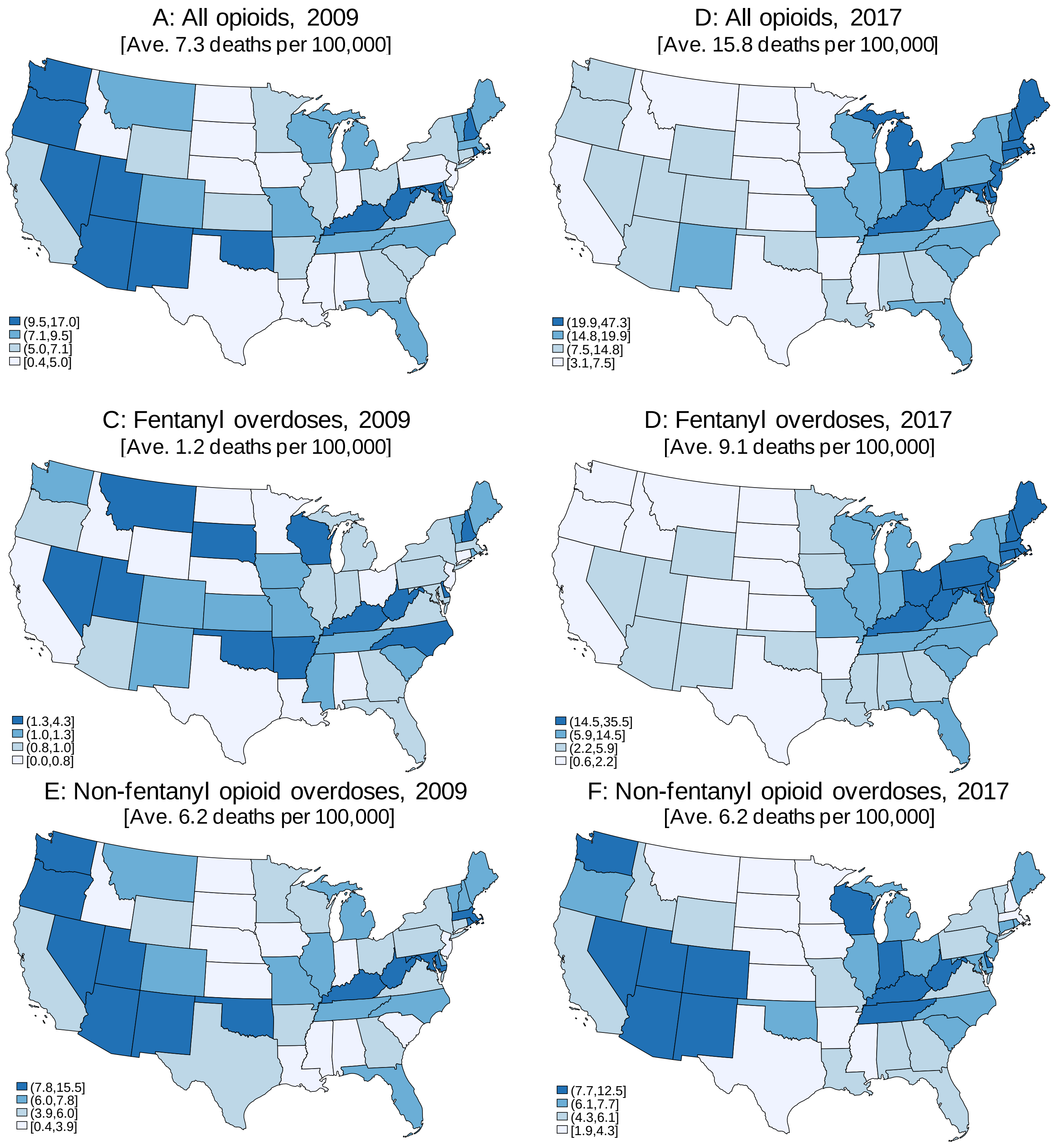
Zou, E. Y. Unwatched pollution: The effect of intermittent monitoring on air quality. *American Economic Review*, 111(7):2101–2126, 2021.

Figure 1 U.S. opioid overdose deaths, 1999-2022



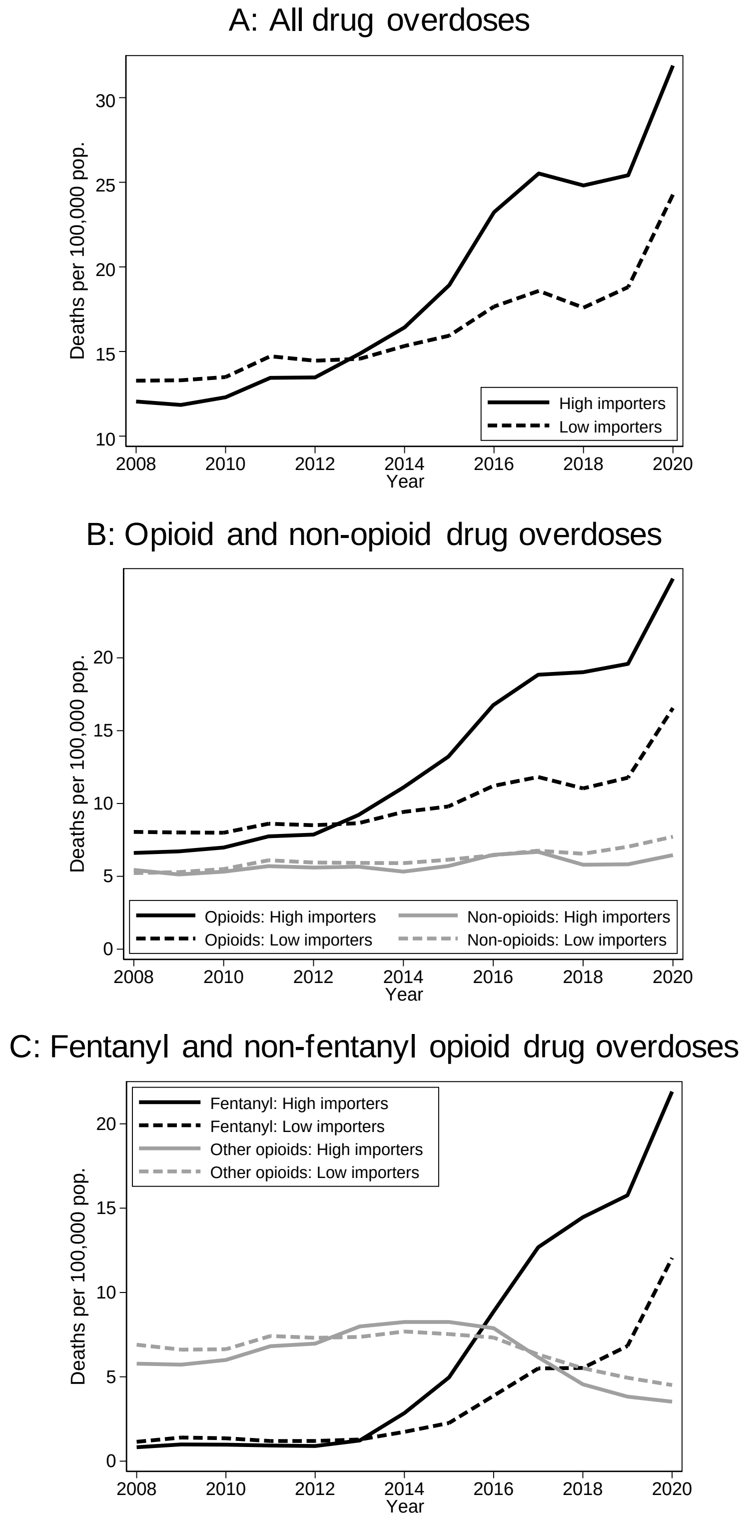
Notes: This figure shows trends in drug overdose deaths per 100,000 population. Data are from the Multiple Cause of Death files and provisional overdose data from the National Center for Health Statistics (Ahmad et al. 2023). Drug overdoses have one of the following underlying cause-of-death codes from the International Classification of Disease, Version 10 (ICD-10): X40-X44, X60-64, X85 and Y10-Y14. Opioid overdoses have any of the following drug identification codes: T40.0-T40.4 and T40.6. For the specific opioid types, the respective ICD-10 drug identification codes are: fentanyl (T40.4); heroin (T40.1); and prescription opioids / oxycodone (T40.2). Some deaths have multiple opioid-related drug identification codes, and are counted in each category of specific opioids.

Figure 2 Distribution of drug overdose death rates before and after the rise of fentanyl



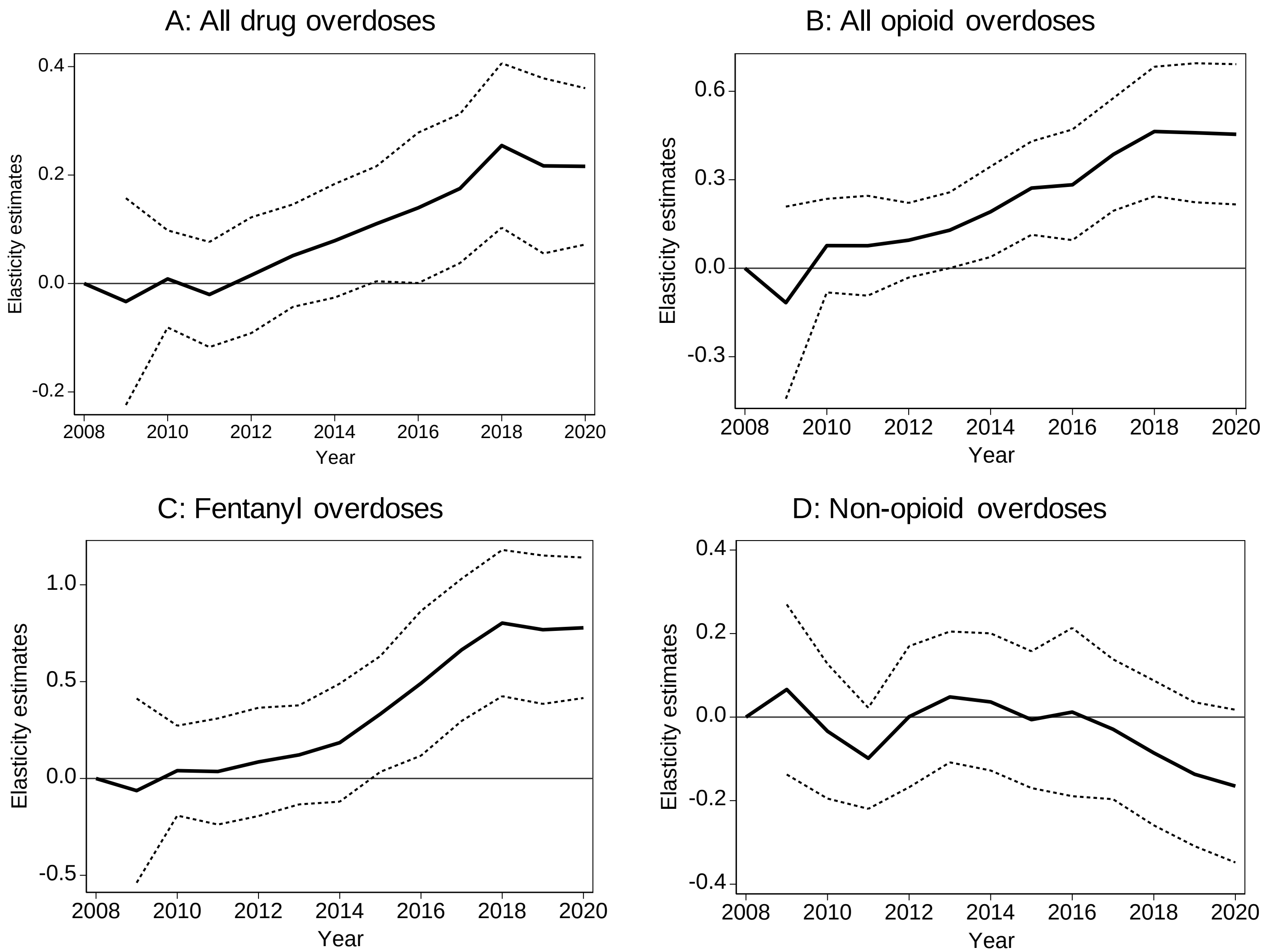
Notes: These figures show the distribution of different types of opioid overdose deaths per 100,000 residents for the continental U.S. in 2009 and 2017, which is four years either side of when fentanyl deaths started to rise in 2013. Shading shows the rates in each year by quartiles, with darker shading indicating higher overdose death rates. Between 2009 and 2017, the 50-state Spearman rank correlation is 0.45 for all opioid overdoses; 0.13 for fentanyl overdoses; and 0.65 for non-fentanyl opioid overdoses.

Figure 3 Drug overdose rates in states with above- and below-median imports per capita



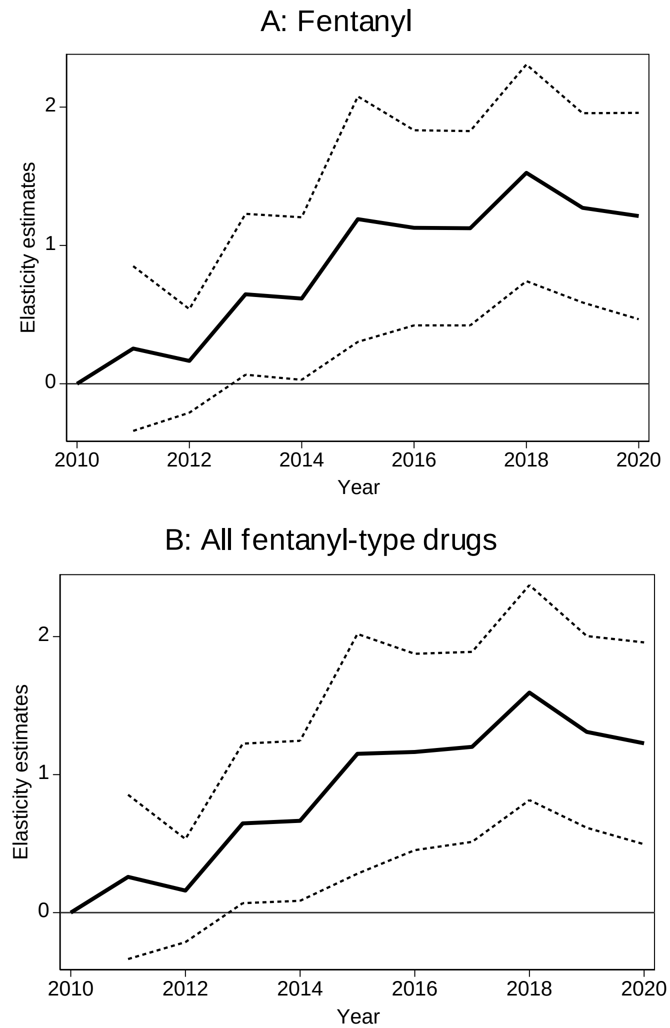
Notes: This figure shows drug overdose trends for two groups of 25 states split by the median value of imports per resident over the 2008-2020 period (which is $3,860 per resident). Drug overdose deaths are those with an ICD-10 underlying cause of death of X40-X44, X60-64, X85 and Y10-Y14. Opioid overdoses are drug overdoses with T40.0-T40.4 or T40.6 drug identification codes, while fentanyl overdoses have the T40.4 drug identification code. The figures show that states defined as "high importing" (above the median) and "low importing" (below the median) have similar drug overdose trends before 2013, but that high-importing states have markedly higher drug overdose rates thereafter. They show that that post-2013 gap is primarily due to fentanyl overdoses.

Figure 4 The relationship between imports and drug overdose deaths



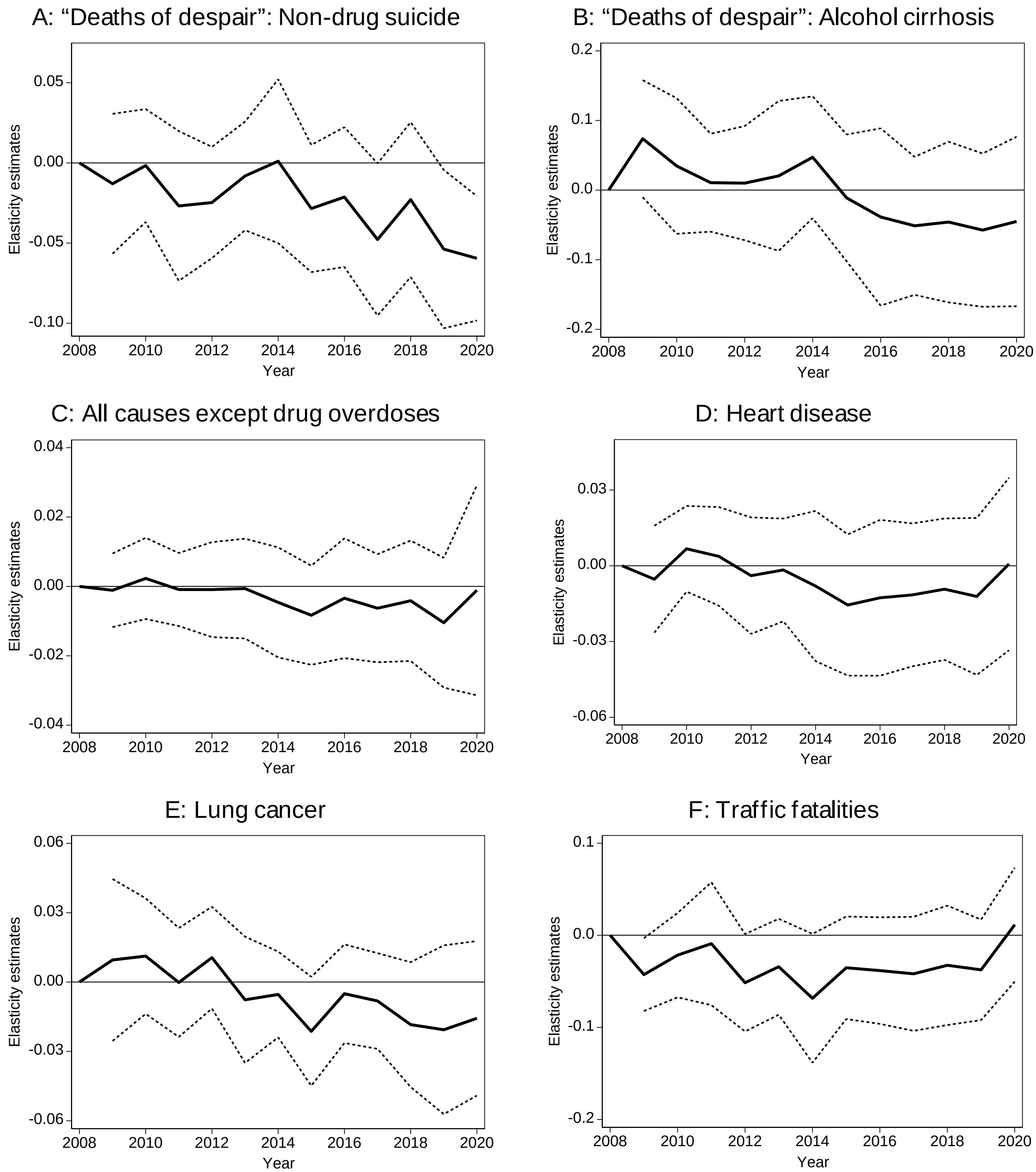
Notes: This figure plots the estimated elasticities and 95% confidence intervals of different drug overdose death rates per 100,000 state residents to the 2008 value of imports per state resident (relative to the 2008 reference period). Drug overdose deaths are those with an underlying cause of death with the following International Classification of Disease, Version 10 (ICD-10) codes: X40-X44, X60-64, X85 and Y10-Y14. Opioid overdoses are defined as drug overdoses with the presence of any of the following drug identification codes: T40.0-T40.4 and T40.6. Fentanyl overdoses are defined as overdoses with the presence of the T40.4 drug identification code. The estimates are based on equation (1), which includes state and Census-region-by-year fixed effects, various time-varying economic and demographic covariates, and allows for an arbitrary correlation in errors at the state level. Each regression uses 650 observations. The estimates are summarized in Table 2. See text for more details.

Figure 5 The relationship between imports and police seizure rates of fentanyl



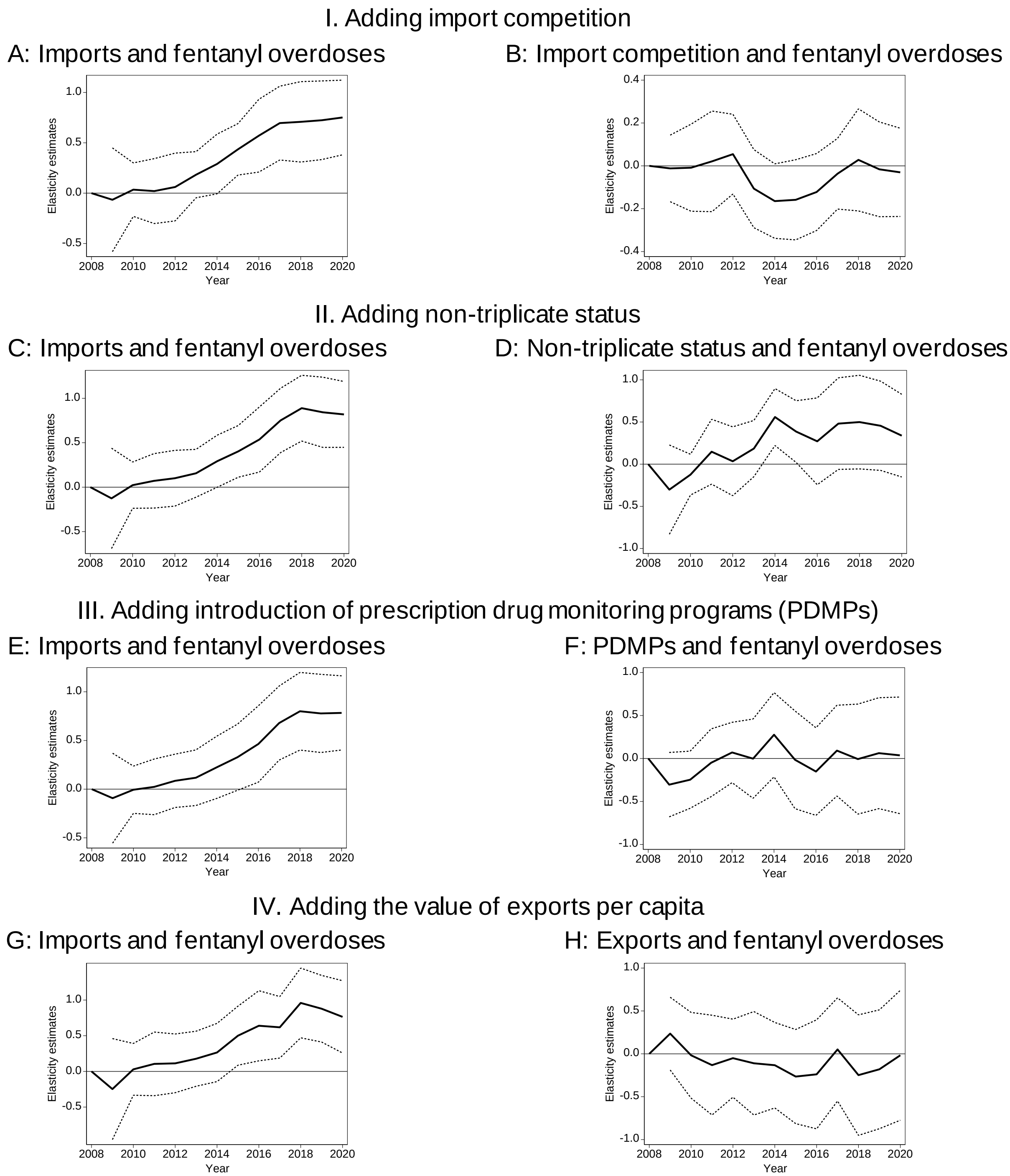
Notes: This figure plots the estimated elasticities and 95% confidence intervals of police seizures per 100,000 state residents to the 2008 value of imports per state resident. Fentanyl-type drugs includes fentanyl and fentanyl analogs (e.g., acetyl fentanyl, carfentanil). The estimates are based on an adapted version of equation (1), where the reference period is 2010 and the year indicator variables are from 2011 to 2020 (as no seizure data are available for 2008 and 2009). A value of 0.01 is added to the seizures per 100,000 residents before we take the natural log, as there are some zeroes in the data. Each regression uses 550 observations. The estimates are summarized in Appendix Table A3. See text for more details.

Figure 6 The relationship between imports and other causes of death



Notes: These figures show estimated elasticities and 95% confidence intervals for various causes per 100,000 state residents to the 2008 value of imports per state resident (relative to 2008). The ICD-10 underlying cause-of-death codes are: non-drug suicide (U03,X65-X84,Y87.0); alcoholic liver disease (K70); all causes except the drug overdose codes (X40-X44,X60-64,X85, Y10-Y14); heart disease (I00-I09,I11,I13,I20-I51); lung cancer (C33-C34); traffic accidents (V02-V04,V09.0,V09.2,V12-V14,V19.0-V19.2, V19.4-V19.6,V20-V79,V80.3-V80.5,V81.0-V81.1,V82.0-V82.1,V83-V86,V87.0-V87.8,V88.0-V88.8,V89.0,V89.2). The estimates are based on equation (1), and each regression uses 650 observations. See the notes for Table 2 and the text for more details.

Figure 7 Assessing the role of determinants of opioid demand

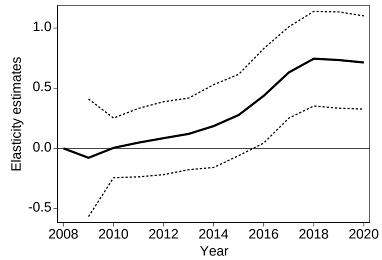


Notes: Each row shows estimated elasticities and 95% confidence intervals from a single regression. The figures on the left show the relationship between fentanyl overdoses and imports, while the figures on the right show the relationship between fentanyl overdoses and an additional state characteristic interacted with year identifiers, which is added to equation (1). These are: (i) a measure of each state's exposure to import competition, using national industry-level imports in each year and the 2000 industry shares of state-level employment; (ii) an identifier for states that did not have a "triplicate" prescription drug monitoring program in the 1990s; (iii) a variable equal to one once modern prescription drug monitoring program (PDMP) laws are enacted in a state, and zero otherwise; (iv) the natural log of the annual real value of exports per state resident. See the text for more details.

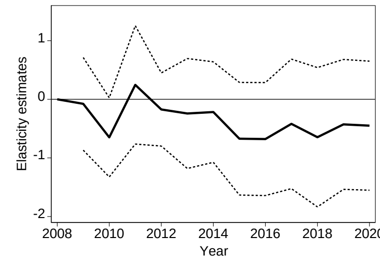
Figure 8 Assessing the role of alternative determinants of fentanyl supply

I. Adding quantity of legal fentanyl shipments

A: Imports and fentanyl overdoses

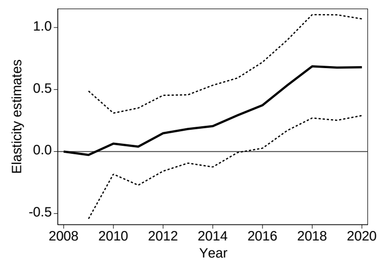


B: Legal fentanyl and fentanyl overdoses

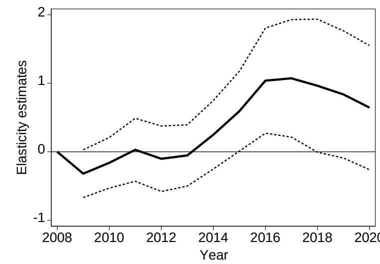


II. Adding east of Mississippi River identifier

C: Imports and fentanyl overdoses

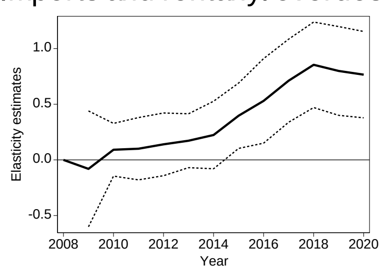


D: East of Mississippi River and fentanyl overdoses

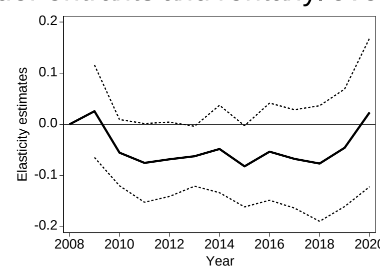


III. Adding U.S. border entrants

E: Imports and fentanyl overdoses

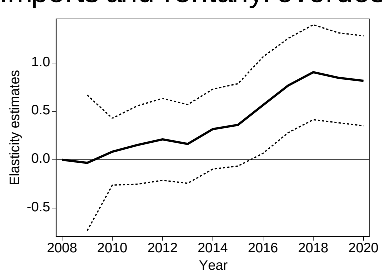


F: Border entrants and fentanyl overdoses



IV. Dropping states bordering Canada and Mexico

G: Imports and fentanyl overdoses



Notes: Each of the first three rows shows estimated elasticities and 95% confidence intervals from a single regression. The figures on the left show the relationship between fentanyl overdoses and imports, while the figures on the right show the relationship between fentanyl overdoses and an additional state characteristic interacted with year identifiers, which is added to equation (1). These are: (i) the natural log of the legal amount of fentanyl shipped annually to each state (grams/resident); (ii) an identifier for states east of the Mississippi River to account for spatial differences in heroin types; and (iii) the natural log of the annual number of inbound U.S. land border entrants per 100,000 state residents (0.01 is added before taking the log of it). The final row shows estimates from equation (1) without the 14 states that have land borders with Canada or Mexico. See the text for more details.

Table 1. States ranked by average annual value of imports per resident ($000s), 2008-2020

Top quintile		Second quintile		Middle quintile		Fourth quintile		Bottom quintile	
State	Ave.	State	Ave.	State	Ave.	State	Ave.	State	Ave.
New Jersey	11.5	New Hampshire	7.2	Massachusetts	4.5	Mississippi	3.4	Alaska	2.3
Michigan	10.5	South Carolina	6.7	Maryland	4.2	Florida	3.2	Nebraska	1.8
Tennessee	9.5	Indiana	6.6	Louisiana	4.1	Nevada	2.9	Colorado	1.8
California	8.7	New York	6.0	Minnesota	4.1	Idaho	2.8	West Virginia	1.7
Kentucky	8.4	Vermont	5.5	North Dakota	3.9	Maine	2.8	Oklahoma	1.7
Delaware	8.3	Connecticut	5.5	Wisconsin	3.8	Virginia	2.7	Hawaii	1.2
Rhode Island	7.7	Washington	5.2	Oregon	3.8	Arizona	2.7	Montana	1.2
Illinois	7.7	Pennsylvania	5.1	Alabama	3.6	Iowa	2.6	New Mexico	1.2
Texas	7.4	Ohio	4.8	Utah	3.6	Missouri	2.5	Wyoming	1.1
Georgia	7.2	North Carolina	4.7	Kansas	3.5	Arkansas	2.5	South Dakota	1.1

Notes: We use the real value of all imports except oil and gas imports, in thousands of 2022 dollars. See Section 3 for more details.

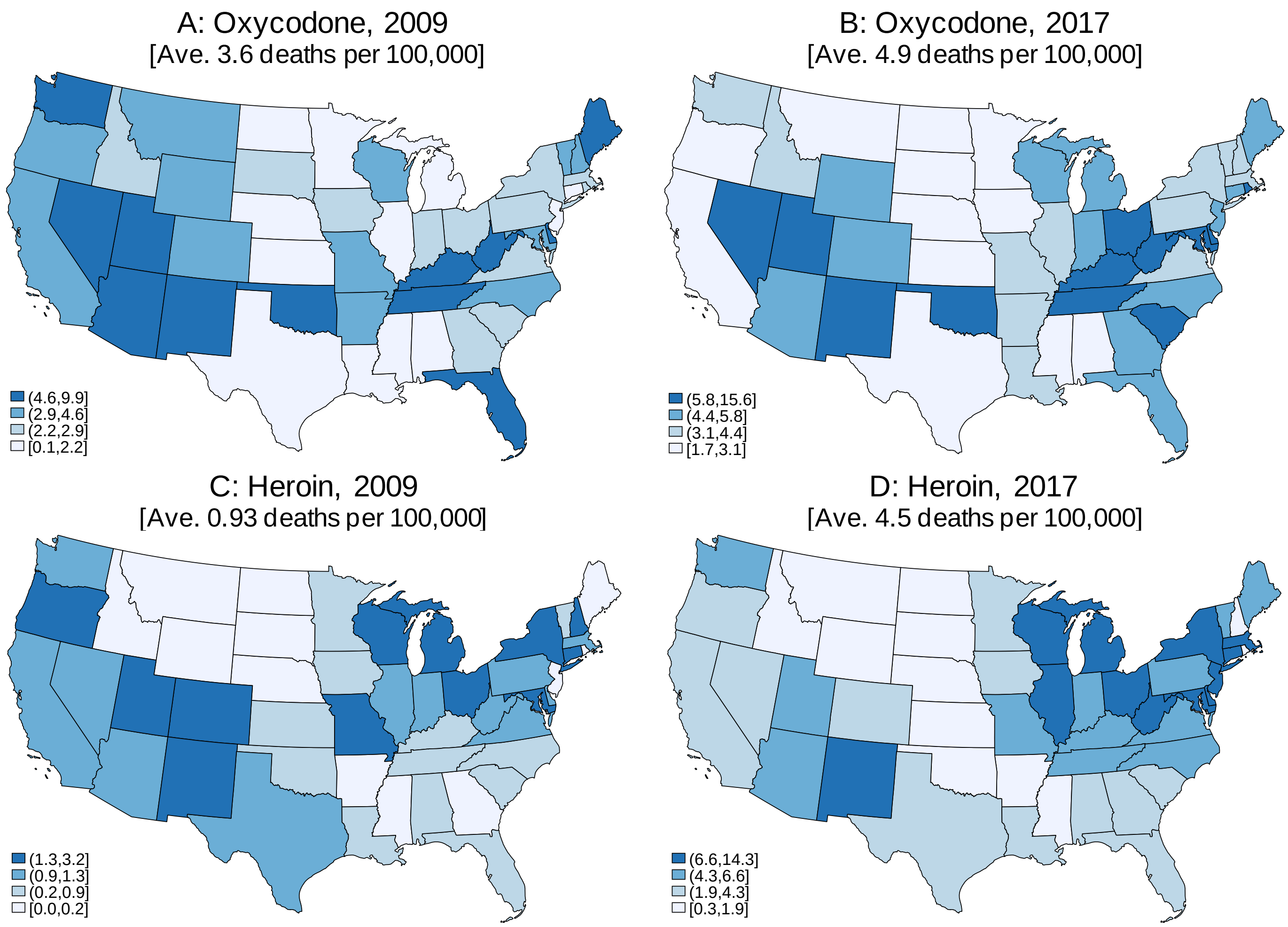
Table 2 The relationship between imports and drug overdoses

	Average elasticity estimates				Mean deaths /
	2009-12	2013-16	2017-20	R-sq.	100,000 pop.
All drug overdoses	-0.008	0.095	0.216**	0.904	17.5
	(0.039)	(0.051)	(0.069)		
All opioid overdoses	0.033	0.219**	0.441**	0.894	11.6
	(0.074)	(0.068)	(0.102)		
Fentanyl overdoses	0.025	0.283*	0.753**	0.909	5.10
	(0.123)	(0.138)	(0.174)		
Non-opioid overdoses	-0.016	0.023	-0.104	0.837	5.99
	(0.066)	(0.076)	(0.075)		

Notes: * denotes $p < 0.05$, ** denotes $p < 0.01$. This table summarizes the estimated elasticities and standard errors of different drug overdose death rates per 100,000 state residents to the 2008 value of imports per state resident (relative to the 2008 reference period). Drug overdose deaths are those with an underlying cause of death with the following International Classification of Disease, Version 10 (ICD-10) codes: X40-X44, X60-64, X85 and Y10-Y14. Opioid overdoses are defined as drug overdoses with the presence of any of the following drug identification codes: T40.0-T40.4 and T40.6. Fentanyl overdoses are defined as overdoses with the presence of the T40.4 drug identification code. The estimates are based on equation (1), which includes year fixed effects, state fixed effects, various time-varying economic and demographic covariates, and allows for an arbitrary correlation in errors at the state level. The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. Each regression uses 650 observations. The annual estimates are plotted in Figure 4. See text for more details.

Appendix for:
"Importing the Opioid Crisis? International Trade and Fentanyl Overdoses"

Figure A1 Relative distribution of oxycodone and heroin overdose death rates in 2009 and 2017

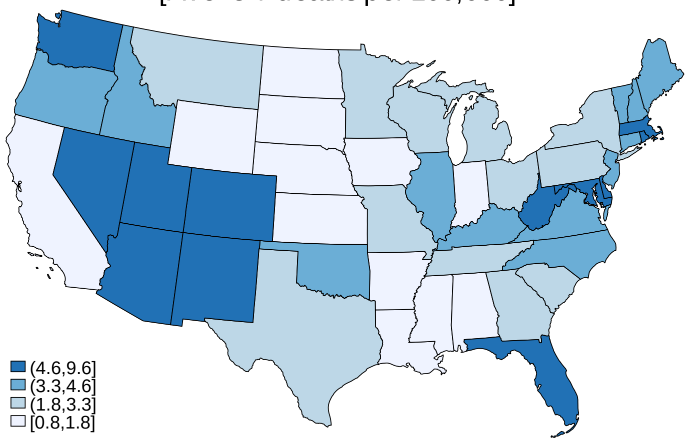


<u>Notes:</u> This figure complements Figure 2 by showing the distribution of oxycodone (prescription opioids) and heroin overdose deaths per 100,000 residents for the continental U.S. in 2009 and 2017, which is four years either side of when fentanyl deaths started to rise in 2013. Some deaths have multiple opioid-related drug identification codes, and are counted in each category of specific opioids. Shading shows the rates in each year by quartiles, with darker shading indicating higher overdose death rates. Between 2009 and 2017, the 50-state Spearman rank correlation is 0.58 for oxycodone overdoses and 0.63 for heroin overdoses, which is much larger than the equivalent fentanyl rank correlation of 0.13 in Figure 2.

Figure A2 The relative distribution of all opioid overdose deaths in 2001, 2009 and 2017

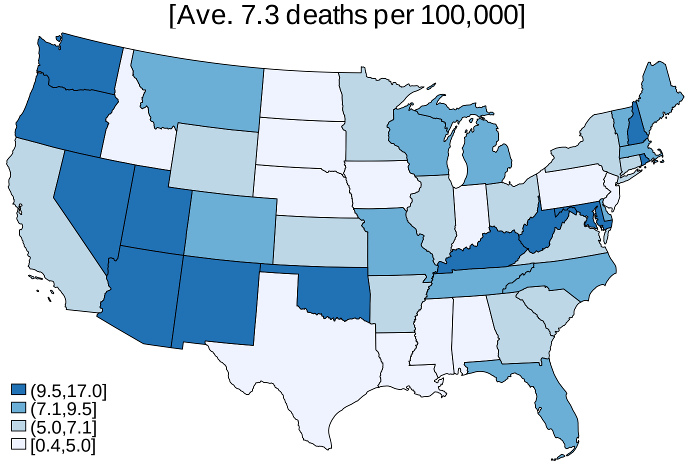
A: 2001

[Ave. 3.7 deaths per 100,000]



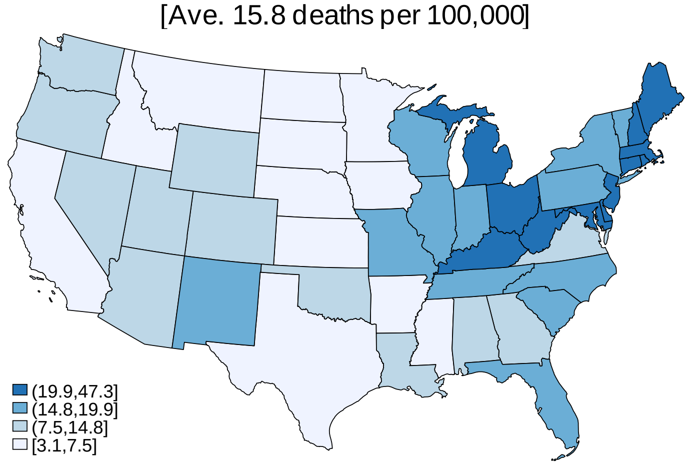
B: 2009

[Ave. 7.3 deaths per 100,000]



C: 2017

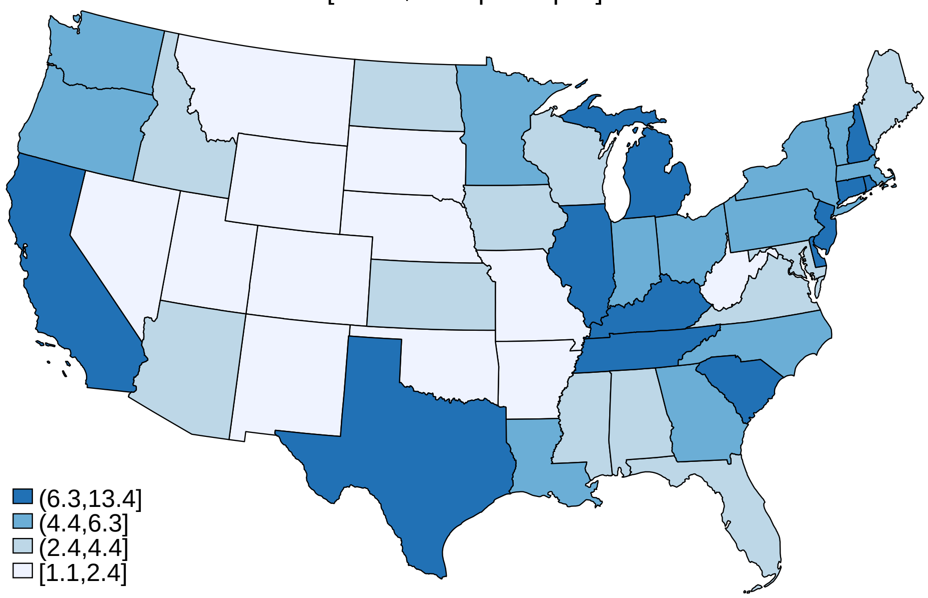
[Ave. 15.8 deaths per 100,000]



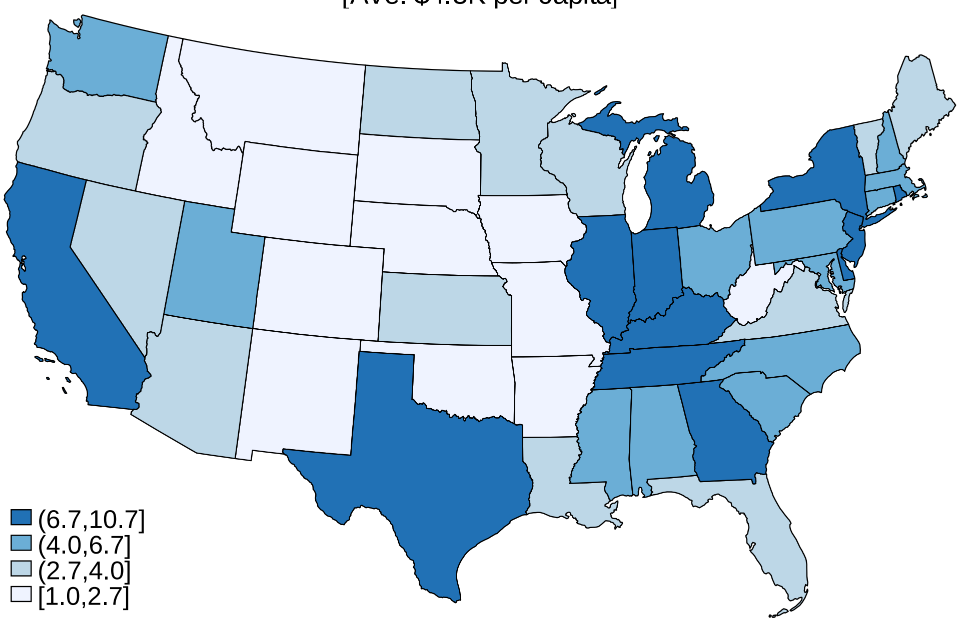
Notes: This figure complements Figure 2 by showing the distribution of opioid overdose deaths per 100,000 residents for the continental U.S. in 2001, in addition to those for 2009 and 2017 shown in Figure 2. Shading shows the rates in each year by quartiles, with darker shading indicating higher overdose death rates. The figure shows that there is much more spatial persistence in opioid overdose rates over the first eight-year period than in the second one, which spans the rise of fentanyl. (The 50-state Spearman rank correlation is 0.67 for 2001-2009 and 0.45 for 2009-2017.)

Figure A3 The relative distribution of imports per capita in 2008 and 2020

A: Value of imports, 2008
[Ave. $4.5K per capita]

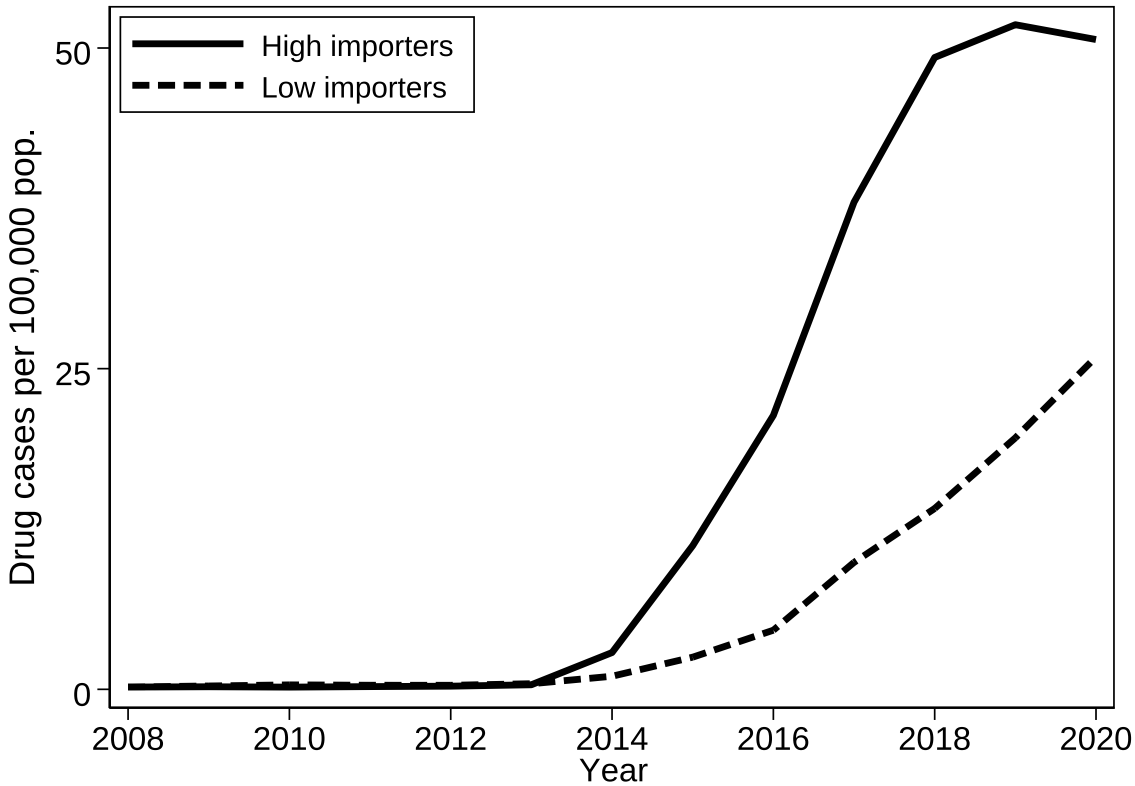


B: Value of imports, 2020
[Ave. $4.5K per capita]



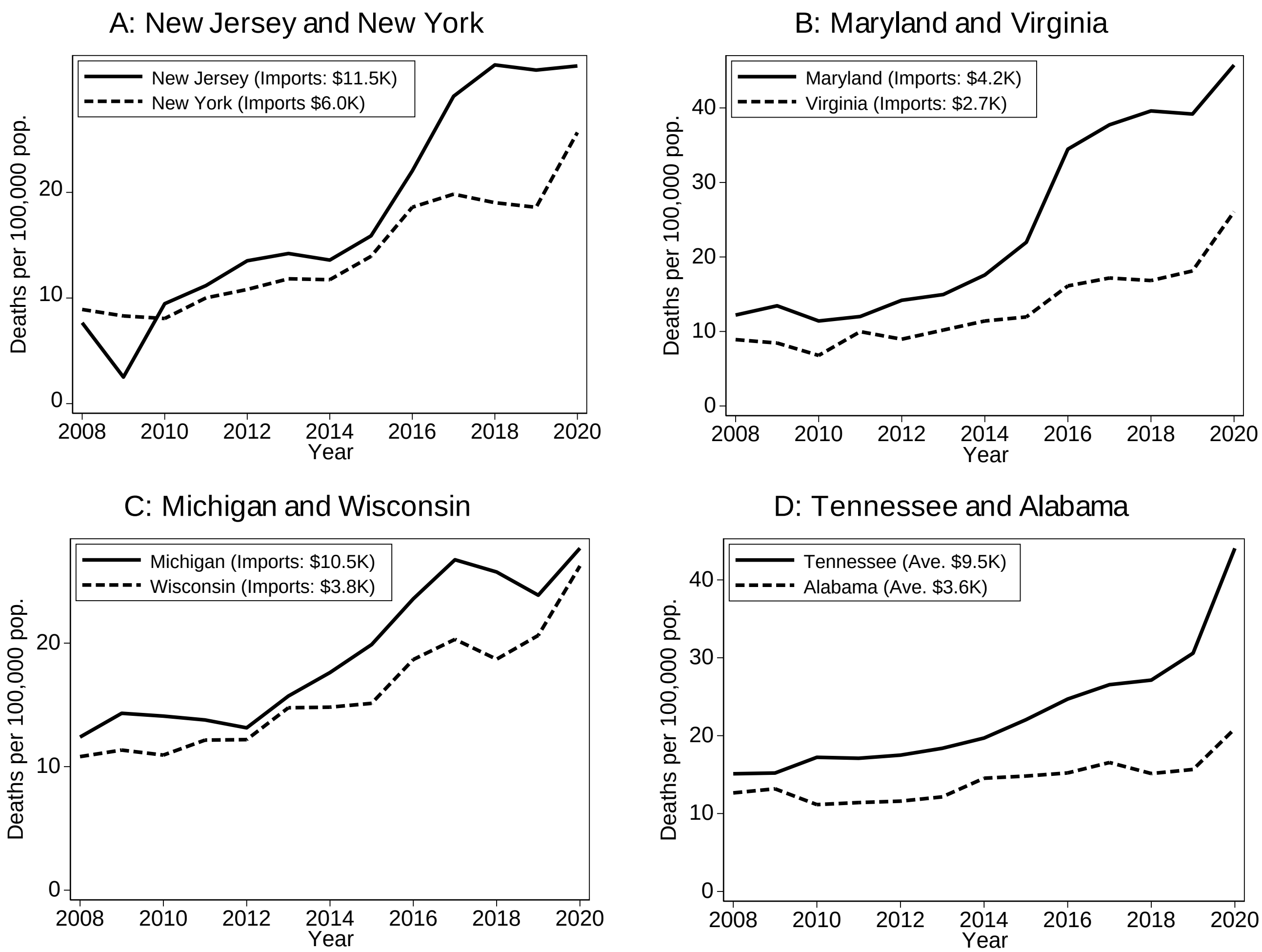
Notes: This figure shows the distribution of the value of imports (excluding oil and gas) per resident for the continental U.S. at the beginning and end of our sample period (2008 and 2020). Shading shows the value of imports in each year by quartiles, with darker shading indicating a higher value of imports. The average value of imports per capita is the same in both years (in 2022 dollars). For all 50 states, the Spearman rank correlation across 2008 and 2020 is 0.90.

Figure A4 The police seizure rates of fentanyl and fentanyl analogs in states with above-median and below-median imports per resident



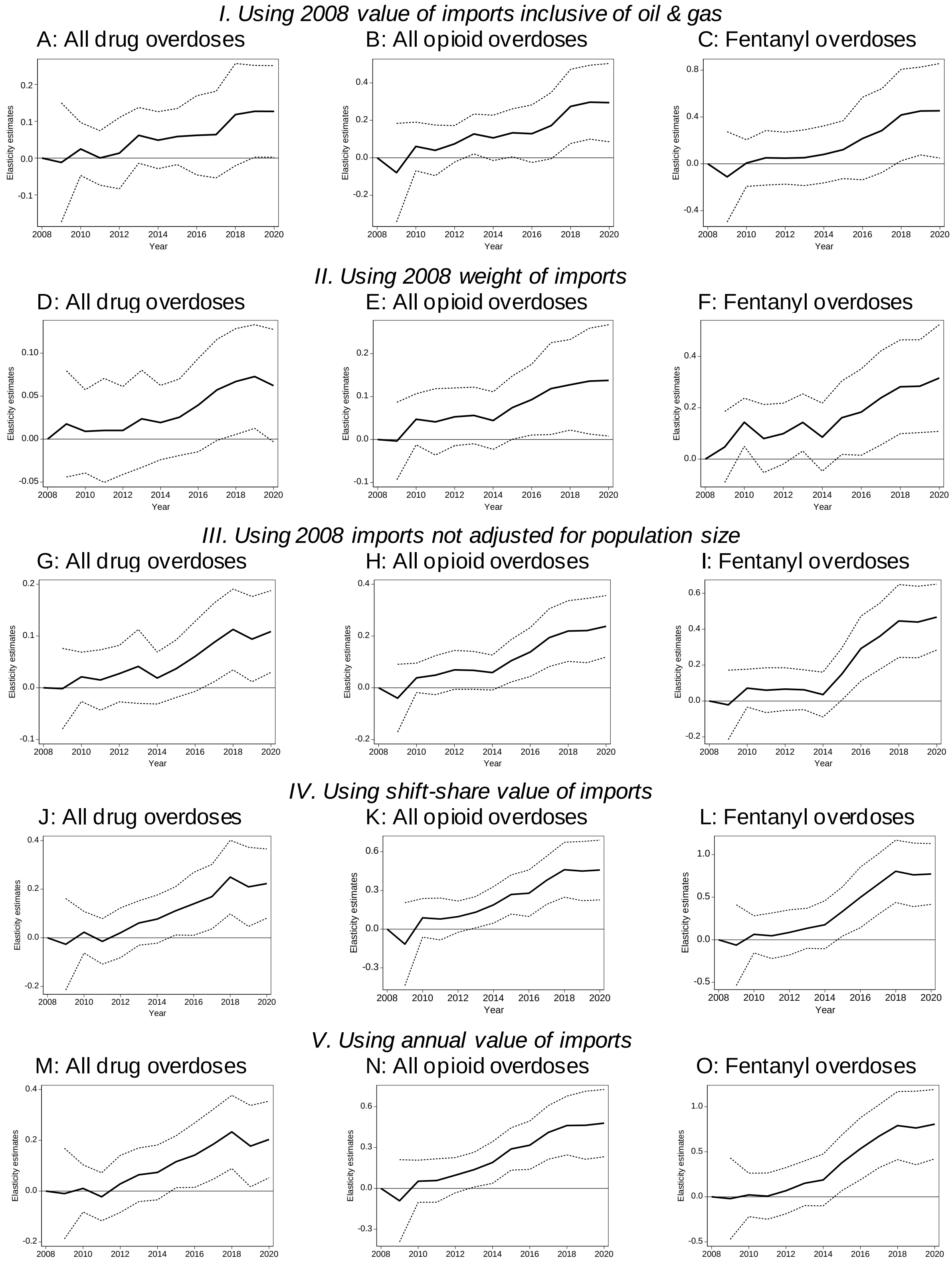
Notes: This figure shows the rates at which police seize fentanyl and fentanyl analogs for two groups of 25 states split by the median value of imports per resident over the 2008-2020 period (which is $3,860 per resident). The figure shows that states defined as "high importing" (above the median) and "low importing" (below the median) have similarly low fentanyl seizure rates before 2013. After 2013, both groups of states have increasing fentanyl seizure rates but high-importing states have markedly higher seizure rates than low-importing states.

Figure A5 Drug overdose deaths in nearby states with different levels of imports



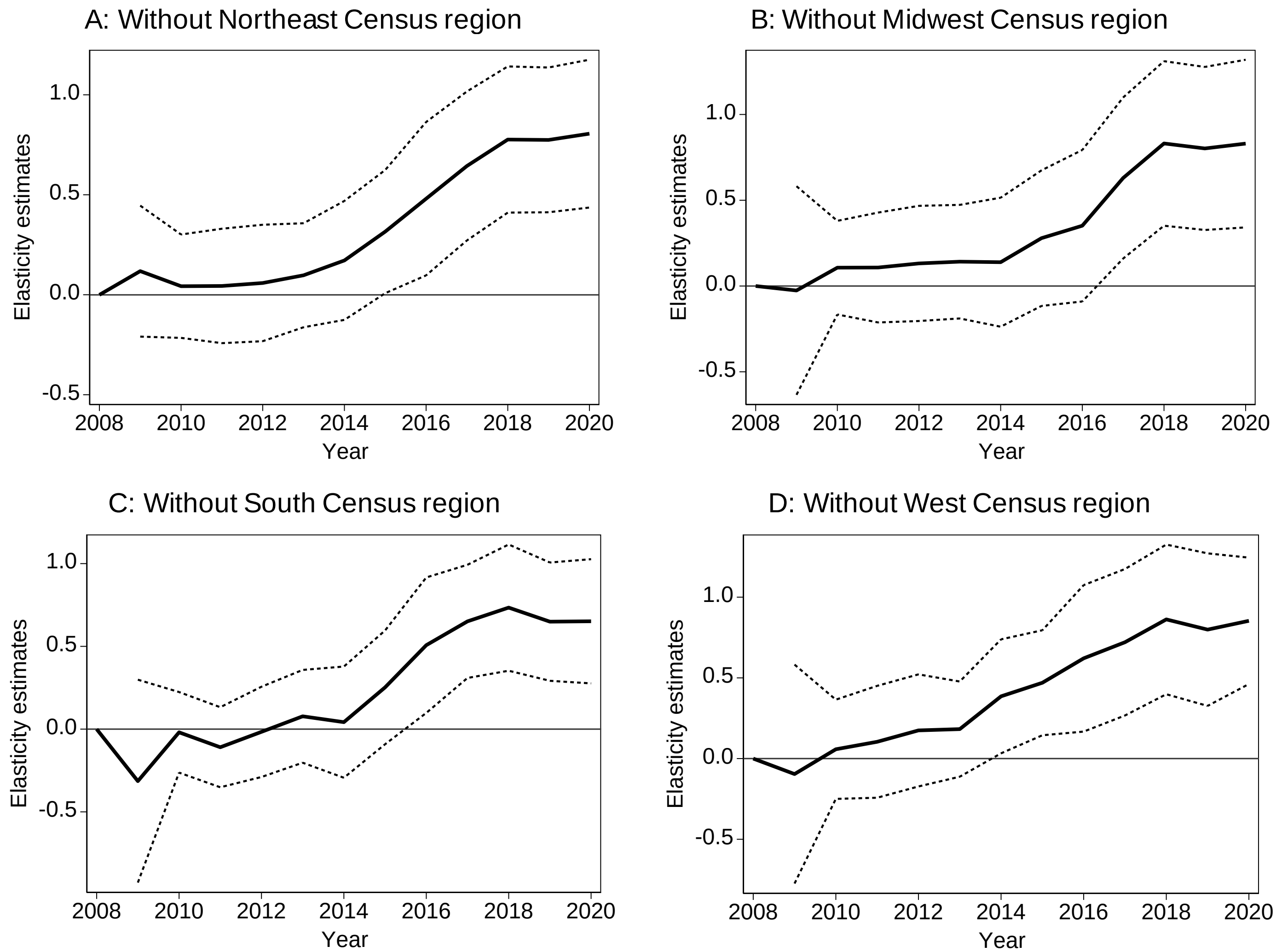
Notes: This figure shows pairwise comparisons of drug overdose trends of larger adjoining states that have different levels of imports per resident. The trend for the higher-importing state is always shown as a solid line, while the trend for the lower-importing state is shown as a dashed line. Each state's average value of imports per resident over the 2008-2020 period is shown in the legends. The comparisons generally shown that these adjoining states had similar drug-overdose trends before around 2013-2015, after which higher-importing states had relatively more drug overdose deaths than lower-importing states.

Figure A6 The relationship between imports and overdoses using different import measures



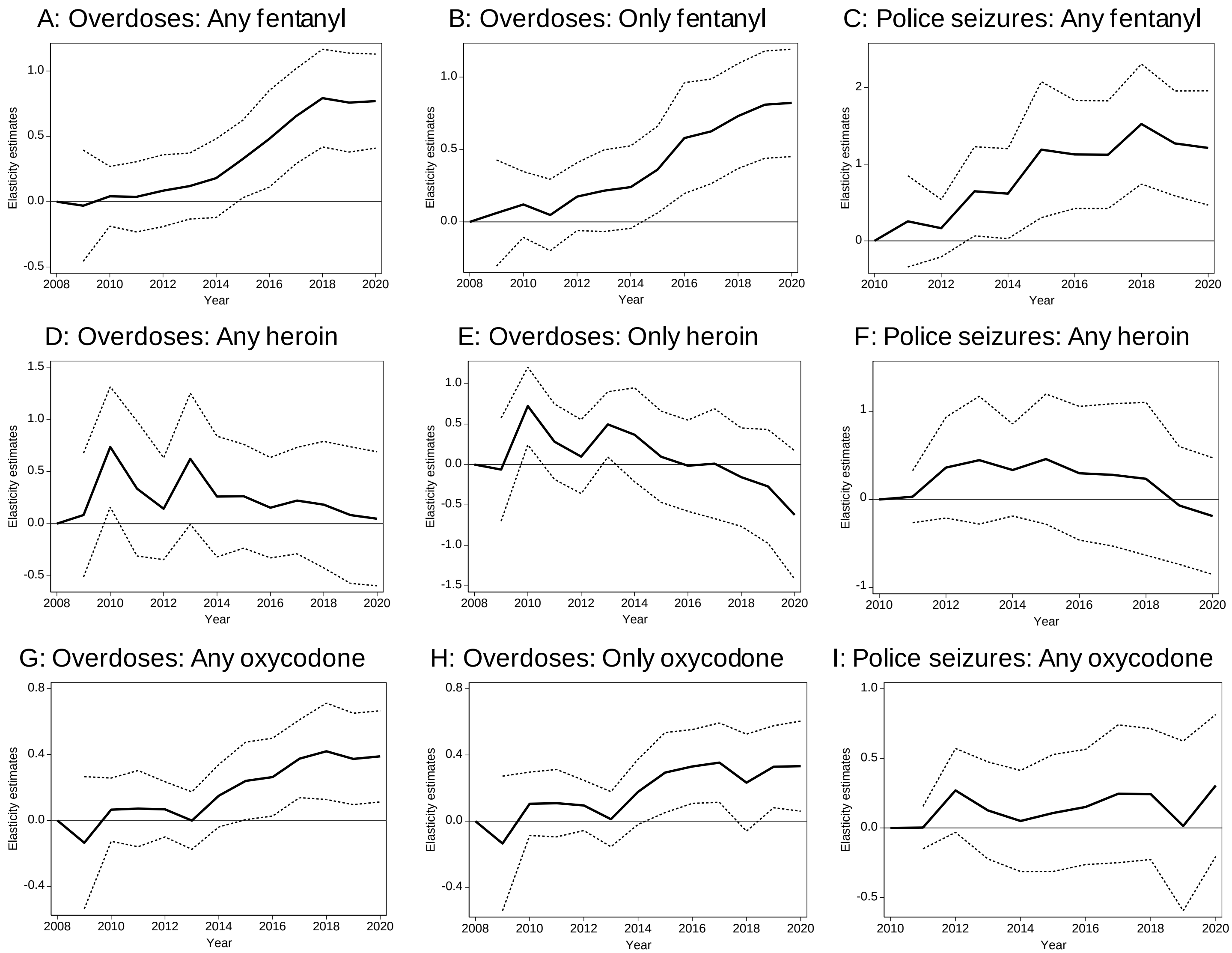
Notes: This figure plots the estimated elasticities and 95% confidence intervals of different measures of imports per state resident for all drug overdoses, all opioid overdoses, and fentanyl overdoses. The estimates are based on equation (1), and use 650 observations. See the notes in Table 2 and the text for more details.

Figure A7 Assessing regional variation in the relationship between imports and fentanyl overdoses



Notes: These figures show, after omitting each Census region in turn, the estimated elasticities and 95% confidence intervals of fentanyl overdoses per 100,000 state residents to the 2008 value of imports per state resident. The estimates are based on equation (1). The observations used and estimates are summarized in Appendix Table A3. See the text for more details.

Figure A8 The relationship between imports and specific opioids



Notes: This figure plots estimated elasticities and 95% confidence intervals of various opioid outcomes to the 2008 value of imports. The panels on the left show estimates for overdose rates when that type of opioid is reported on the death certificate. The panels in the middle show estimates for overdose rates when only one type of opioid is reported on the death certificate. The panels on the right show estimates for police seizures where each opioid is identified through forensic analysis; the data include seizures where multiple opioids are present. For all outcomes, 0.01 is added before taking logs, as some observations are zero. The estimates are based on equation (1); the seizure estimates use a reference period of 2010 and year indicators from 2011 to 2020 (as no seizure data are available for 2008 and 2009). The overdose estimates use 650 observations, while the seizure estimates use 550 observations. See the text for more details.

Table A1 Summary Statistics

	Obs.	Mean	Std. dev.	Min.	Max.
Drug overdose rates per 100,000 residents					
All drug overdoses	650	17.6	8.70	2.19	74.5
All opioid overdoses	650	11.6	8.25	0.41	63.3
Non-opioid overdoses	650	5.99	2.72	0.74	22.9
Fentanyl overdoses	650	5.10	7.84	0.01	58.4
Fentanyl overdoses when only opioid	650	3.17	5.28	0.01	40.6
Non-fentanyl overdoses	650	6.45	3.48	0.40	24.7
Heroin overdoses	650	2.85	2.77	0	15.2
Heroin overdoses when only opioid	650	1.47	1.36	0	7.46
Oxycodone overdoses	650	4.35	2.88	0.08	24.2
Oxycodone overdoses when only opioid	650	2.88	2.02	0.05	19.4
Methadone overdoses	650	1.34	0.87	0	4.94
Methadone overdoses when only opioid	650	0.86	0.59	0	3.58
Only other and unspecified opioids	650	0.52	0.68	0	6.45
Other causes of death per 100,000 residents					
Non-drug suicide	650	13.7	3.98	6.01	29.2
Alcoholic liver disease	650	6.79	3.31	2.35	24.2
All deaths except drug overdoses	650	863	141	490	1,388
Heart disease	650	262	48.1	123	391
Lung cancer	650	50.4	12.8	13.7	84.6
Motor vehicle accidents	650	13.2	4.54	5.21	28.4
Main import and export measures per resident					
Value of imports, ex. oil and gas ($000s)	650	4.53	2.76	0.63	13.4
Weight of imports, ex. oil and gas (000kg)	650	1.87	3.28	0.02	28.4
Value of exports ($000s)	650	3.29	1.90	0.18	12.2
Forensic cases of police seizures per 100,000 residents					
Fentanyl	550	9.85	24.0	0	146
Fentanyl and fentanyl analogs	550	11.8	29.7	0	218
Heroin	550	38.6	43.3	0	315
Oxycodone	550	13.6	15.2	0	125
Methadone	550	1.70	1.79	0	16.1

Note: This table describes features of the key data used in the analysis. See Section 3 in the text for more details.

Table A2 The robustness of results to different regression specifications

	Elasticity estimates			
	2009-12	2013-16	2017-20	R-sq.
A. All drug overdoses				
Only year fixed effects	0.013	0.180**	0.337**	0.313
	(0.027)	(0.043)	(0.062)	
+ State fixed effects	0.013	0.180**	0.337**	0.868
	(0.028)	(0.045)	(0.065)	
+ Year x Census region	0.017	0.081*	0.185**	0.899
	(0.033)	(0.040)	(0.062)	
+ Covariates (Main specification)	-0.008	0.095	0.216**	0.904
	(0.039)	(0.051)	(0.069)	
B. All opioid overdoses				
Only year fixed effects	0.036	0.330**	0.588**	0.306
	(0.056)	(0.057)	(0.086)	
+ State fixed effects	0.036	0.330**	0.588**	0.857
	(0.058)	(0.059)	(0.089)	
+ Year x Census region	0.031	0.174**	0.373**	0.883
	(0.058)	(0.060)	(0.106)	
+ Covariates (Main specification)	0.033	0.219**	0.441**	0.894
	(0.074)	(0.068)	(0.102)	
C. Fentanyl overdoses				
Only year fixed effects	0.054	0.672**	1.136**	0.624
	(0.086)	(0.137)	(0.177)	
+ State fixed effects	0.054	0.672**	1.136**	0.866
	(0.090)	(0.143)	(0.184)	
+ Year x Census region	0.079	0.367**	0.813**	0.894
	(0.092)	(0.137)	(0.196)	
+ Covariates (Main specification)	0.025	0.283*	0.753**	0.909
	(0.123)	(0.138)	(0.174)	

Notes: * denotes p<0.05, ** denotes p<0.01. This table summarizes how the relationship the 2008 value of imports and different drug overdose rates varies with the controls included in equation (1). For each overdose rate, the first row shows the estimates and standard errors with only year fixed effects; the second shows the results once state fixed effects are added; the third shows the results once Census-region-by-year fixed effects are added; and the fourth shows results with the time-varying covariates also added, which are the same estimates presented in Table 2. See the notes for Table 2 and the text for more details.

Table A3 Assessing geographic concentration of relationship between imports and fentanyl

	Elasticity estimates				
	2009-12	2013-16	2017-20	R-sq.	Obs.
Full sample (main results)	0.025	0.283*	0.753**	0.909	650
	(0.123)	(0.138)	(0.174)		
Without Northeast Census region	0.066	0.267*	0.750**	0.896	533
	(0.120)	(0.137)	(0.169)		
Without Midwest Census region	0.080	0.228	0.773**	0.917	494
	(0.147)	(0.176)	(0.223)		
Without South Census region	-0.115	0.220	0.672**	0.911	442
	(0.107)	(0.150)	(0.159)		
Without West Census region	0.060	0.415**	0.809**	0.917	481
	(0.162)	(0.150)	(0.206)		

Notes: * denotes $p<0.05$, ** denotes $p<0.01$. This table summarizes results assessing the geographic concentration of the relationship between the 2008 value of imports and fentanyl overdoses. The top row shows the baseline results from Table 2, while the remaining rows show the results when omitting each of the four Census regions. The estimates are based on equation (1), which includes year fixed effects, state fixed effects, various time-varying economic and demographic covariates, and allows for an arbitrary correlation in errors at the state level. The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. Each regression uses 650 observations. The annual estimates are plotted in Figure A7. See the text for more details.

Table A4 Relationship between imports and police seizures of fentanyl / fentanyl analogs

		Average elasticity estimates			
		2011-12	2013-16	2017-20	R-sq.
Fentanyl seizures					
Sample	*Outcome*				
40 states with positive rates	[ln(case rates)]	0.207	0.623*	1.166**	0.925
		(0.162)	(0.313)	(0.375)	
40 states with positive rates	[ln(case rates +0.01)]	0.200	0.595	1.136**	0.926
		(0.154)	(0.306)	(0.370)	
All states	[ln(case rates +0.01)]	0.210	0.895**	1.283**	0.899
		(0.197)	(0.286)	(0.326)	
All fentanyl-type drugs (fentanyl & analog) seizures					
Sample	*Outcome*				
40 states with positive rates	[ln(case rates)]	0.201	0.635*	1.221**	0.931
		(0.162)	(0.306)	(0.379)	
40 states with positive rates	[ln(case rates +0.01)]	0.194	0.608*	1.191**	0.932
		(0.155)	(0.300)	(0.373)	
All states	[ln(case rates +0.01)]	0.209	0.907**	1.333**	0.905
		(0.199)	(0.283)	(0.321)	

Notes: * denotes $p < 0.05$, ** denotes $p < 0.01$. This table summarizes the estimated elasticities and standard errors of police forensic seizures per 100,000 state residents to the 2008 value of imports per state resident. We use the number of fentanyl cases and all fentanyl-type cases (fentanyl plus fentanyl analogs, e.g., acetyl fentanyl, carfentanil). For each, we show that adding 0.01 to case rates has little impact on the estimates using the sample of 40 states with positive case rates throughout the sample period. All of the estimates are based on an adapted version of equation (1), where the reference period is 2010 and the year indicator variables are from 2011 to 2020 (as no seizure data are available for 2008 and 2009). The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. The annual estimates for all states are plotted in Figure 5. See the notes to Table 2 and the text for more details.

Table A5 Imports and fentanyl overdoses with controls for non-imports explanations

	Elasticity estimates				
	2009-12	2013-16	2017-20	R-sq.	Obs.
Baseline specification	0.025	0.283*	0.753**	0.909	650
	(0.123)	(0.138)	(0.174)		
Import competition	0.013	0.370**	0.720**	0.915	650
	(0.146)	(0.121)	(0.176)		
States' non-triplicate status	0.017	0.347**	0.826**	0.912	650
	(0.141)	(0.133)	(0.176)		
Prescription drug monitoring program laws	0.003	0.284	0.760**	0.911	650
	(0.119)	(0.151)	(0.183)		
Trade activity: Controlling for value of exports	0.0002	0.396*	0.805**	0.911	650
	(0.189)	(0.186)	(0.214)		
Diversion of legal fentanyl shipments	0.015	0.255	0.706**	0.912	650
	(0.133)	(0.155)	(0.180)		
Heroin differences east/west of Mississippi River	0.056	0.263	0.645**	0.921	650
	(0.134)	(0.142)	(0.189)		
Border smuggling: U.S. border crossing controls	0.063	0.331*	0.783**	0.911	650
	(0.130)	(0.135)	(0.183)		
Border smuggling: Removing U.S. border states	0.104	0.352	0.834**	0.915	468
	(0.184)	(0.191)	(0.223)		

Notes: * denotes p<0.05, ** denotes p<0.01. This table summarizes results assessing the robustness of the relationship between the 2008 value of imports and fentanyl overdoses. The top row shows the baseline results from Table 2. The other results are after conditioning on an additional state characteristic, which is generally interacted with the year identifiers as follows: (1) a measure of each state's exposure to import competition, using national industry-level imports in each year and the 2008 industry shares of state-level employment; (2) an identifier equal to one for states that did not have a "triplicate" prescription drug monitoring program in the 1990s; (3) a variable equal to one once modern prescription drug monitoring program (PDMP) laws are enacted in a state, and zero otherwise; (4) the natural log of the annual real value of exports per state resident; (5) the natural log of the legal amount of fentanyl shipped annually to each state, measured in grams per resident; (6) an identifier equal to one for states east of the Mississippi River to account for spatial differences in heroin types; and (7) the natural log of the annual number of inbound U.S. land border entrants per 100,000 state residents (where 0.01 is added to all observations before taking the log of it); and (7) the natural log of the annual real value of exports per state resident. The final results show: (8) estimates without the 14 states that have land borders with Canada or Mexico. See the text for more details.

Table A6 The relationship of shares of import characteristics to fentanyl overdoses

	2009-12	2013-16	2017-20	Share of imports
Country/region of origin				
Value of imports	0.017 (0.143)	0.284 (0.217)	0.679** (0.201)	--
Shares: Mexico	0.065 (0.080)	0.075 (0.105)	0.154 (0.106)	8.1%
Canada	-0.045 (0.232)	-0.157 (0.345)	-0.327 (0.279)	23.5%
Asia	0.033 (0.211)	-0.149 (0.166)	-0.007 (0.175)	37.1%
South/Central America	0.205* (0.101)	0.258* (0.131)	0.452** (0.155)	5.0%
Europe	0.175 (0.201)	0.032 (0.303)	0.075 (0.283)	24.6%
Africa/Oceania	-0.078 (0.080)	-0.024 (0.107)	0.007 (0.120)	1.8%
Mode of transport				
Value of imports	0.058 (0.130)	0.293 (0.165)	0.756** (0.192)	--
Shares: Sea	0.188 (0.266)	0.020 (0.261)	0.248 (0.294)	46.1%
Air	0.071 (0.165)	-0.096 (0.157)	0.024 (0.265)	25.6%
Land / packages: Canada & Mexico	0.077 (0.217)	-0.063 (0.231)	-0.018 (0.251)	23.8%
Packages: Rest of world	0.097 (0.072)	-0.045 (0.079)	0.036 (0.120)	4.1%
Industry (NAICS code)				
Value of imports	0.027 (0.106)	0.210 (0.143)	0.567** (0.149)	--
Shares: Agriculture, forestry, fishing & hunting (11)	-0.062 (0.078)	0.057 (0.061)	0.199* (0.100)	3.1%
Chemical manufacturing (325)	-0.067 (0.086)	-0.083 (0.104)	0.161 (0.108)	11.9%
Primary metal manufacturing (331)	0.001 (0.063)	0.110 (0.068)	0.174* (0.080)	8.8%
Computer/elec. product manufacturing (334)	-0.155 (0.115)	-0.225 (0.132)	0.002 (0.149)	16.2%
Transportation equipment manufacturing (336)	-0.105 (0.069)	-0.024 (0.078)	0.099 (0.099)	14.2%

Notes: * denotes $p<0.05$, ** denotes $p<0.01$. The table shows the relationship between different import characteristics and fentanyl overdoses at the state level, while allowing the overall value of imports to have a distinct relationship to fentanyl overdoses. The estimates come from modified versions of equation (1), where the *share* of each import subsample is separately interacted with the year indicator variables. All estimates are presented (e.g., all country/region estimates come from a single regression). The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. See text for more details.

Table A7 The relationship of values of import characteristics to fentanyl overdoses

	2009-12	2013-16	2017-20	Share of imports
Country/region of origin				
Mexico	0.040 (0.072)	0.062 (0.092)	0.080 (0.115)	8.1%
Canada	-0.146 (0.129)	-0.137 (0.166)	-0.281 (0.173)	23.5%
Asia	-0.016 (0.139)	-0.17 (0.165)	-0.161 (0.185)	37.1%
South/Central America	0.175 (0.093)	0.200 (0.115)	0.321* (0.140)	5.0%
Europe	0.047 (0.115)	0.097 (0.174)	0.228 (0.219)	24.6%
Africa/Oceania	-0.084 (0.082)	-0.002 (0.126)	-0.013 (0.142)	1.8%
Mode of transport				
Sea	0.042 (0.108)	0.272* (0.123)	0.503** (0.197)	46.1%
Air	-0.048 (0.092)	-0.047 (0.094)	0.084 (0.122)	25.6%
Land / packages: Canada & Mexico	-0.064 (0.116)	0.087 (0.164)	0.098 (0.156)	23.8%
Packages: Rest of world	0.043 (0.068)	-0.044 (0.078)	0.029 (0.115)	4.1%
Industry (NAICS code)				
Agriculture, forestry, fishing & hunting (11)	-0.014 (0.078)	0.103 (0.058)	0.252** (0.091)	3.1%
Chemical manufacturing (325)	-0.033 (0.094)	-0.023 (0.097)	0.202* (0.091)	11.9%
Primary metal manufacturing (331)	0.041 (0.065)	0.149* (0.065)	0.170* (0.074)	8.8%
Computer/electronic product manufacturing (334)	-0.059 (0.083)	-0.110 (0.106)	0.030 (0.131)	16.2%
Transportation equipment manufacturing (336)	-0.032 (0.057)	0.090 (0.062)	0.129 (0.081)	14.2%
All other imports	-0.002 (0.177)	-0.126 (0.244)	-0.267 (0.288)	45.8%

Notes: * denotes p<0.05, ** denotes p<0.01. The table shows the relationship between different import characteristics and fentanyl overdoses. The estimates come from modified versions of equation (1), where the 2008 value per capita of each import subsample is separately interacted with the year indicator variables. All estimates are presented (e.g., all country/region estimates come from a single regression). The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. See text for more details.

Table A8 LASSO selections using import shares by origin, mode, industry

Period	Import type		LASSO	Post-OLS
Country/region of origin				
2013-2016	Value of imports		0.088	0.273
	Shares:	Imports from Asia	-0.034	-0.120
2017-2020	Value of imports		0.448	0.651
	Shares:	Imports from South/Central America	0.105	0.176
		Imports from Africa	0.077	0.092
		Imports from Canada	-0.154	-0.151
Mode of transport				
	None selected			
Industry (NAICS)				
2013-2016	Value of imports		0.081	0.227
	Shares:	Electronic manufacturing (334)	-0.089	-0.158
2017-2020	Value of imports		0.524	0.675
	Shares:	Primary metal manufacturing (331)	0.073	0.129
		Agriculture, forestry, fishing & hunting (11)	0.068	0.126
		Chemical manufacturing (325)	0.098	0.123
Interaction of origin and mode of transport				
2013-2016	None selected			
2017-2020	Value of imports		0.243	0.291
	Shares:	Sea imports from South/Central America	0.077	0.125
		Air imports from Africa	0.055	0.110
		Sea imports from Africa	0.027	0.055
		Sea imports from Mexico	0.008	0.018
		Air imports from Canada	-0.125	-0.192
Interaction of origin and industry (NAICS)				
2013-2016	*Shares:*	Oceanian primary metal manufacturing (331)	0.006	0.035
		Oceanian transportation equipment manufacturing (336)	-0.007	-0.011
		Oceanian chemical manufacturing (325)	-0.009	-0.031
2017-2020	Value of imports		0.196	0.226
	Shares:	Asian transportation equipment manufacturing (336)	0.049	0.114
		African transportation equipment manufacturing (336)	0.032	0.054
		European chemical manufacturing (325)	0.039	0.047
		European primary metal manufacturing (331)	0.014	0.039
		Oceanian agriculture, forestry, fishing & hunting (11)	0.021	0.032
		Oceanian primary metal manufacturing (331)	0.002	0.021

Notes: Using fentanyl overdoses deaths per 100,000 residents, this table shows the types of imports selected by the LASSO procedure, including their LASSO and Post-OLS estimates. For each time period, the import types are ordered by post-OLS magnitudes. All models include state, year and region-by-period fixed effects, and the economic and demographic covariates included in equation (1). All of these are partialled out of the LASSO estimation procedure. We add 0.01 to the import-share variables before taking logs. The set of variables available for LASSO are the 2008 imports per capita and 2008 import-type shares interacted with the 2013-2016 and 2017-2020 time periods. The lambda penalty parameters for each model are selected based on cross-validation, and are 25.84 for origin, 41.15 for mode of transport, 21.45 for industry, 49.56 for origin-by-mode, and 86.61 for origin-by-industry.