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IMPORTING THE OPIOID CRISIS? INTERNATIONAL TRADE AND FENTANYL OVERDOSES

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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 on how this happens. We show that a substantial amount of fentanyl smuggling occurs via legal trade flows, with a positive relationship between state-level imports and drug overdoses that accounts for 15,000-20,000 deaths per year. This relationship is not explained by geographic differences in "deaths of despair," general demand for opioids, or job losses from import competition. Our results suggest that fentanyl smuggling via imports is pervasive and a key determinant of opioid problems.

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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 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 gunshots (∼46,000), traffic accidents (∼47,000), homicides (∼26,000), liver disease (∼57,000), breast cancer (∼43,000), or prostate cancer (∼33,000).[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 during the 2000s, to around 11,000 deaths by 2010 (Alpert et al. 2022; Arteaga and Barone 2023). While policy 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. There were 76,000 fentanyl deaths in 2022, representing 90% of all opioid overdose deaths. 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 driven by fentanyl.[2] This suggests that new supply-side factors are now driving the opioid crisis.

[1] Authors' calculations using the Centers for Disease Control and Prevention (CDC) Multiple Cause of Death Files we use in this paper and described in Section 3, and CDC provisional overdose data (Ahmad et al. 2023). These data are also used to create Figures 1 and 2.

[2] Appendix Figure A1 show further breakdowns by opioid type. Appendix Figure A2 shows that there is much more spatial persistence in opioid overdoses over a similar time period (2001-2009) than between 2009 and 2017.

In this paper, we show that legal trade is a key factor driving fentanyl supply by documenting a relationship between international imports and fentanyl overdoses. Illicit fentanyl is produced abroad (Pardo et al. 2019). However, there is little information on how it is smuggled into the U.S., with the Drug Enforcement Administration (DEA) emphasizing the roles of Mexican gangs smuggling fentanyl across the Southwest border and the use of mail packages from China (DEA 2019; 2021). We assess the empirical relationship between imports and fentanyl overdoses at the state level, with the idea that supply frictions result in overdoses disproportionately occurring near smuggling locations.[3] Specifically, using CDC mortality data and U.S. Census import data for 2008-2020, we show that there is a positive relationship between states' imports per resident and drug overdose death rates that begins in 2013. The relationship increases over time, and accounts for 15,000-20,000 deaths per year over the 2017-2020 period.

We take advantage of substantial import variation to establish this relationship. 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. Moreover, 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).

Results 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 2017, drug overdose deaths per resident are approximately 40% higher in states with above-median import levels than in other states. These differences, which persist through 2020, are driven by fentanyl overdoses. Our regression estimates show that 10% more imports per resident is associated with a 5.5% increase in opioid deaths and an 8.1% increase in fentanyl deaths over the 2017-2020 period. There is a similar relationship between imports and fentanyl seized by local police, which is a complementary measure of drug market activity.

Further results suggest that the recent relationship between legal imports and fentanyl problems is causal. First, we show that imports affect drug overdoses – rather than the other way around – by documenting a similar relationship using pre-treatment import patterns. Second,

[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). There is existing empirical support for the presence of local supply frictions in illicit drug markets, with crack cocaine arriving first in states close to key smuggling locations (Evans et al. 2016); proximity to Florida's "pill mills" affecting the size of oxycodone problems (Evans et al. 2019); and heroin prices being lower near smuggling locations in Australia (Moore et al. 2005).

we show that import patterns are not related 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). Third, we control for additional state characteristics that potentially affect fentanyl overdoses, 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); the presence of modern prescription drug monitoring programs (Buchmueller and Carey 2018); (iii) the amount of fentanyl used legally in medical procedures, which may be diverted from healthcare facilities (Walters 2018); (iv) states' proximity to the Mexican and Canadian borders, which may make fentanyl smuggling easier (Pardo et al. 2019); and (v) the value of exports, a measure of trade openness and economic activity. None of these factors meaningfully affect the nature of the relationship between imports and fentanyl overdoses.

We focus on specific import characteristics to understand how trade flows are 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. Imports from Europe and Latin America are associated with fentanyl deaths, as are chemical and agricultural imports. As discussed in the next section, U.S. government agencies like the DEA and CBP often focus on China and Mexico, although fentanyl seizures from European and Latin American shipments do occur and there is evidence that smugglers are active in those regions. Our results suggest that the use of imports to smuggle fentanyl is more pervasive than currently appreciated. They also suggest that smugglers account for the endogeneity of enforcement when deciding how to smuggle fentanyl into the U.S., and that broader or data-driven screening efforts may save lives.[4] 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.

Our paper contributes to a growing literature that focuses on understanding and combating the opioid crisis.[5] However, a recent review of economic studies on the opioid crisis that covered

[4]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).

[5]For example, recent papers provide insights into the role of marketing OxyContin (Alpert et al. 2022; Arteaga

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.[6] We provide novel insights into this understudied market.

The distributional implications of trade have long been recognized, with recent evidence showing 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; Adda and Fawaz 2020).[7] Rather than focusing on how *import competition* affects overdoses via opioid demand, our results indicate that *imports* affect opioid supply due to fentanyl smuggling opportunities. Note that import competition is distinct from imports, as states that import goods from abroad are not necessarily those whose workforce is adversely affected by import competition. 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.[8]

We also contribute to a longstanding literature in trade on understanding how legal imports aid smuggling. Historically, most documented smuggling was related to evading tariffs and duties (e.g., Bhagwati 1964; Fisman and Wei 2004; Chalendard et al. 2023), although research has also examined how legal trade is used to smuggle illicit goods (Fisman and Wei 2009), including illicit drugs (Russo 2014).[9] 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, we find

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).

[6] Information on the fentanyl market is sparse, 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).

[7] Import competition has also been shown to affect other outcomes, such as violet crime and racial progress (Dell et al., 2019; Batistich and Bond, 2023).

[8] 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 15,000-20,000 deaths per year are valued at $150-200 billion. This is on the order of 20% of the welfare gains from trade (Costinot and Rodriguez-Clare, 2018).

[9] Russo (2014) finds some cross-country evidence that imports reduce cocaine prices, which he argues is due to increased smuggling opportunities. There are also several papers in economics on understanding drug trafficking through other means, including how gangs smuggle drugs via sea and land (Dell 2015; Mejia and Restrepo 2016; Hidalgo et al. 2022), and how ethnic networks aid drug smuggling (McCully, 2023).

that U.S. imports are being used to smuggle sizeable amounts of a potent illicit drug.

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 drug smuggling that are different to those emphasized publicly by law enforcement.

Our findings point to the potential benefits of better screening of 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.[10] However, it focused on smuggling from China and Mexico, as do many law enforcement strategies and multi-agency initiatives (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 have a weak or even negative relationship to fentanyl overdoses. However, the importance of the overall volume of imports and imports coming from Europe and Latin America suggests that more resources should be devoted to customs screening. For example, our estimates imply that moderating the relationship between imports and fentanyl overdoses by even 20% would save around 3,000-4,000 lives per year and be valued at around $30-40 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.[11]

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, overdose prevention, local policing, as well as medical care and family support. The rationale for providing more assistance to residents in these states may be 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 might help develop policies to better address this large and growing public health crisis.

[10] trumpwhitehouse.archives.gov/wp-content/uploads/2019/08/Fentanyl-Advisory-Movement-Tab-C.pdf.

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

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 structure to fentanyl and mimic its pharmacological effects, were developed soon after.[12] 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. The overdose risks of fentanyl motivated limits on its potency when approved for use in the U.S. Inappropriate medical prescribing and patient misuse became common once it was available for chronic pain, and there were 1,000-3,000 fentanyl overdose deaths each year between 2002 and 2012 (Stanley 2014; Pardo et al. 2019). However, the medical use of fentanyl has decreased markedly in recent years (Stein et al. 2023). In 2020, only one kilogram of fentanyl was dispensed by pharmacies in the United States.[13]

2.2 Illicitly manufactured fentanyl

The recent rise in fentanyl abuse and 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 global 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 syn-

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

[13] Authors' calculations from the DEA's Automation of Reports and Consolidated Orders System (ARCOS). See Section 3.4 for a description of these data.

[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.

thesize 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 it harder to regulate fentanyl. 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). Other countries have lagged the U.S. in terms of oversight. 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 in the U.S. and elsewhere that created demand for fentanyl. Apart from pre-existing opioid demand, the increase in the global supply of fentanyl since 2013 seems to be exogenous to local factors in the U.S.

China has the second-largest pharmaceutical industry – behind the U.S. – and the largest for generic pharmaceuticals. This gives fentanyl producers cheap access to the necessary chemical ingredients, equipment, and technicians. The Chinese Government was slow to ban key precursors and fentanyl analogs, and 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, the DEA recently highlighting India and Mexico as important producers (DEA 2021). However, there is little evidence of domestic production, perhaps because the two key precursor chemicals for fentanyl became controlled substances in the U.S. in 2007 and 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 overland. 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)

There is a belief that increasing amounts of fentanyl are being manufactured in Mexico using fentanyl precursors trafficked from China, then finished fentanyl is smuggled across the border into the U.S.[15] This may be a response to China and the U.S. adopting stricter mail monitoring policies (Felbab-Brown 2022). The largest number of seizures of illicit fentanyl 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.[16]

However, there is a great deal of uncertainty about how fentanyl is smuggled into the U.S. We have already noted that the White House advised companies in 2019 to protect their supply chains against fentanyl smuggling (see footnote 10). The potency of fentanyl means that commercial quantities can be easily slipped inside legal imported goods. Law enforcement has seized fentanyl hidden in imports of, for example, pharmaceuticals, nutritional supplements, cosmetics, computer keyboards, ovens, coffee makers, and industrial equipment.[17]

Fentanyl smuggling involves more countries than is generally appreciated. The DEA and CBP have detected fentanyl trafficking from many other countries, including Belgium, Canada, the Dominican Republic, Estonia, Fiji and Taiwan.[18] Shutting down dark web marketplaces led to arrests in Austria, Brazil, France, Germany, the Netherlands, Poland, Switzerland, and the United Kingdom.[19] Furthermore, many countries have their own fentanyl problems and challenges around fentanyl smuggling (Pardo et al. 2019). 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.[20]

The pervasiveness of illicit fentanyl generates numerous potential smuggling routes, other than simply from China and Mexico. This may help to explain puzzling differences between

[15] Fentanyl from Mexico is about 5-10% pure and fentanyl directly from China is ∼90% (Pardo et al. 2019).

[16] See Pardo et al. (2019), https://www.state.gov/secretary-antony-j-blinken-at-the-u-s-mexico-high-level-security-dialogue/, https://www.cbp.gov/newsroom/national-media-release/dhs-doubles-down-cbp-efforts-continue-combat-fentanyl-and-synthetic.

[17] See DEA (2019; 2021), https://www.cbp.gov/newsroom/local-media-release/22-pill-presses-257-pill-press-parts-fentanyl-and-xylazine-cincinnati, https://www.westernmassnews.com/2023/10/26/federal-government-says-it-plans-go-after-legal-goods-tied-illegal-fentanyl-trade-new-strategy/.

[18] www.cbsnews.com/news/dea-seizes-200-kilos-fentanyl-chemicals-china-undercover/, www.dea.gov/press-releases/2019/05/09/five-estonian-residents-arrested-conspiring-import-carfentanil-and, www.justice.gov/opa/pr/justice-department-announces-first-ever-indictments-against-designated-chinese-manufacturers, www.cbp.gov/newsroom/local-media-release/22-pill-presses-257-pill-press-parts-fentanyl-and-xylazine-cincinnati, https://home.treasury.gov/news/press-releases/jy1629

[19] https://www.justice.gov/opa/speech/attorney-general-merrick-b-garland-deliver-remarks-announcing-results-largest.

[20] https://www.afp.gov.au/news-centre/media-release/fentanyl-warning-following-australias-largest-detection-deadly-opioid.

the location of major fentanyl seizures and where fentanyl problems occur. The DEA and CBP seize a substantial amount of fentanyl, mostly at the Southwest Border (Pardo et al. 2019; DEA 2021).[21] Yet, as shown in Figure 2, fentanyl overdose deaths are concentrated in the Midwest and Northeast.[22] It is difficult to reconcile these patterns, especially since research shows that illicit drugs problems occur near key smuggling locations (e.g., Moore et al. 2005; Evans et al. 2016). Furthermore, opioid overdoses were high in the Southwest prior to the fentanyl surge, providing potential demand for fentanyl near Mexican smuggling locations. Ultimately, this suggests that fentanyl seizures may be highly endogenous to enforcement efforts, and that fentanyl smuggling into the Midwest and Northeast may be more substantial 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).[23]

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.[24] Similar screening devices operate at U.S. ports of entry, including rail and truck customs facilities, and for air cargo at departing airports. Physical searches of U.S. imports

[21] In 2022, the DEA seized 379 million doses of fentanyl in the form of 51 million pills and 10,000 pounds of powder (https://abcnews.go.com/Politics/dea-seized-fentanyl-kill-american-2022/story?id=95625574).

[22] The DEA understand these patterns; it includes such figures in documents (e.g., DEA 2019; 2021).

[23] www.cbp.gov/sites/default/files/documents/rc_security_profile_overview_3.pdf

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

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.[25] 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.[26]

While fentanyl and its analogs are seized using these methods, they have their 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).[27] In addition, while CBP has centralized intelligence officials that review 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).[28] This allows us to identify specific opioids: heroin and methadone have their own drug identification codes, 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.[29]

[25] `https://www.tsi-mag.com/seeing-the-unseeable-todays-cargo-screening/`

[26] `www.dhs.gov/science-and-technology/news/2019/09/24/snapshot-synthetic-opioids-detection`

[27] `www.oig.dhs.gov/sites/default/files/assets/2019-10/OIG-19-67-Sep19.pdf`

[28] Deaths are coded using the International Classification of Diseases, Tenth Revision (ICD-10). Drug overdoses are defined as deaths with underlying cause of death codes X40–X44, X60–64, X85, or Y10–Y14. Drug identification codes are used to 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); methadone (T40.3); and fentanyl and other synthetic opioid analgesics (T40.4).

[29] 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`.

Coroners or medical examiners generally determine the cause of death and complete a death certificate. The National Center for Health Statistics then codes and standardizes this information to create an underlying cause of death and report the presence of specific drugs. There are inconsistent approaches to testing for drugs and completing death certificates, leading to substantial under-reporting of opioid overdoses and misreporting of specific opioids (e.g., 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 drugs.

3.2 Trade data

Our trade data are from the U.S. Census' Trade Online portal.[30] 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).[31] 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.[32]

Our primary measure is the real value of all imports except for oil and gas, which are generally imported using specialized ships and pipelines, rather than in shipping containers or

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

[31] 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 US). 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`).

[32] Therefore, 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.

packages.[33] We use import weight in robustness exercises, and information on the country of origin, method of transport and type of product to examine effect heterogeneity and understand smuggling routes. We also use state-level data on the real value of exports in placebo analyses.[34]

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.[35] 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 since 2010 the data in NFLIS annual reports are statistically adjusted to take account of reporting and sampling issues (Pitts et al. 2023). We use annual state-level counts of fentanyl, fentanyl analogs, heroin, oxycodone, and methadone.

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, especially if the criminal justice policies and resources within a state are generally consistent over time.[36]

[33]Oil and gas imports (NAICS 211) represent 12% of the value of imports, so their removal creates a measure more reflective of imports that could be used to smuggle drugs. We also provide estimates where our import measure includes oil and gas imports.

[34]We convert to 2022 dollars using the U.S. Bureau of Economic Analysis Exports of Goods price series (available at: `https://fred.stlouisfed.org/series/A253RD3Q086SBEA`).

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

[36]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.

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.[37] We use the American Community Survey to calculate annual state population shares by sex, race/ethnicity, age, educational attainment, and marital status.[38] We also use labor force participation and unemployment rates from the Bureau of Labor Statistics' Local Area Unemployment Statistics, and real Gross Domestic Product from the Bureau of Economic Analysis.[39]

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).[40] 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).[41] 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).[42] Finally, to account for drug smuggling that is a function of border crossings, we use annual statistics from the Bureau of Transportation Statistics on inbound border crossings by state and year at the US-Canada and US-Mexico borders. We focus on total border crossings, which occur by car, bus, train, or on foot.[43]

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

[38]We calculate shares by sex-by-age (male/female by 0-24, 25-44, 45-64, 65+ years); race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other); educational attainment for ages 25+ (less than high school, high school graduate, some college, college graduate); and marital status (single, married, separated, divorced, widowed) (Ruggles et al. 2023).

[39]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

[40]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)

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

[42]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`.)

[43]Available at: `https://www.bts.gov/browse-statistical-products-and-data/border-crossing-data/border-crossingentry-data`.

3.5 Summary statistics

Combining of these data sources results in a balanced panel of all 50 states. All of the variables are available annually throughout the 2008-2020 period except for police drug seizure rates, 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 generally use the natural log of both our outcome variables and import measures, 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 materially affect regression estimates (Mullahy and Norton 2022, Chen and Roth 2023).[44]

4 Descriptive evidence on imports and overdoses

In this section, we describe state-level import patterns and connect them 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 states with the lowest per-capita import 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

[44] 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.

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 transportation infrastructure (e.g., Duranton et al. 2014, Coşar and Fajgelbaum 2016, Donaldson 2018). Others find that differences across states and provinces are only partly explained by these factors (Wolf 2000; Millimet and Osang 2007). For example, Hillberry and Hummels (2008) finds that local industrial composition and the shipping of intermediate goods are important determinants of domestic trade patterns. Similarly, Dvorkin and Shell (2016) argue that proximity to trading partners and industrial specialization explains state differences in international imports, which in turn is often driven by state's natural endowments, agglomeration, and the persistence of historical shocks.[45] The important point for our analysis is that state-level variation in imports is unlikely to be driven by unobserved time-varying factors that are correlated with opioids.

The volume and composition of imports in our data do appear to reflect historical patterns and longstanding comparative advantages. For instance, at the 3-digit NAICS level, 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 over a century ago. Indiana's most valuable category of imports 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 good is Computer and Electronic Products (NAICS 334), a sector that has benefited from the close relationship 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

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

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 US 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.[46]

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. We will further assess this by examining the relationship of imports to population health and factors known to have affected the opioid crisis. We will also use data on imports from before the rise of fentanyl to address concerns that state-level import flows may respond endogenously to opioid demand.

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 becoming the dominant opioid. Figure 2 shows that the spatial distribution of opioid overdose deaths changed with the rise of fentanyl, driving a concentration of opioid overdose deaths in the Midwest and Northeast. Together, these show that there was a sharp increase in fentanyl supply that did not simply respond to preexisting opioid demand.

We now connect drug overdose rates to import patterns. To do so, we divide states into two equal groups based on their average annual value of imports over the 2008-2020 period. "High-import" states have average annual imports above the median value of $3.86K per resident, while "low-import" states have average annual imports below it. States are ordered by this measure in Table 1: the high-import group covers New Jersey to North Dakota, while the low-import group covers Wisconsin to South Dakota.[47]

In Figure 3, we plot the average annual fatal drug overdose rates per 100,000 residents for high-import and low-import states. 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).

[46]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.

[47]We later use the 2008 value of imports per capita as the import measure throughout the sample period. 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 for Oregon.

While low-import states have the highest rate in each year, on average the rate in high-import states is only 9% smaller than in low-import states. Moreover, that difference is incredibly stable: the rate in high-import 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 higher- and lower-import states were shaped by similar forces during the period preceding the rise of fentanyl.

The two groups of states have starkly different trends 2013 onward. The gap between the low- and high-import groups reverses between 2012 and 2013, with high-import states having 2% higher drug overdose death rates than low-import states in 2013. This difference rapidly widens, and by 2017 the average drug overdose death rate in high-import states is 37% higher than in low-import 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-import states dwarfs the 29% increase in low-import states. The sizeable gap persisted through to the end of our sample period; the relative difference was largest in 2018 (at 41%), while the absolute difference was largest in 2020 (at 7.6 drug overdose deaths per 100,000 residents).

If the gap between low-import and high-import states present between 2008 and 2012 had persisted throughout the sample period, then there would have been around 19,000 fewer deaths annually during the 2017-2020 period.[48] This calculation ignores many factors we will address in our regression-based analysis, such as low-import states also being treated by imports — just less intensively than high-import states — and the potential role of other determinants of drug overdoses. Despite this, given the compelling nature of the raw trends, it provides a sense of the scale of drug overdose deaths that may be connected to import flows.

Figure 3 also includes information on drug overdose deaths for the same high- and low-import states by whether or not an opioid was identified (in Panel B) and — conditional on opioid involvement — whether or not fentanyl was identified (in Panel C). In combination, these panels show that the growing difference in drug overdoses between high- and low-import states after 2012 is entirely driven by fentanyl overdoses. Over the 2014-2017 period, the annual difference in fentanyl overdose deaths between high- and low-import states is 90-104% of the equivalent gap for all drug overdoses. Over the 2018-2020 period, fentanyl deaths account for

[48]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 the respective annual population numbers in the high-import states. These states are more populous than low-import 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-import states having a 9% lower drug overdose rate than low-import states throughout), then deaths in high-import states would be 20,137 lower each year over the 2017-2020 period.

more than the equivalent gap for all drug overdoses (i.e., 124-135%). This suggests that fentanyl may recently be crowding out more non-fentanyl drug overdoses in high-import states than in low-import states.[49] We also plot fentanyl police seizure rates in high- and low-import states, and find a qualitatively similar pattern to those for drug overdoses (Appendix Figure A4).[50]

Finally, given that recent opioid overdose rates are highest in the Midwest and Northeast, we assess whether the association between imports and drug overdoses only occurs at the regional level. We do so by presenting some pairwise comparisons of overdose deaths for larger neighboring states with different import flows. We present overall drug overdose rates for New Jersey/New York; Michigan/Wisconsin; Tennessee/Alabama; and Maryland/Virginia (Appendix Figure A5). 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 high-import state has a higher drug overdose death rate than the low-import state in recent years. This suggests that imports are associated with differences at a local level.

Overall, the descriptive evidence points to a connection between import patterns and fentanyl overdose deaths. There is nothing to indicate that state patterns in import flows 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.

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

[49] Over the 2018-2020 period, fentanyl overdoses account for 111-114% of the gap for all opioid overdoses, suggesting that some of this crowd out is happening within opioid overdose types.

[50] 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-import states.

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 potentially exacerbated states' sensitivity to this shock by facilitating fentanyl smuggling. This is consistent with fentanyl-related supply chain warnings from the federal government, customs seizures, drug interdiction operations, as well as our own descriptive evidence. We primarily use the contemporaneous value of imports as a consistent measure of import activity, but also use alternate measures of import activity. We are initially agnostic about the role of import characteristics — such as product types, source countries and mode of transport — as there is no definitive evidence on how any fentanyl smuggling could be occurring.

Third, given the nature of the fentanyl supply shock and the structure of our data, we rely on two key identifying assumptions. One is that import differences across states are unrelated to non-smuggling factors that may affect the demand or supply of fentanyl and other drugs (conditional on controls). We 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. The second key assumption is that import flows do not respond to smuggling opportunities, leading to reverse causality. We address this possibility by estimating the relationship based on state-level imports from the start of our sample period, in 2008, which precedes the fentanyl supply shock by several years.

Our primary estimating equation is:

$$lnY_{st} = \alpha_s + \gamma_t + \beta_1 lnImports_{st} + \sum_{t=2009}^{2020} \beta_t lnImports_{st} \times \mathbf{1}(Year = t) + \mathbf{X}_{st}\theta + \epsilon_{st} \qquad (1)$$

Where Y_{st} represents the number of deaths per 100,000 residents in state s and year t. $Imports_{st}$ is the value of imports per resident. It 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 the value of imports in each year (relative to 2008).

We include a full set of state fixed effects (α_s) to account for permanent state differences in overdose outcomes, and a full set of year fixed effects (γ_t) to account for common overdose determinants over time. 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), race/ethnicity(non-Hispanic white, non-Hispanic black, Hispanic, other), and educational attainment (less than high school, high school graduate, college graduate); the natural log of GDP per resident; the 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 is before the 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 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 in Figure 4A using all drug overdose deaths per 100,000 residents as our outcome variable. Early in the sample period, from 2009 to 2012, the elasticity estimates are 0.04 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 plateau at around 0.25 from 2016. In Table 2, the average coefficients (standard errors) in the four-year groups are -0.02 (0.04) for 2009-2012; 0.14 (0.06) for 2013-2016; and 0.26 (0.08) 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. For both outcomes, 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 fentanyl deaths from 2015. Summary estimates for the 2017-2020 period imply that a 10% higher value of imports per resident is associated with a 5.5% higher opioid death rate and an 8.1% higher fentanyl death rate.

We also present estimates for non-opioid drug overdose deaths. There is no meaningful relationship between imports and non-opioid overdose deaths from 2009 through 2017, with annual coefficients that are smaller than 0.1 in absolute magnitude and not statistically different from zero. The estimates for 2018, 2019 and 2020 are -0.14, -0.25 and -0.27 respectively, with the latter two statistically significant at the 5% level. The summary estimate for the 2017-2020 period implies that a 10% higher value of imports per capita is associated with a 1.9% lower non-opioid death rate, which is statistically significant at the 5% level. This suggests that non-opioid drug overdose deaths may be crowded out by opioid deaths late in the sample period.

These regression results are in line with the descriptive evidence. There is a meaningful and statistically significant relationship between imports and drug overdose deaths that develops in line the with rise of fentanyl problems around 2013 and is strongest for fentanyl overdoses. To further understand the importance of our regression controls, we present results for all drug, opioid and fentanyl overdose deaths using more parsimonious versions of equation 1 (Appendix Table A2). Removing state fixed effects increases the 2017-2020 estimates for all drugs and fentanyl overdoses by 20-30%, although does not change the estimates for opioid overdoses. The results for all three outcomes are similar with or without the time-varying covariates. These estimates suggest that the empirical relationship between imports and drug overdoses is slightly affected by permanent differences across states, but not by states' changes in population characteristics or broad measures of economic activity.

We also present results for all drug, opioid and fentanyl overdose death rates using alternate measures of imports (Appendix Figure A6 and Table A3). We first use the value of imports inclusive of oil and gas imports. The estimates are slightly smaller in magnitude, although they are qualitatively similar to the main estimates. These differences are consistent with oil and gas imports not being be an important smuggling channel.[51] We also use the average weight of non-oil-and-gas imports per resident, where weight is measured in kilograms. Recall that this measure does not include imports sent via mail or courier packages, or imports coming from

[51]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.

Canada and Mexico by land (i.e., transported by rail or truck). Import weight per resident has a positive and statistically significant relationship to drug overdose deaths post-2013. The elasticity estimates are smaller in magnitude, although the coverage and underlying variation of this import measure is quite different. Overall, the overdose-import relationship is robust to different measures of imports.

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 15,720 drug overdose deaths, 19,544 opioid overdose deaths, and 17,328 fentanyl deaths. The consistency of these results points to fentanyl driving the recent empirical relationship between imports and drug overdoses. They also suggest that any crowdout of non-opioid deaths is having a small impact on overall drug overdose deaths.

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 imports per resident and fentanyl seizure rates in Figure 5 and Appendix Table A4. We use a modified version of equation 1 with 2010 as the reference year, as these data start in 2010. One limitation of the seizure data is that 4.2% of the observations are zeroes, so we add 0.01 before taking the log of seizure rates.[52] The annual elasticity estimates for fentanyl seizures are qualitatively similar to those for drug overdose deaths. Elasticities average 0.18 for 2011 and 2012, and are not statistically significant at the 5% level. They steadily increase in magnitude post-2013, becoming statistically significant at the 1% level from 2014. The average elasticities are 1.3 for the 2013-2016 period and 1.6 for

[52] We chose 0.01, as it is around the minimum seizure rate when values are positive. Additional results for the 40 states with positive seizure rates throughout the sample period indicate that the estimates are similar with and without adding it. 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).

the 2017-2020 period (see Table A4). The elasticity estimates are almost identical when we combine fentanyl and fentanyl analogs, which increase seizure rates by around 60%.[53]

Despite inherent differences in terms of how overdose deaths and police seizures are collected and measured, the similarity of these estimates provides strong empirical support for imports facilitating fentanyl smuggling since 2013.

6.3 Imports and opioids other than fentanyl

We now use the mortality and seizure data to estimate the relationship between imports and oxycodone, heroin, and methadone. 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 the potential role of broader changes in opioid demand.

In Figure 6, we plot the annual elasticity estimates for fentanyl, heroin, oxycodone and methadone overdose deaths when they are the only opioid reported, alongside equivalent results for the police seizures of each drug. We focus on overdoses deaths with one opioid present, while the seizure data include cases with multiple opioids.[54] We also provide summary estimates in Appendix Tables A5 and A6.[55] The results for overdose deaths where fentanyl is the only opioid present are almost identical those already presented (the seizure results are from Figure 5). Both heroin overdoses and seizures have an inverted-U relationship to imports that peaks around 2014 and turns negative around 2019. The estimates are generally imprecise. Oxycodone overdoses have a positive and statistically significant relationship to imports of around 0.3 from 2014 to 2020, while the oxycodone seizure estimates are smaller and not statistically different from zero. Both methadone overdoses and methadone seizures have a positive relationship to imports that increases over time and becomes statistically significant by the end of the sample period.

These estimates are in line with fentanyl-related spillovers. The heroin estimates are consistent with heroin initially being a complement to fentanyl before becoming a substitute (Pardo et al., 2019). The methadone estimates are consistent with drug treatment responding to the changing geography of the opioid crisis driven by fentanyl problems. The most unusual result is

[53]Fentanyl analogs also contribute to fentanyl overdose deaths, as they are included in the T40.4 drug identification code in the mortality data.

[54]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. Some observations are zero, so 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 results are similar with this adjustment. We do not use these results to scale effect sizes (Mullahy and Norton 2022, Chen and Roth 2023).

[55]For completeness, we report results in Table A5 for overdoses where only "other and unspecified opioids" are present (i.e., the T40.6 drug code). They have an imprecise relationship to imports.

the positive relationship between imports and oxycodone deaths, although this 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 sensitivity to imports and other relationships only develop after the surge in fentanyl supply.

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. Moreover, we have shown that states with high and low levels of imports per resident experienced similar trends in drug overdoses prior to 2013, and that import patterns do not strongly influence non-fentanyl drug overdose deaths.

We further investigate whether our findings are due to other explanations by considering four types of additional evidence. First, we assess whether reverse causality affects the imports-overdose relationship by using imports that precede the rise of fentanyl. Second, we conduct several placebo tests by estimating the relationship between imports and other causes of death. Third, we control for additional state characteristics that potentially affect fentanyl overdoses by adding them to the right-hand side of equation 1 and separately interacting them with the year indicator variables. This allows us to document the role of other state characteristics, such as import competition and OxyContin marketing, and assess whether they account for the positive relationship between imports and fentanyl overdoses. Fourth, we estimate the relationship between imports and fentanyl overdoses without states bordering Mexico and Canada, as a way of checking whether we are mistaking proximity to border smuggling as trade activity.

7.1 Reverse causality

Imports likely affect drug overdoses, rather than the other way around. While it seems unlikely that fentanyl smuggling is lucrative enough to meaningfully affect import patterns, we check this by using imports from several years before the surge in fentanyl supply.

We report results using the value of imports in 2008 in equation 1 (instead of annual imports). These estimates, which are presented in Appendix Figure A7 and Table A7, are almost identical to the main estimates. This is to be expected given the persistence in import patterns throughout our sample period. These findings indicate that imports increase drug overdoses, rather than imports responding endogenously to fentanyl demand.

7.2 Placebo tests using other causes of death

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

Deaths of despair. Recently, 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 test for this using deaths due to these other causes in Figures 7A and 7B, and in Appendix Table A8. There is no meaningful empirical relationship between imports and either of these causes of death.[56]

Causes of death related to population health. We also use all non-drug deaths, lung cancer deaths, heart disease deaths, and traffic fatalities as placebo outcomes. 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 7C-7F and in Appendix Table A8. None of these mortality rates have a meaningful relationship with imports during our sample period. Moreover, the precise estimates for these more common causes of death result in 95% confidence intervals that generally rule out elasticities greater than 0.05 in absolute magnitude.

7.3 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, here

[56]The only statistically significant estimate is for non-drug suicides in 2020, which has a coefficient (standard error) of -0.06 (0.02). This may reflect drug suicides recently crowding out non-drug suicides, or be due to chance.

we 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 2000 and national 6-digit NAICS industry imports to calculate import competition in the following way:

$$ImpComp_{st} = \sum_{n} \left(\frac{empl_{sn2000}}{empl_{n2000}} * imports_{nt} \right) \tag{2}$$

Where s represents the state, t the year, and n the industry. This measures how national imports affect some states more than others based on production patterns in 2000. We add import competition to equation 1 and separately interact it with the year indicator variables to measure the impact of import competition on fentanyl overdoses over time.

In Table 3, we present estimates for the separate relationships that imports and import competition have with fentanyl overdoses. The elasticity estimates for imports are little changed, with an average elasticity estimates of 0.52 over 2013-2016 and 0.77 over the 2017-2020 period. Import competition has a statistically significant relationship of -0.18 to fentanyl overdoses during the 2013-2016, with smaller and less precise estimates in other years.

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 degree that import competition affects opioid demand, it is distinct from the relationship between imports and fentanyl overdoses that we document.

7.4 Other determinants of opioid demand

We now consider the potential role of other factors that affect opioid demand.

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 by interacting an identifier for non-triplicate states with the individual year identifiers and adding these terms to equation 1. We present the results in Table 3. Although the estimated relationship between non-triplicate status and fentanyl overdoses is positive and increasing in magnitude over time, albeit imprecisely, the estimated relationship between imports and fentanyl overdoses remains the same in terms of size and precision.

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. 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 Table 3. The coefficients measuring the relationship between PDMP and fentanyl overdoses are small and not statistically different from zero, while the relationship between imports and fentanyl overdoses is unchanged from before.

7.5 Alternate determinants of fentanyl supply

This section examines the potential role of other factors related to fentanyl supply.

Diversion of legal fentanyl. The US 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 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 Table 3. The coefficients identifying the relationship between legal fentanyl and fentanyl overdoses are generally negative, but never at statistically significant levels. The relationship between imports and fentanyl overdoses remains similar after accounting for the possible diversion of legal fentanyl from healthcare settings.

Smuggling across US 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 smuggled over these borders (e.g., Pardo et al. 2019; DEA 2021) and border states also generally have higher imports per resident.

We account for this using state-year data on inbound entrants at the US-Canada and US-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.[57] The results are presented in Table 3. Controlling for border crossings into the US does not affect the relationship between imports and fentanyl overdoses.

We also show results using the original equation 1 and the 36 states without a border with Canada or Mexico. For this sample, the average elasticity estimates are 0.45 for 2013-2016 and 0.85 for 2017-2020, with both statistically significant at the 5% 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 land borders have in facilitating drug smuggling.

7.6 Exports as a placebo measure of trade and economic activity

Economic activity and trade openness may influence overdose deaths. 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. The results are presented in Table 3. 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.

7.7 Summary

In this section, we have considered reverse causality; the relationship of six non-drug-related causes of death to state-level imports; the effects of adding six state-specific factors that may affect the relationship between imports and fentanyl overdoses; and a sample restriction that drops border states, which may be particularly sensitive to the effects of cross-border smuggling. All of this additional evidence points to imports aiding the smuggling of fentanyl in recent years, rather than being correlated with other determinants of fentanyl demand and supply.

[57]This is the only variable in this section that has any zero values.

8 The role of import characteristics

More imports, regardless of type, decrease the probability of detection and facilitate drug smuggling (Pitt, 1981). However, we can potentially 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 different types of imports and customs processes are involved with imports coming from sea, air, land, or in the 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 in 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 and Canada (e.g., DEA 2019; 2021). In truth, there is substantial uncertainty about which countries are being used to smuggle fentanyl. In addition to separately identifying imports from those three countries, we also divide imports into four regional groups: Europe; Asia (not including China); Latin America (Central and South America); and Africa/Oceania.

We adjust equation 1 by adding the natural log of the share of imports from each country/region, and separately interact each log share with the year indicators. We omit the log share from Africa/Oceania. This specification allows for worldwide import volume to have a distinct role from imports coming from particular locations. We also use a second specification that does not account for overall import volumes, but instead allows the log value of imports from each country/region and its interaction with the year identifiers to enter equation 1 separately. This allows us to include imports from Africa/Oceania, and for the value of imports from each origin to have a direct association with fentanyl drug overdoses. For both specifications, we report the average elasticity estimates over four-year periods (2009-2012, 2013-2016, and 2017-2020).

Results for fentanyl overdoses from the primary specification are presented in Table 4. The estimates for the overall value of imports are similar to the main results in Table 2. Country/ region of origin is also important, with positive statistically significant estimates for European and Latin American import shares in 2013-2016 and 2017-2020, and a negative statistically significant estimate for Chinese shares in 2013-2016. Most other import-share estimates are positive, although they are smaller in magnitude and not statistically different from zero.

We assess the robustness of these results using the second specification that does not account for overall import volumes (Appendix Table A9), and by estimating the primary specification for all opioid overdoses (Appendix Table A10). Across these results, European and Latin American imports are consistently associated with higher drug overdose rates, while Chinese imports have no robust relationship to drug overdoses. Canadian shares are positively related to opioid overdoses at statistically significant levels in 2013-2016 and 2017-2020, which – together with positive but imprecise estimates for Canadian shares in Table 4 – provides suggestive evidence that Canadian imports are facilitating fentanyl smuggling too.[58]

These results provide new insights into the role of imports' country of origin. Overall imports matter, which suggests that greater trade flows reduce detection risks. European import shares, which account for 28% of all imports, have an elasticity to fentanyl overdoses of around 0.3 since the rise of fentanyl. Latin American are also positively related to fentanyl overdoses, although they only represent 4.2% of imports, and Canadian imports also potentially facilitating smuggling. There is little evidence that imports from China or Mexico are facilitating smuggling, perhaps because of enhanced efforts to screen imports from these countries and/or smugglers are aware of this scrutiny and are using other smuggling routes. These findings indicate that drug smuggling is more ubiquitous and diverse than previously realized.

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 transported via sea, air, land/mail from Canada and Mexico, and mail from elsewhere.[59] Sea represents 46% of all imports; air represents 26%; land/mail packages from Canada and Mexico represent 24%; and mail packages from elsewhere account for 4% of all imports.

[58] We also present the fentanyl and opioid overdose annual estimates for the import shares for China, Canada, Europe and Latin America in Appendix Figure A8. These show that Europe, Latin America and Canada have statistically significant positive estimates for both fentanyl and all opioid overdoses, while there are not any statistically significant estimates for China using all opioid overdoses.

[59] 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 total value of imports and sea-plus-air imports. We define mail packages from elsewhere as the difference between total value of imports and sea-plus-air imports for all other countries.

We estimate the relationship between the different modes of transport and drug overdoses using the same specifications (omitting mail when using import shares). We report the fentanyl results in Table 4 and Appendix Table A9, and all opioid results using import shares in Appendix Table A10. When analyzed in terms of import shares, overall import volumes remain important. There are no other statistically significant estimates. When we use the value of imports for each mode, there are statistically significant positive estimates for sea imports that likely reflects its role in driving overall import volumes. The estimates for mail packages from elsewhere 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 Industries

Features of the imported good (i.e. packaging, size, volume, weight, cavities) may make some products more conducive to drug smuggling than others. Lacking evidence on which features and products provide the best smuggling opportunities, we instead analyze the role six NAICS industry categories that represent sizeable shares of 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 study these relationships using the same approaches and drug overdose outcomes, with imports outside of these six industries omitted from the first specification. Results are again reported in Tables 4, A9 and A10. Overall import volumes remain important in the first specification. Across the results, agriculture, forestry, fishing and hunting products have a positive and statistically significant to drug overdoses in the 2017-2020 period. Chemical manufacturing imports have a positive relationship in drug overdoses in 2017-2020 in two of three results, with a positive estimate in the main results that is not quite statistically significant at the 5% level. The 2017-2020 elasticity estimates for the shares of these products are around 0.2. None of the estimates for the other industries are statistically significant at the 5% level.

These industry results are noisy, but they do suggest that some product types are more conducive to smuggling. Overall, agriculture and chemical products have the strongest relationship with fentanyl overdoses. This is 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). 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 the Least Absolute Shrinkage and Selection Operator (LASSO) to select industry and regulatory controls to predict air pollution gap hot-spots.

We focus on 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.[60] We use a LASSO model that include state and year fixed effects, which are partialled out by the LASSO estimation procedure. We select the lambda penalty parameter based on cross-validation, and report LASSO and post-OLS estimates. As before, we use the fentanyl overdose rate as our primary outcome and complement it by using the rate for all opioid overdoses as an alternative outcome.

Given policy often focuses on countries or regions, we present results for the separate interaction between imports' country/region of origin and the other import characteristics. Specifically, our first approach interacts country/region and 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.

The selected variables and post-OLS estimates are presented in Appendix Table A11. Consistent with our previous findings, the LASSO estimates suggest that the overall import volumes have the strongest relationships with fentanyl/opioid deaths in both time periods. For fentanyl, LASSO selects eight types of imports in the 2013-2016 period and 13 types in the 2017-2020 period. The results are broadly consistent to those in Table 4. European sea imports have the largest positive estimate for 2013-2016, and European air imports have the largest one for 2017-2020. Chinese sea imports have the largest negative estimates in both periods. For all opioids,

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

LASSO selects fewer of the import-share variables, although the selected variables deliver the largest estimates in the fentanyl-overdose model.

There are changes over time in terms of which modes drive the positive European and Latin American relationships, suggesting that smugglers may shift modes of transport.[61] African air imports have a positive relationship to fentanyl overdoses in both periods, which is not detected previously.[62] There are some interesting results for Mexican imports, with positive estimates for sea imports in both periods but negative estimates for land imports in 2013-2016 and air imports in 2017-2020. This is consistent with law enforcement paying attention to the Southwest Border and flights from Mexico, and smugglers using sea imports in response. The Chinese results also highlight that authorities may be effective at discouraging their use in fentanyl smuggling. Differences in the number of variables selected in the two models highlight how authorities could vary outcomes and penalty thresholds depending on their capacity to target specific imports.

We perform a similar exercise for country/region interacted with industry, using the same six industry groups as before and presenting the results in Appendix Table A12. Unsurprisingly, the overall value of imports remains important in both periods. In the 2013-2016 period, only two share variables are selected in each specification, although no import type is consistently selected and all of the estimates are small. During the 2017-2020 period, in both sets of results the largest positive estimates are for European chemical manufacturing; European machinery manufacturing; and European and African agricultural imports. Chinese computer and electronic manufacturing is consistently selected with negative estimates. These results highlight the role of smuggling via European chemical imports, which include pharmaceuticals. They also show that agricultural products from several regions are positively related to drug overdoses, while computer and electronic goods are negatively related.[63]

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.

[61] In the 2013-2016 period, sea imports are more important than air imports from Europe, while only air imports from Latin America are selected by LASSO. In the 2017-2020 period, the relative importance of transport mode reverses for European imports and sea imports from Latin America replace air imports in the selected variables.

[62] We include Africa and Oceania as separate regions in this analysis.

[63] Understanding the potential role of packaging, supply-chain security and customs screening in making computers and electronics unattractive to smugglers may help to reduce smuggling via other goods.

9 Discussion and conclusion

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 legal imports and the number of fentanyl overdoses within a state emerges from 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 general demand for opioids; factors affecting other "deaths of despair"; broader determinants of mortality; import competition; the long-lasting effects of OxyContin marketing; the presence of prescription drug monitoring programs; proximity to the Mexican or Canadian borders, or the number of people crossing them; 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.

Our estimates indicate that fentanyl smuggled via legal imports killed approximately 15,000-20,000 Americans per year over the 2017-2020 period. This represents on the order of 30-40% of all opioid deaths over these years. If we combine estimates from the literature for the value of statistical life and the gains from trade associated with U.S. imports, it is clear that fentanyl smuggling represents an important new external cost of trade. A value of statistical life (VSL) of $10 million implies the mortality consequences of 15,000-20,000 deaths per year are valued at $150-200 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 were 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 are many times

[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).

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 are focused on China and Mexico, missing the contributions of overall import volumes and imports being shipped from places like Europe and Latin America.[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 (Schuckit, 2016). Implicitly, this would assist those adversely effected by globalization, which in this case are fentanyl users whose substance abuse and mortality risks have been increased by trade-related fentanyl smuggling.

Of course, there is much more to understand about illicit fentanyl smuggling than is possible in this study. Drug smuggling is inherently secretive. We do not know exactly how imports are used to smuggle fentanyl and how fentanyl is distributed locally. It is possible that there are spillovers across states that increase the drug overdoses associated with this smuggling activity. We also do not know exactly what policies will reduce this smuggling, 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). Furthermore, we lack representative data on fentanyl prices and purities, a longstanding concern when it comes to drug policy that makes it difficult to understand market dynamics (Manski et al. 2001).

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

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

[67] For example, in the White House's latest *National Drug Control Strategy*, the only mention of maritime port security is in relation to working with the Mexican Government to limit the effectiveness of Mexican gangs. (`www.whitehouse.gov/wp-content/uploads/2022/04/National-Drug-Control-2022Strategy.pdf`)

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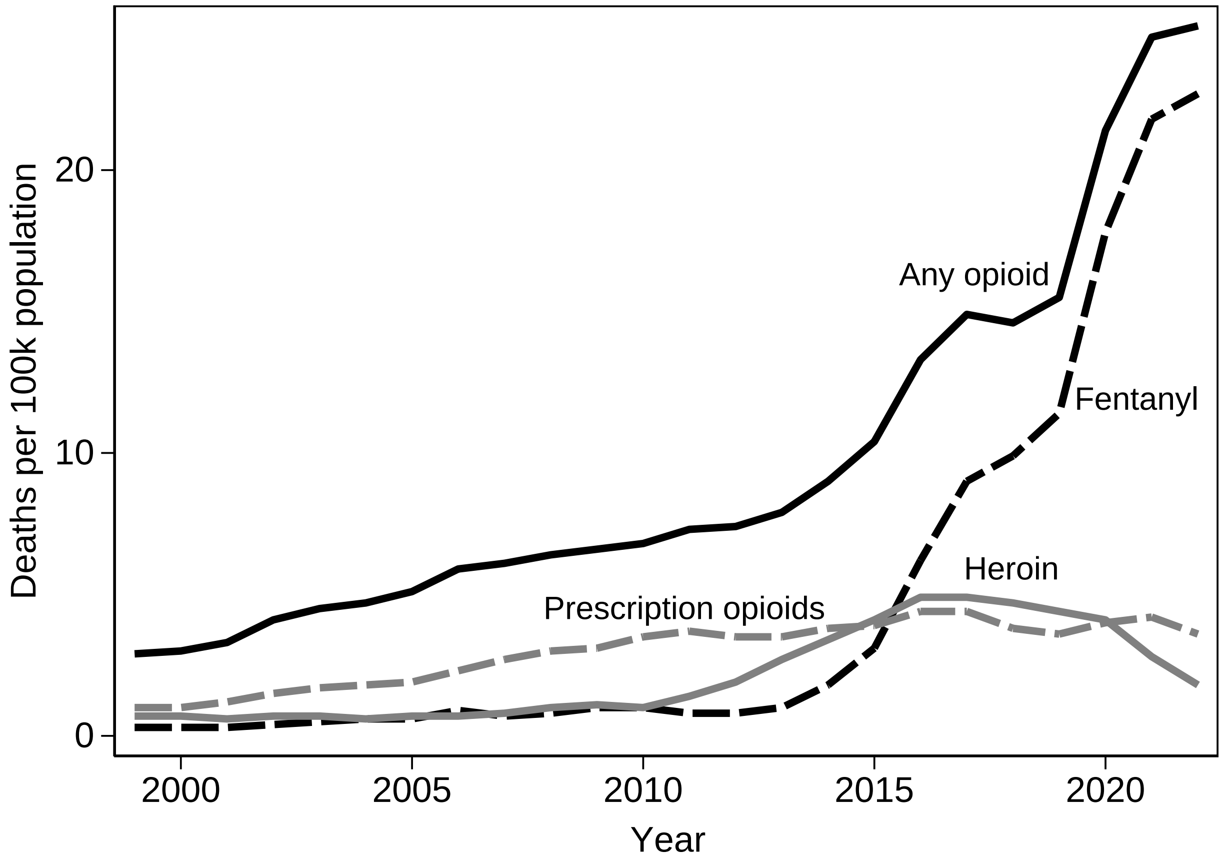
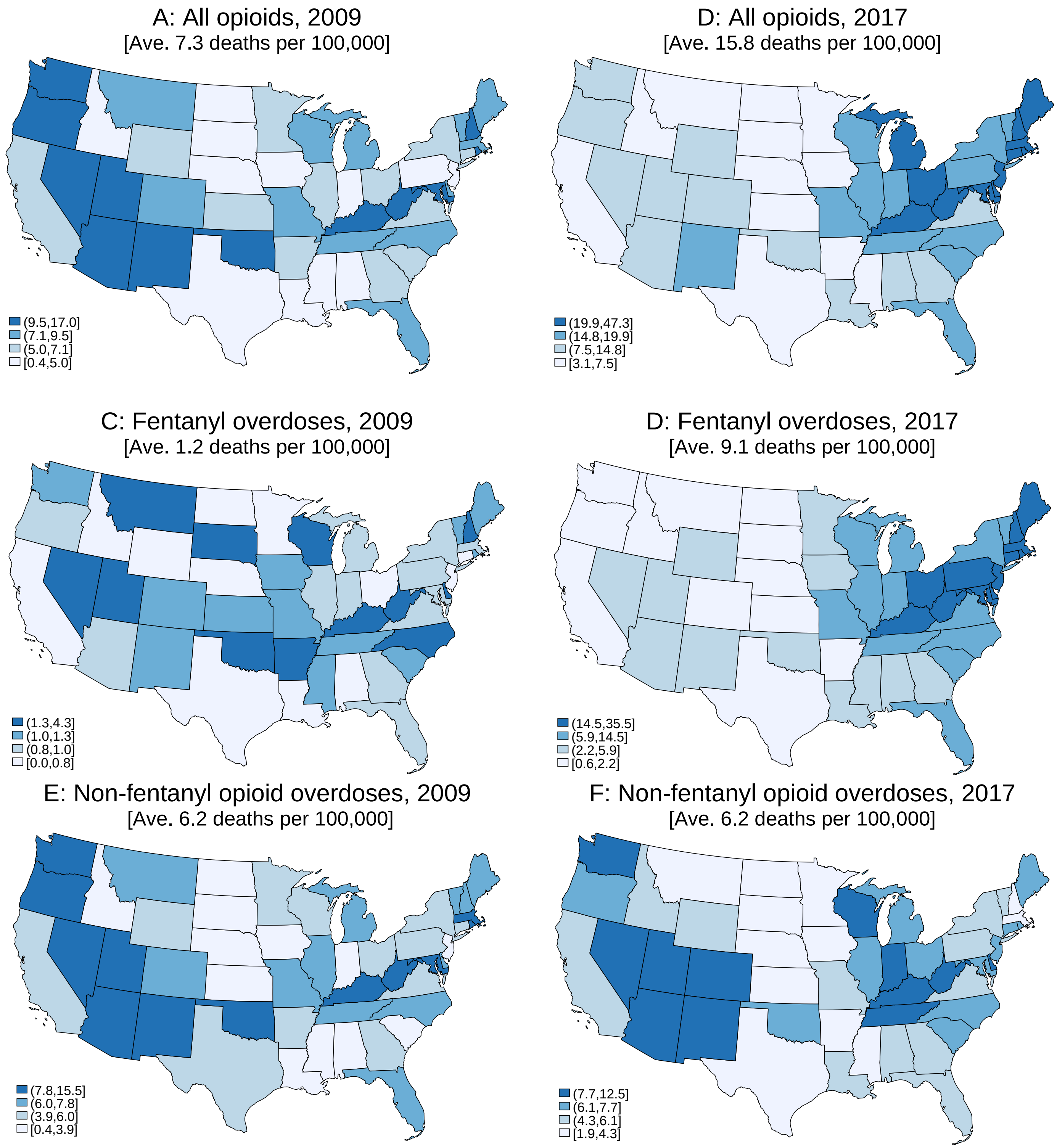
Figure 1 U.S. opioid overdose deaths, 1999-2022



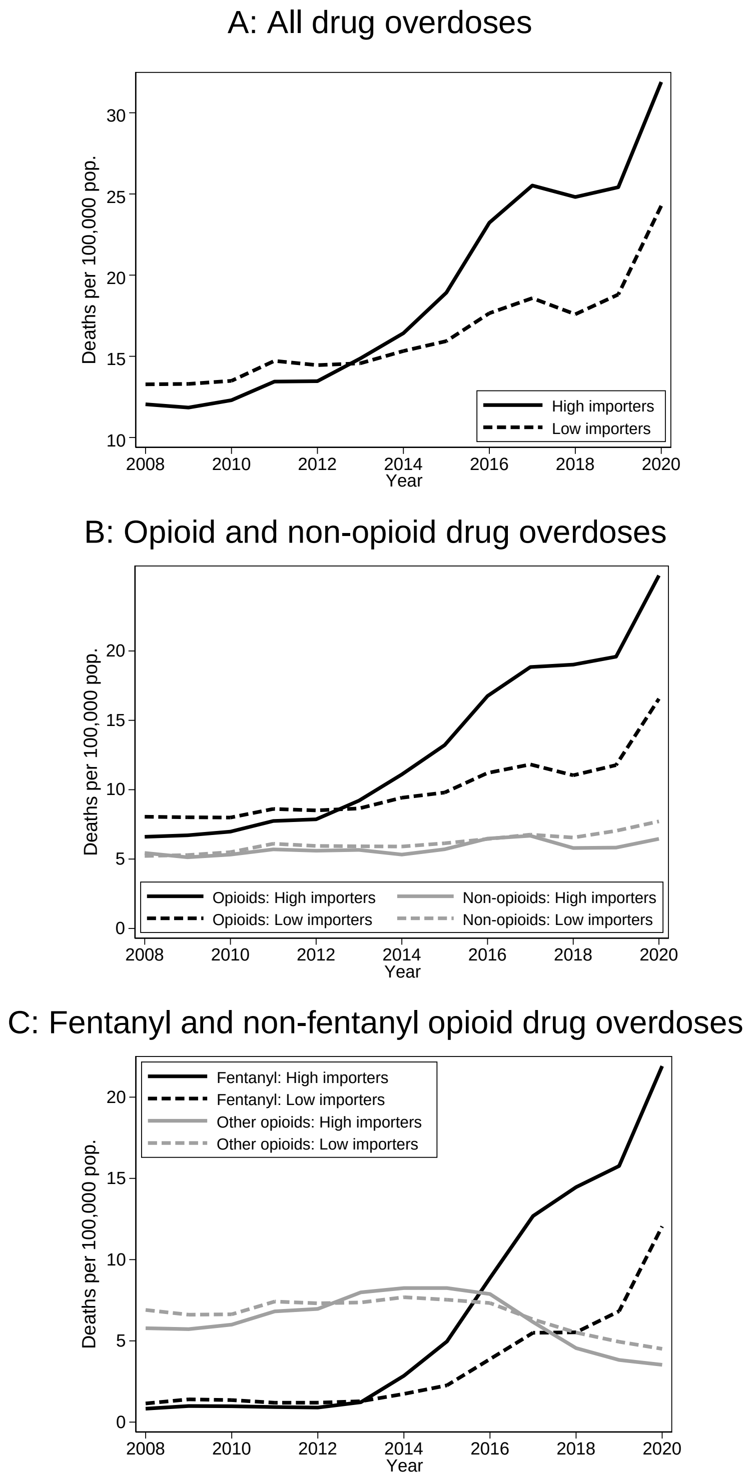
Notes: This figure shows trends in drug overdose deaths per 100,000 population. Data are from the Multiple Cause of Death files and provisional overdose data from the National Center for Health Statistics (Ahmad et al. 2023). Drug overdoses have one of the following underlying cause-of-death codes from 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 Relative distribution of drug overdose death rates four years either side of rise of fentanyl



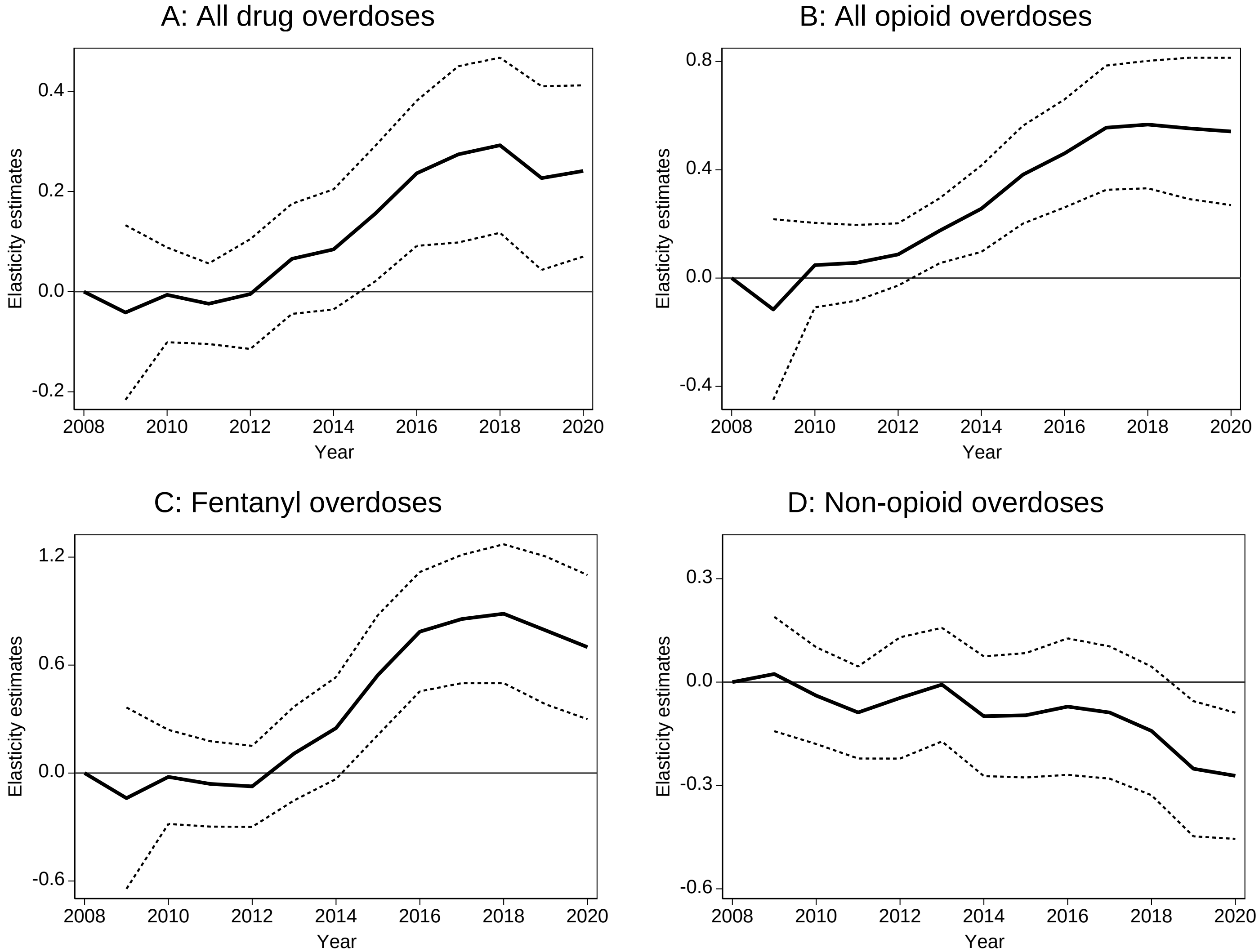
Notes: These figures show the distribution of different types of opioid overdose deaths per 100,000 residents for the continental US in 2009 and 2017, which is four years either side of when fentanyl deaths started to rise in 2013. Shading shows the rates in each year by quartiles, with darker shading 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 2008 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 death 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 importers" (above the median) and "low importers" (below the median) have similar drug overdose trends before 2013, but that high-importer states have markedly higher drug overdose rates thereafter. They show that that post-2013 gap is primarily due to fentanyl overdoses.

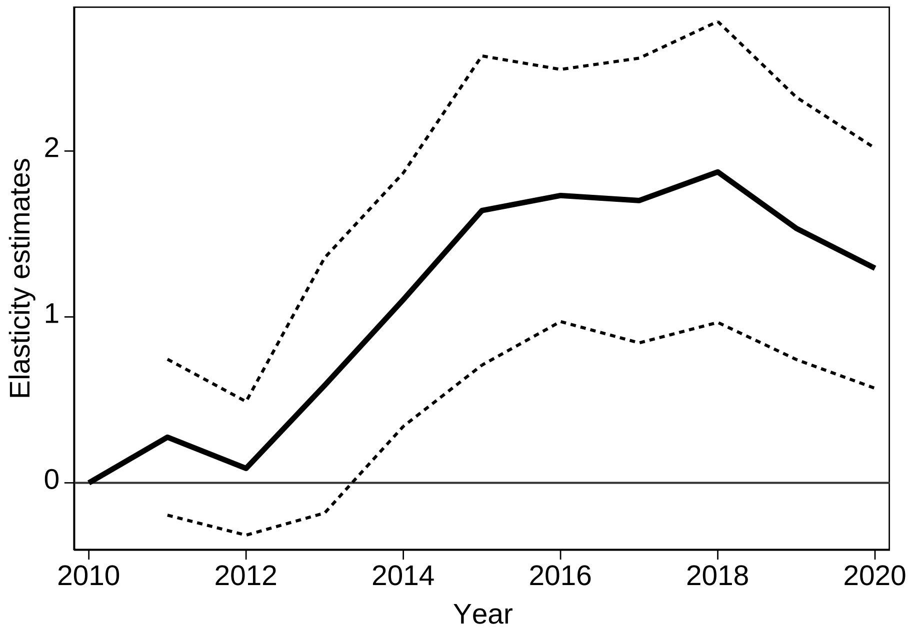
Figure 4 The relationship between imports and drug overdose deaths



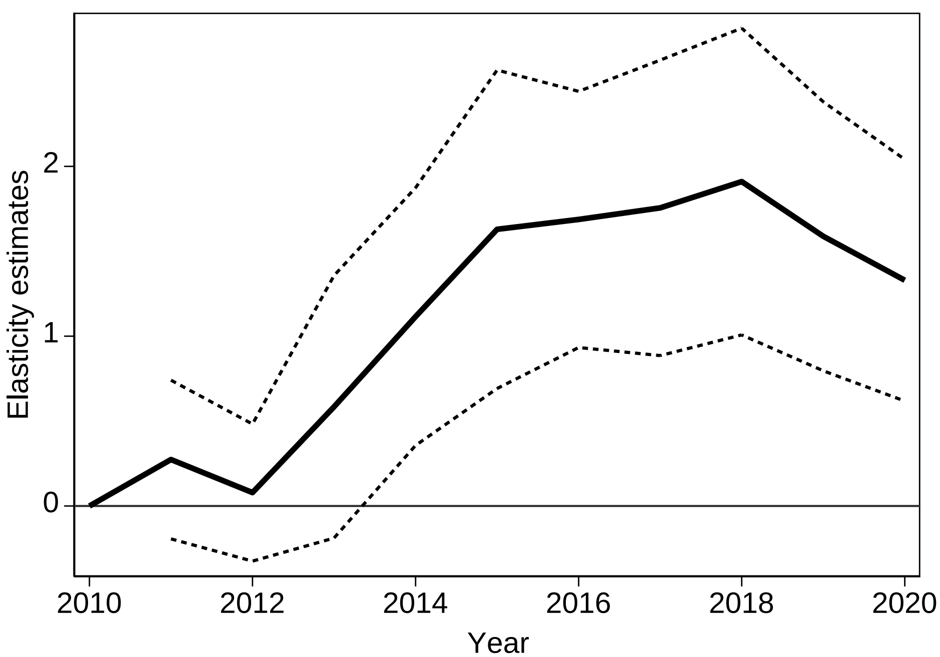
Notes: This figure plots the estimated elasticities and 95% confidence intervals of different drug overdose death rates per 100,000 state residents to the real value of imports per state resident (relative to the 2008 reference period). Drug overdose death are those with an underlying cause of death 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. Each regression uses 650 observations. The estimates are summarized in Table 2. See text for more details.

Figure 5 The relationship between imports and forensic analysis of police seizures

A: Fentanyl

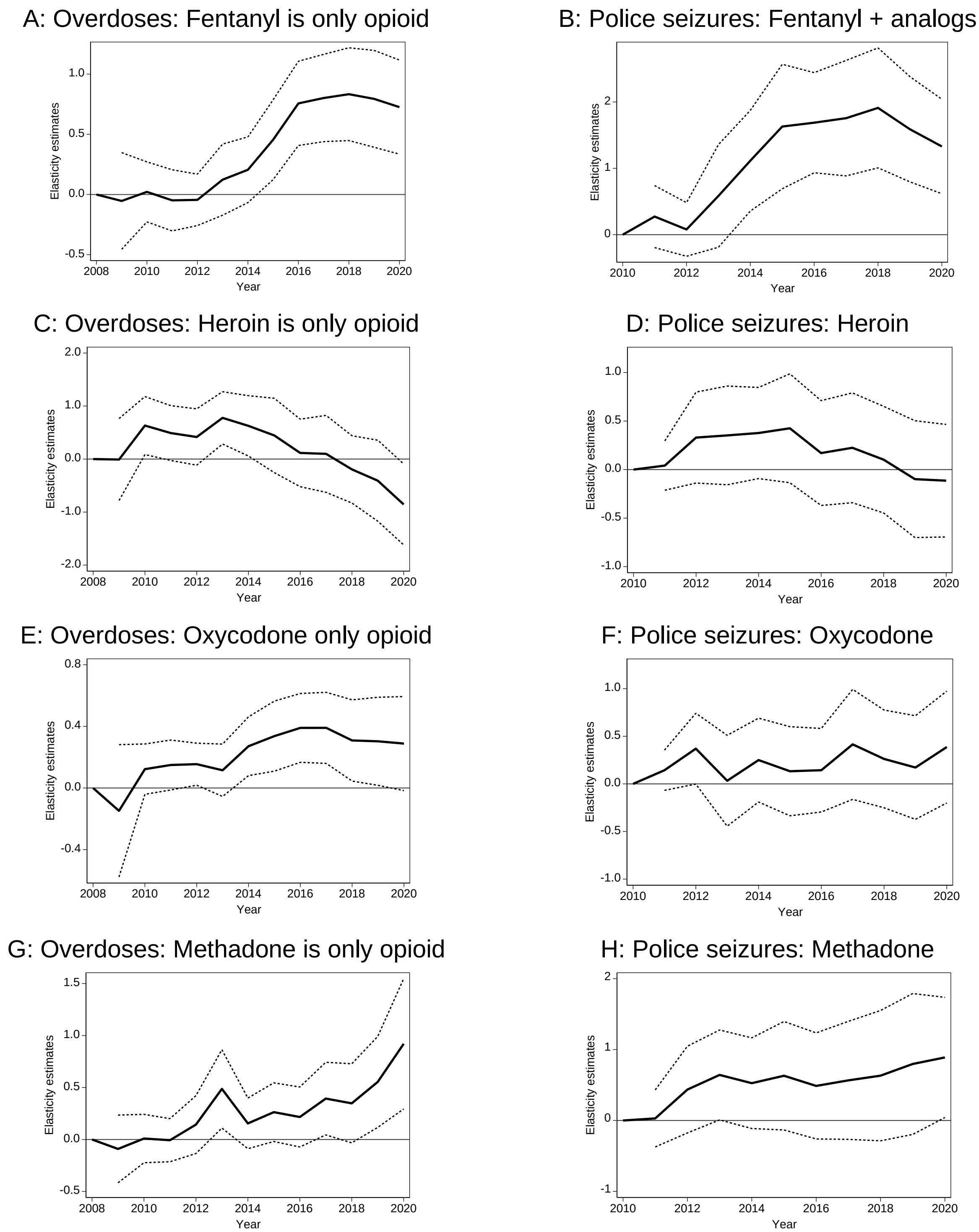


B: Fentanyl and fentanyl analogs



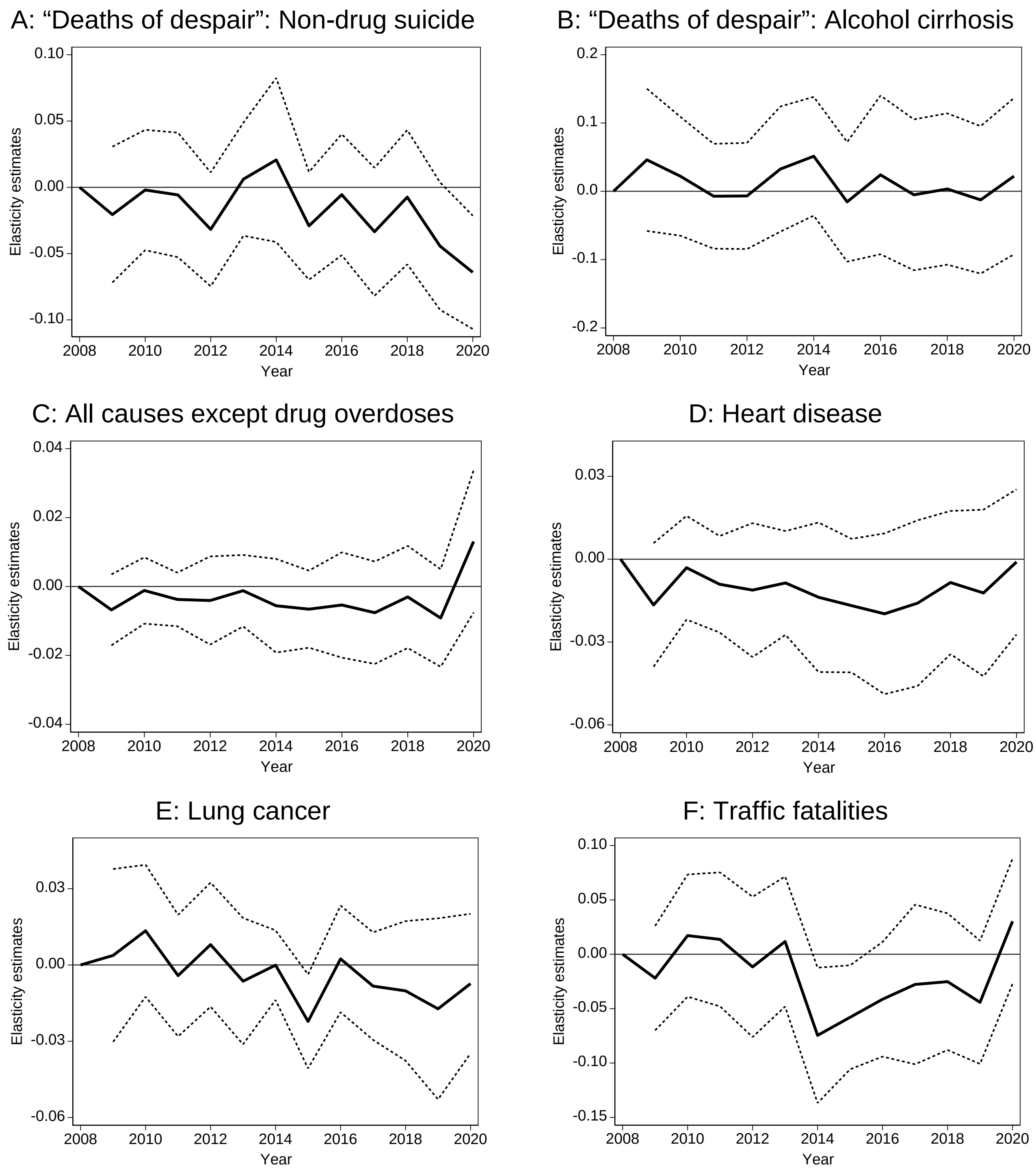
Notes: This figure plots the estimated elasticities and 95% confidence intervals of police seizures per 100,000 state residents to the real value of imports per state resident. We use the number of fentanyl cases excluding and including fentanyl analogs (e.g., acetyl fentanyl, carfentanil). The estimates 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 A4. See text for more details.

Figure 6 The relationship between imports and specific opioids



Notes: This figure plots the estimated elasticities and 95% confidence intervals of different opioid outcomes to imports. The panels on the left show the estimates for drug 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 includes seizures where multiple opioids may be present. For all outcomes, 0.01 is added before we take the log 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. The estimates are summarized in Appendix Tables A4, A5 and A6. See text for more details.

Figure 7 The relationship between imports and other causes of death



Notes: This figure plots the estimated elasticities and 95% confidence intervals for different causes of death to the real value of imports. The respective 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); and 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. The estimates are summarized in Appendix Table A7. See text for more details. See the notes to Table 2 and 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

Elasticity estimates	All drug overdoses	All opioid overdoses	Fentanyl overdoses	Non-opioid overdoses
2009-2012	-0.019 (0.037)	0.019 (0.072)	-0.074 (0.115)	-0.037 (0.060)
2013-2016	0.136* (0.060)	0.319** (0.076)	0.422** (0.136)	-0.068 (0.084)
2017-2020	0.259** (0.084)	0.554** (0.118)	0.809** (0.182)	-0.188* (0.087)
R-squared	0.885	0.879	0.893	0.830
Mean deaths / 100,000 pop.	17.5	11.6	5.10	5.99

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 real value of imports per state resident (relative to the 2008 reference period). Drug overdose death 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.

Table 3 Assessing alternatives for the relationship between imports and fentanyl overdoses

	Adding import competition	Adding non-triplicate status	Adding PDMP laws	Adding legal fentanyl shipments	Adding US border traffic	Non-border state sample	Adding value of exports
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Imports – average elasticity estimates							
2009-2012	-0.088 (0.149)	-0.079 (0.125)	-0.094 (0.114)	-0.075 (0.119)	-0.066 (0.117)	-0.071 (0.173)	-0.145 (0.159)
2013-2016	0.519** (0.117)	0.469** (0.135)	0.418** (0.142)	0.427** (0.140)	0.431** (0.131)	0.451* (0.186)	0.628** (0.167)
2017-2020	0.767** (0.177)	0.862** (0.181)	0.823** (0.181)	0.804** (0.195)	0.819** (0.183)	0.849** (0.225)	0.925** (0.244)
Other state characteristics – average elasticity estimates							
2009-2012	0.014 (0.084)	-0.141 (0.116)	-0.122 (0.134)	-0.336 (0.269)	-0.032 (0.025)	--	0.154 (0.206)
2013-2016	-0.184** (0.069)	0.348 (0.217)	0.014 (0.219)	-0.352 (0.434)	-0.051 (0.029)	--	-0.276 (0.240)
2017-2020	-0.075 (0.090)	0.405 (0.229)	0.118 (0.240)	-0.317 (0.491)	-0.039 (0.051)	--	-0.069 (0.311)
R-squared	0.899	0.896	0.895	0.896	0.895	0.901	0.897
Obs.	650	650	650	650	650	468	650

Notes: * denotes p<0.05, ** denotes p<0.01. This table shows the relationship between imports and fentanyl overdoses at the state level after conditioning on additional state characteristics (columns 1-5 & 7), or changing the sample (column 6). The top panel summarizes the estimated elasticities and standard errors between fentanyl drug overdose deaths per 100,000 state residents and the real value of imports per state resident (relative to the 2008 reference period). The bottom panel summarizes the estimates and standard errors of fentanyl drug overdose death rates per 100,000 state residents to each additional state characteristic (relative to the 2008 reference period). Both sets of estimates come from a single, modified version of equation (1), which includes the additional state characteristic interacted separately with the year fixed effects. The additional state characteristic by column is: (1) a measure of each state's exposure to import competition, which uses national industry-level imports in each year and their 2000 shares of industry employment; (2) an identifier equal to one for states that did not have a "triplicate" prescription drug monitoring program in the 1990s (i.e., all states except for California, Idaho, Illinois, New York, and Texas); (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 legal amount of fentanyl shipped annually to each state, measured in grams per resident; (5) the natural log of the annual number of inbound US 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. Column (6) shows estimates from equation (1) without the 14 states that have land borders with Canada or Mexico. The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. See the text for more details.

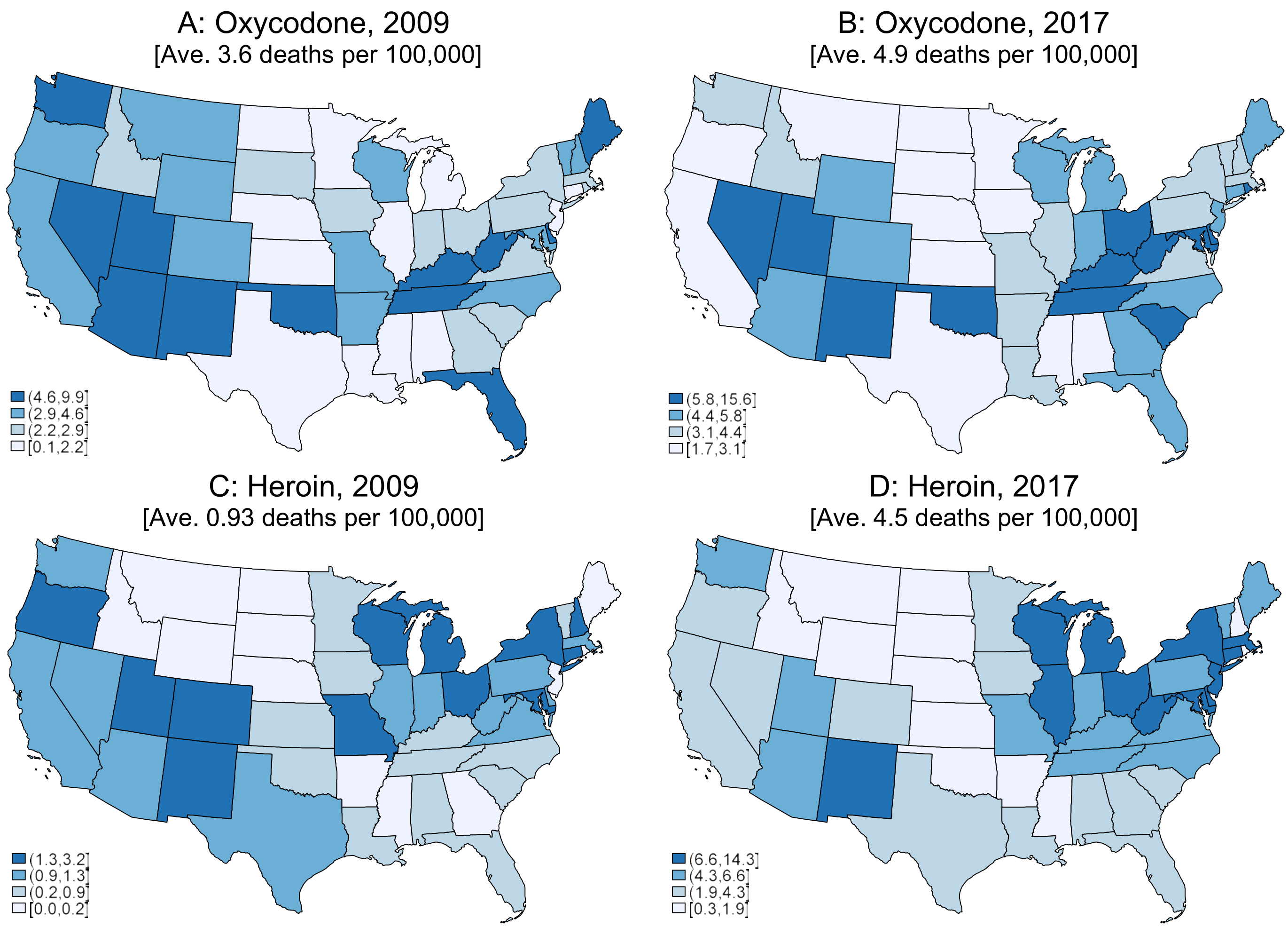
Table 4 The relationship of import characteristics to fentanyl overdoses

	2009-12	2013-16	2017-20	Share of imports
Country/region of origin				
Value of imports	-0.084 (0.110)	0.448** (0.173)	0.795** (0.185)	--
Shares: China	-0.080 (0.138)	-0.360** (0.136)	-0.301 (0.156)	18.0%
Canada	0.029 (0.134)	0.174 (0.155)	0.222 (0.204)	17.4%
Mexico	0.025 (0.067)	0.067 (0.105)	0.114 (0.143)	10.5%
Europe	-0.043 (0.154)	0.365** (0.187)	0.426** (0.208)	27.7%
Asia (except China)	-0.108 (0.175)	0.272 (0.230)	0.177 (0.213)	20.4%
South & Central America	0.129 (0.111)	0.254* (0.124)	0.384** (0.115)	4.2%
Mode of transport				
Value of imports	-0.169 (0.103)	0.281 (0.168)	0.652** (0.199)	--
Shares: Sea	0.074 (0.143)	-0.172 (0.211)	0.049 (0.215)	46.1%
Air	0.202 (0.124)	-0.087 (0.142)	0.029 (0.219)	25.6%
Land / packages: Canada & Mexico	-0.122 (0.148)	-0.334 (0.174)	-0.176 (0.212)	23.8%
Industry (NAICS code)				
Value of imports	-0.173 (0.134)	0.339* (0.172)	0.639** (0.180)	--
Shares: Computer/electronic product manufacturing (334)	-0.041 (0.068)	-0.037 (0.107)	0.058 (0.114)	16.2%
Transportation equipment manufacturing (336)	0.020 (0.095)	-0.174 (0.129)	0.100 (0.158)	14.2%
Chemical manufacturing (325)	0.062 (0.087)	-0.020 (0.109)	0.243 (0.131)	11.9%
Primary metal manufacturing (331)	-0.270 (0.161)	-0.199 (0.157)	-0.323 (0.195)	8.8%
Machinery manufacturing (333)	0.025 (0.107)	0.170 (0.115)	0.198 (0.117)	4.9%
Agriculture, forestry, fishing & hunting (11)	-0.011 (0.067)	0.131 (0.072)	0.320** (0.106)	3.1%

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. The estimates come from modified versions of equation (1), where the annual value 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.

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

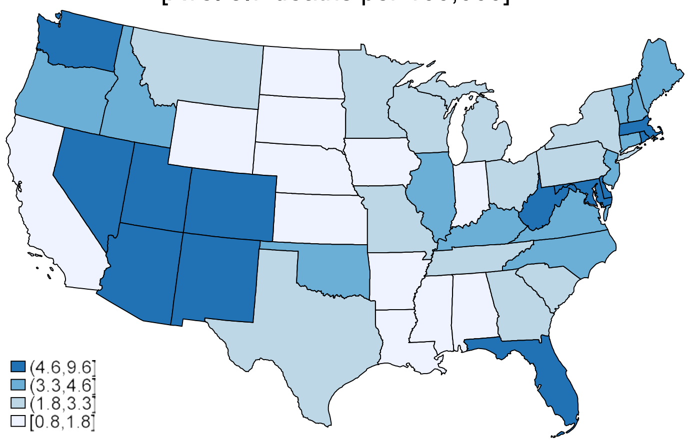


Notes: This figure complements Figure 2 by showing the distribution of oxycodone (prescription opioids) and heroin overdose deaths per 100,000 residents for the continental US in 2009 and 2017, which is four years either side of when fentanyl deaths started to rise in 2013. Some deaths have multiple 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

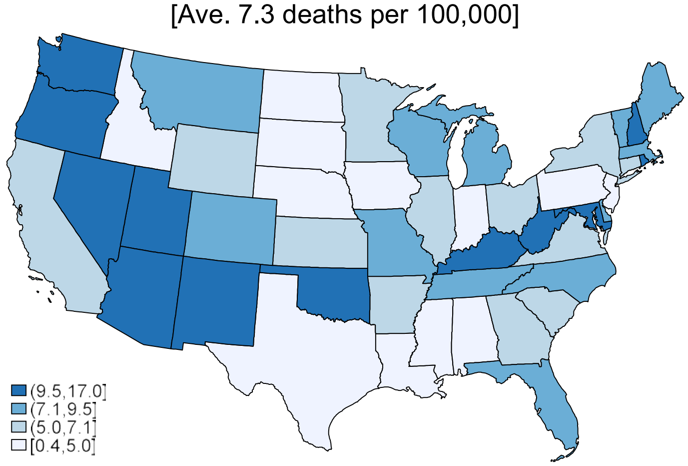
A: 2001

[Ave. 3.7 deaths per 100,000]



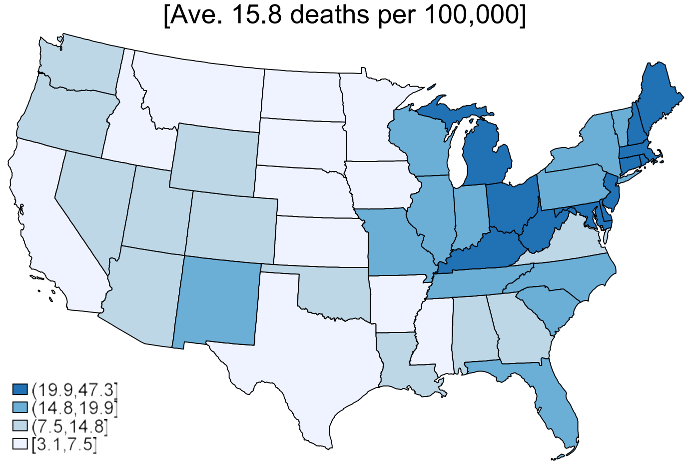
B: 2009

[Ave. 7.3 deaths per 100,000]



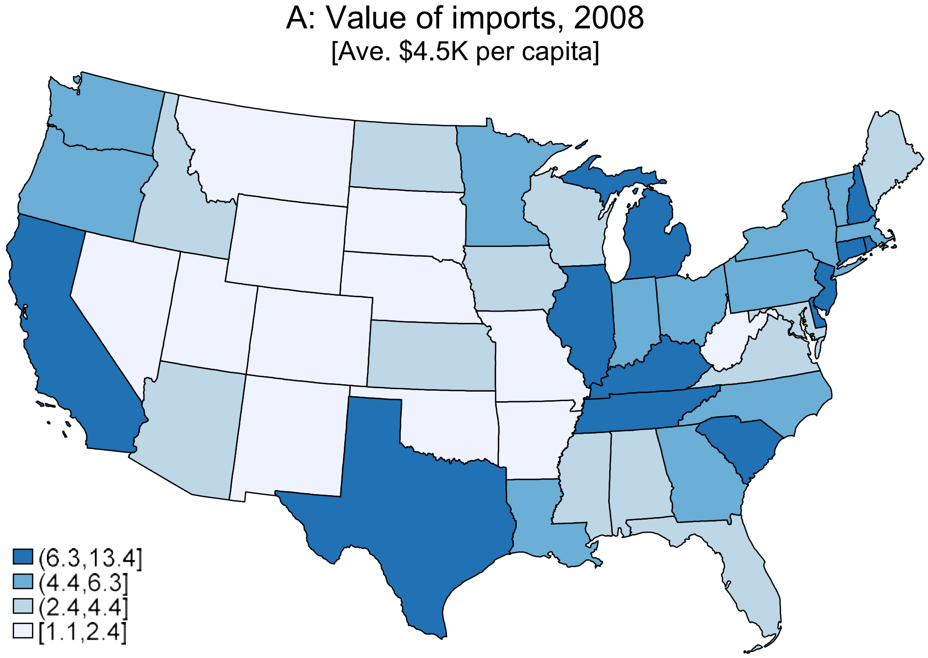
C: 2017

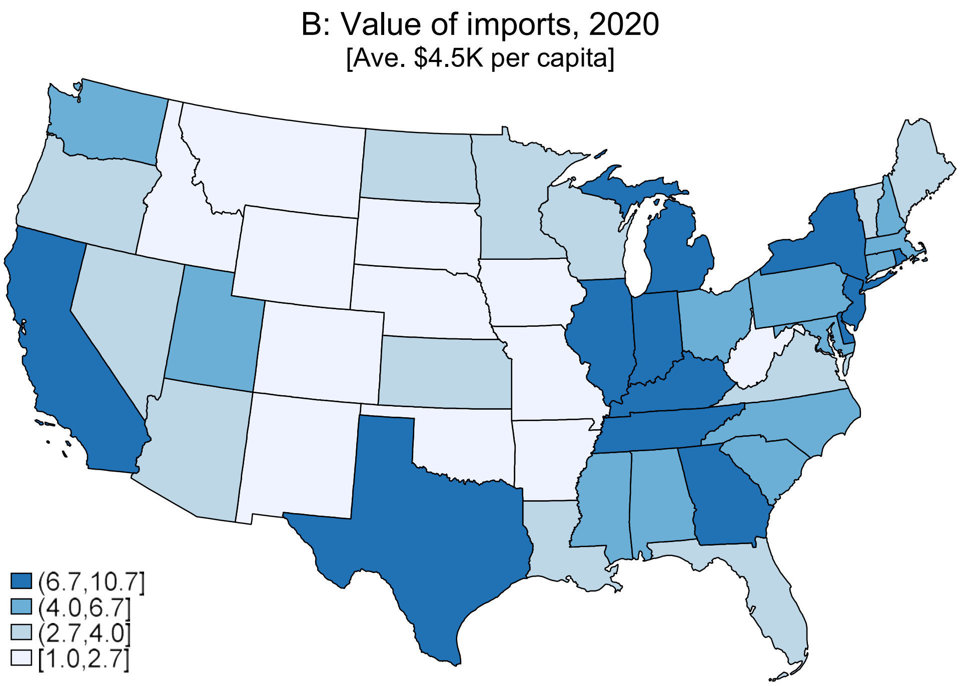
[Ave. 15.8 deaths per 100,000]



Notes: This figure complements Figure 2 by showing the distribution of opioid overdose deaths per 100,000 residents for the continental US 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.)

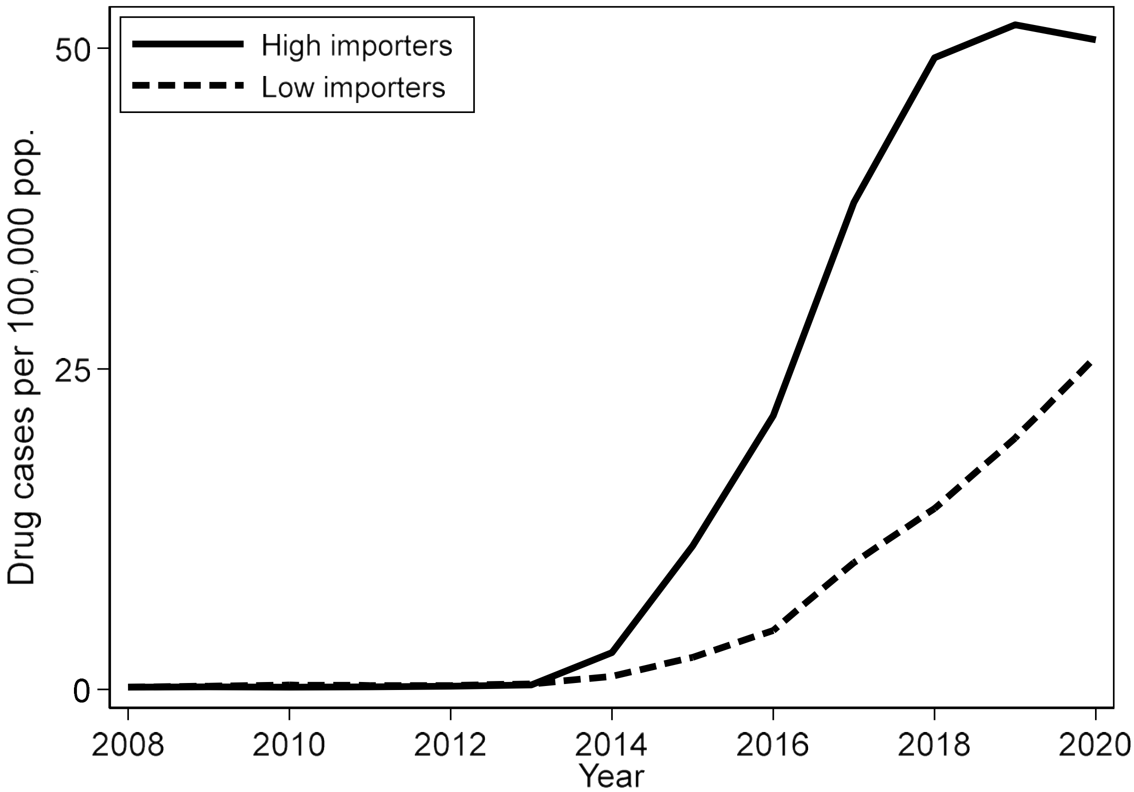
Figure A3 The relative distribution of imports per capita in 2008 and 2020





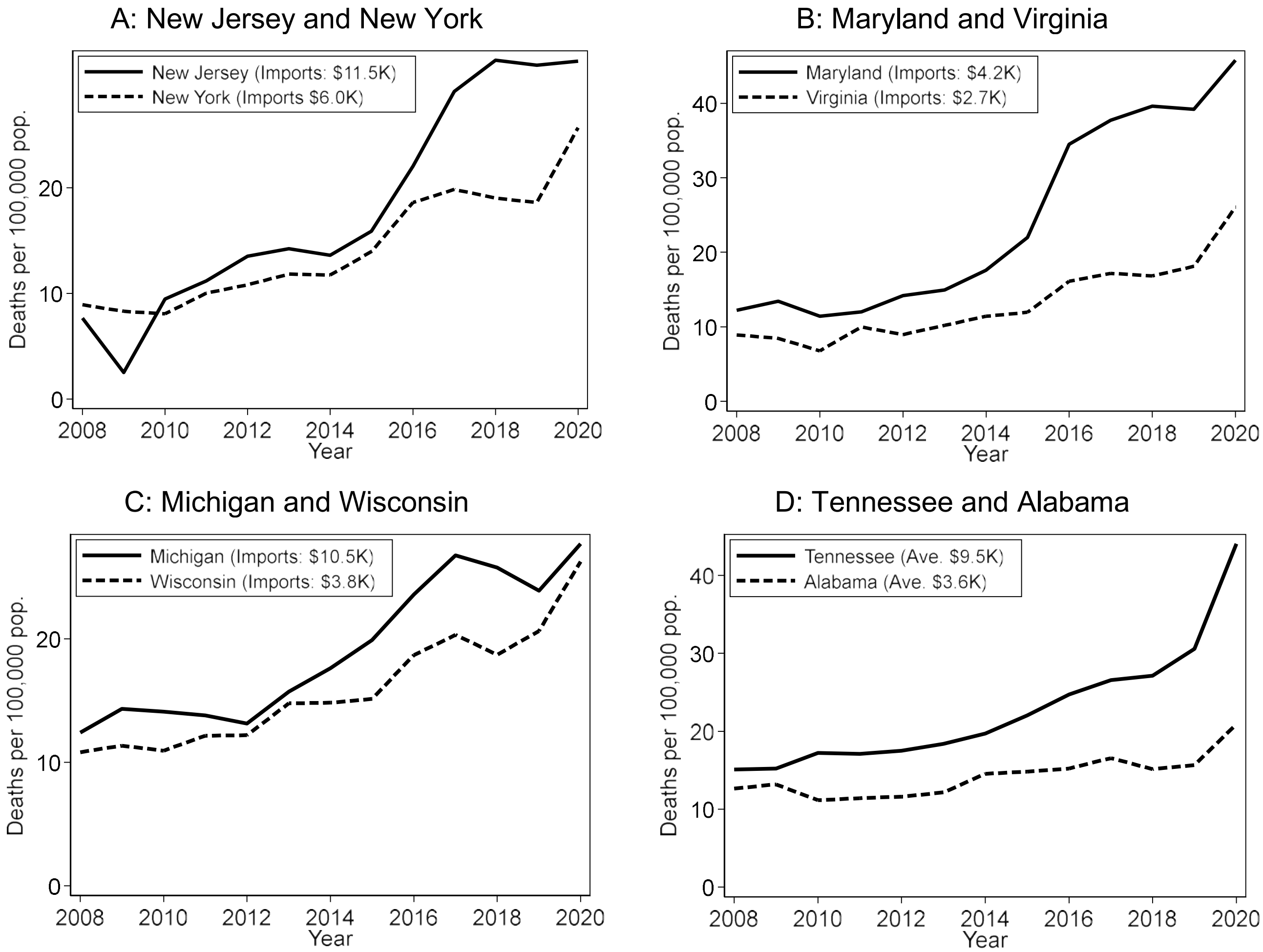
Notes: This figure shows the distribution of the value of imports (excluding oil and gas) per resident for the continental US at the beginning and end of our sample period (2008 and 2020). Shading shows the value of imports in each year by quartiles, with darker shading indicating a higher value of imports. 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



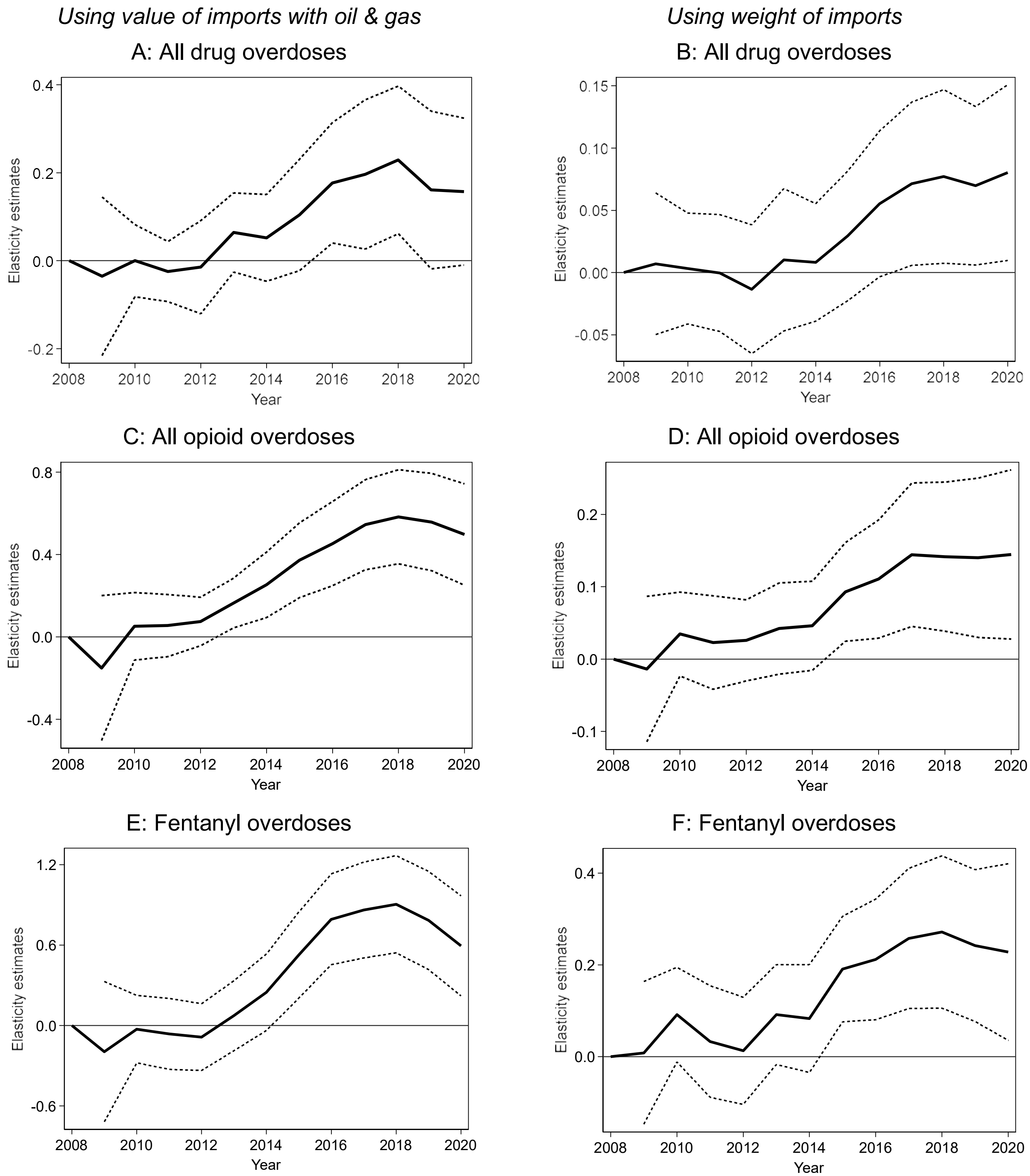
Notes: This figure shows the rates at which police seize fentanyl and fentanyl analogs for two groups of 25 states split by the median value of imports per resident over the 2008-2020 period (which is $3,860 per resident). The figure shows that states defined as “high importers” (above the median) and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

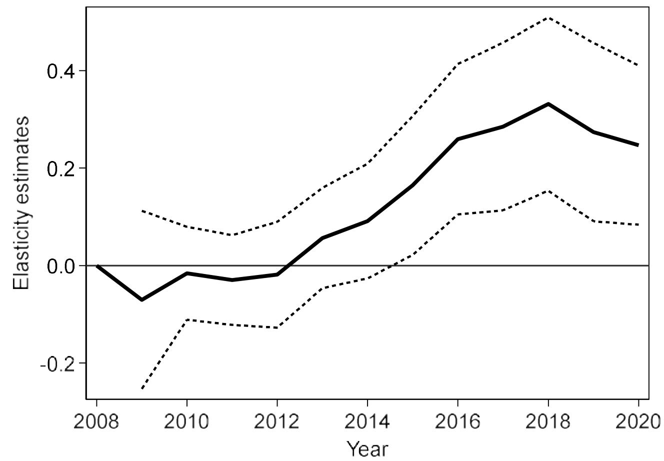
Figure A6 The relationship between overdoses and imports using different import measures



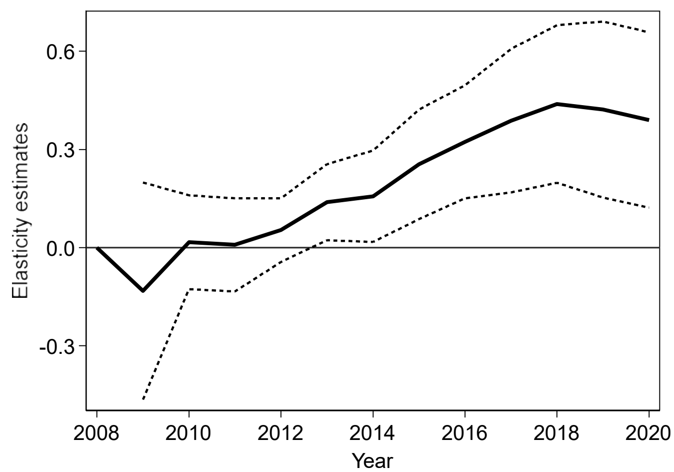
Notes: This figure plots the estimated elasticities and 95% confidence intervals of different measures of imports per state resident for all drug overdoses, all opioid overdoses, and fentanyl overdoses. The panels on the left show estimates using the value of imports inclusive of oil and gas imports. The panels on the right show estimates using the weight of imports in kilograms, which are recorded for sea and air imports (but not land or mail imports). The estimates are based on equation (1), and use 650 observations. These estimates are summarized in Appendix Table A3. See the notes in Table 2 and the text for more details.

Figure A7 The relationship between the 2008 value of imports and drug overdoses

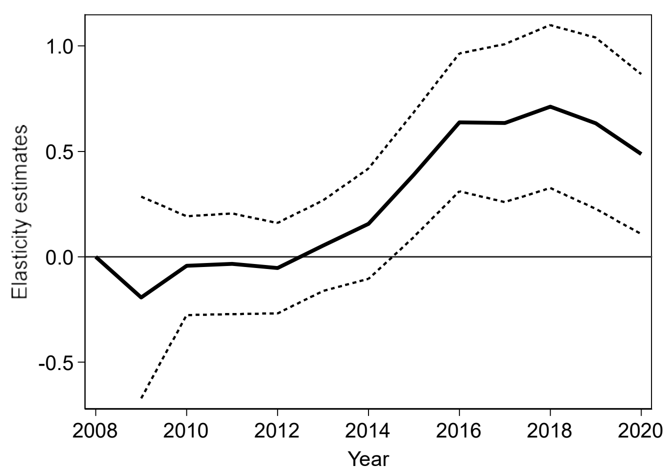
A: All drug overdoses



B: All opioid overdoses

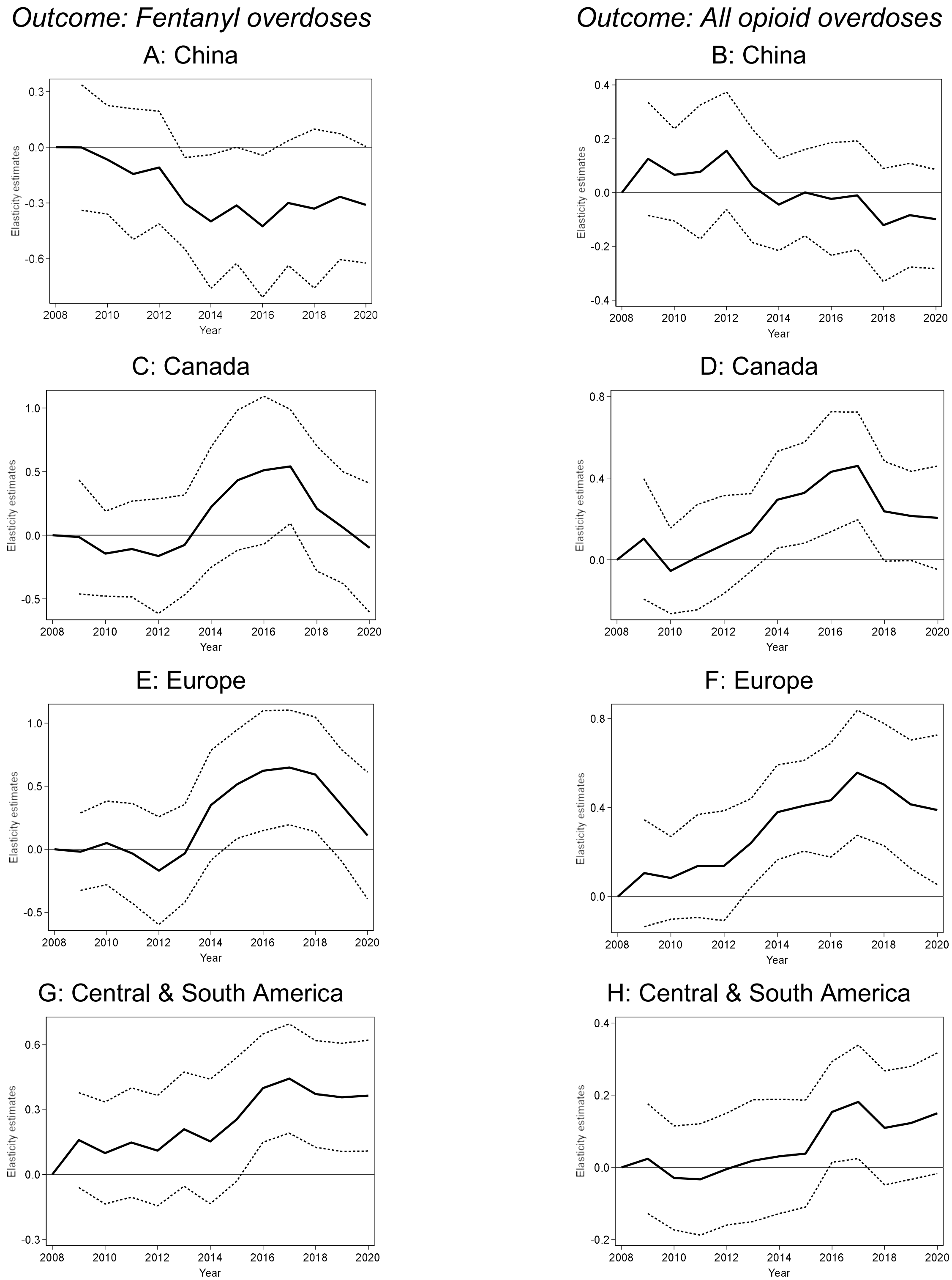


C: Fentanyl overdoses



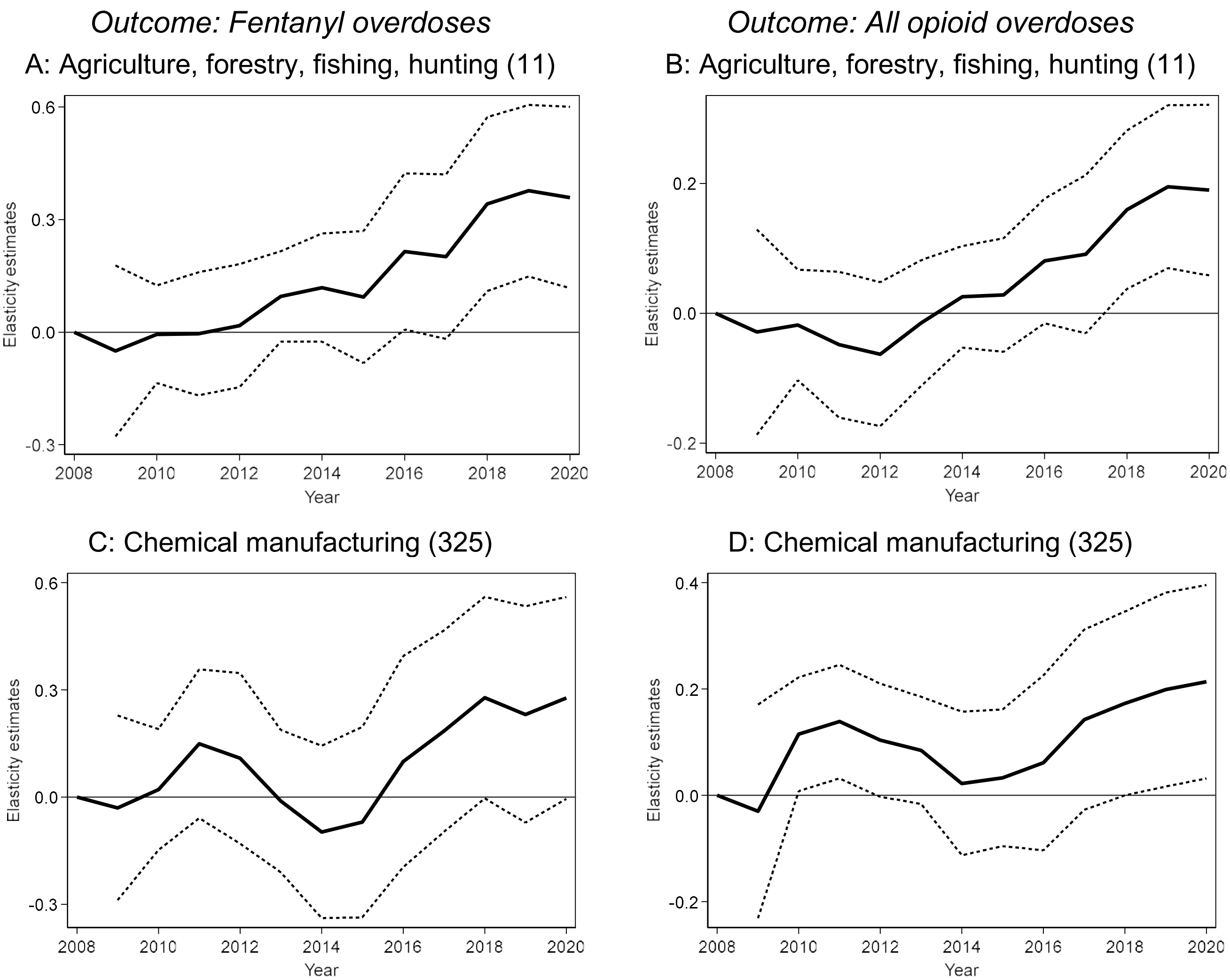
Notes: This figure shows the estimated elasticities and 95% confidence intervals using the 2008 value of imports. The estimates are based on equation (1), and use 650 observations. These estimates are summarized in Appendix Table A7. See the notes in Table 2 and the text for more details.

Figure A8 Heterogeneity by selected country-of-origin import shares



Notes: This figure shows the estimated elasticities and 95% confidence intervals for import shares by selected countries/regions of origin. The estimates come from modified versions of equation (1), where the annual value of each import subsample is separately interacted with the year indicator variables. For each overdose outcome, all estimates come from a single regression (along with the other results summarized in Table 4 and Appendix Table A10). There are 650 observations in each regression. See the notes in Table 2 and the text for more details.

Figure A9 Heterogeneity by selected industry import shares (NAICS codes



Notes: This figure shows the estimated elasticities and 95% confidence intervals for import shares by selected industry groupings. The estimates come from modified versions of equation (1), where the annual value of each import subsample is separately interacted with the year indicator variables. For each overdose outcome, all estimates come from a single regression (along with the other results summarized in Table 4 and Appendix Table A10). There are 650 observations in each regression. See the notes in Table 2 and 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

	All drug overdoses			All opioid overdoses			Fentanyl overdoses		
	Only year FE	Year & state FE	Main model	Only year FE	Year & state FE	Main model	Only year FE	Year & state FE	Main model
Annual elasticities									
2008	--	--	--	--	--	--		--	--
2009	-0.004 (0.080)	-0.042 (0.087)	-0.042 (0.087)	-0.064 (0.150)	-0.116 (0.166)	-0.116 (0.166)	-0.065 (0.217)	-0.139 (0.251)	-0.139 (0.251)
2010	0.078 (0.040)	-0.006 (0.047)	-0.006 (0.047)	0.120 (0.067)	0.048 (0.078)	0.048 (0.078)	0.127 (0.092)	-0.021 (0.130)	-0.021 (0.130)
2011	0.044 (0.038)	-0.024 (0.040)	-0.024 (0.040)	0.111 (0.057)	0.056 (0.070)	0.056 (0.070)	0.132 (0.085)	-0.060 (0.118)	-0.060 (0.118)
2012	0.075 (0.049)	-0.005 (0.055)	-0.005 (0.055)	0.138* (0.058)	0.087 (0.057)	0.087 (0.057)	0.165 (0.092)	-0.074 (0.112)	-0.074 (0.112)
2013	0.123** (0.041)	0.066 (0.055)	0.066 (0.055)	0.181** (0.052)	0.175** (0.060)	0.175** (0.060)	0.312* (0.122)	0.109 (0.130)	0.109 (0.130)
2014	0.135** (0.042)	0.084 (0.060)	0.084 (0.060)	0.249** (0.063)	0.256** (0.079)	0.256** (0.079)	0.463** (0.137)	0.250 (0.141)	0.250 (0.141)
2015	0.208** (0.048)	0.156* (0.067)	0.156* (0.067)	0.394** (0.075)	0.382** (0.090)	0.382** (0.090)	0.786** (0.162)	0.545** (0.166)	0.545** (0.166)
2016	0.279** (0.064)	0.236** (0.072)	0.236** (0.072)	0.453** (0.090)	0.461** (0.099)	0.461** (0.099)	0.998** (0.186)	0.786** (0.165)	0.786** (0.165)
2017	0.318** (0.072)	0.274** (0.088)	0.274** (0.088)	0.533** (0.102)	0.555** (0.114)	0.555** (0.114)	1.073** (0.189)	0.856** (0.177)	0.856** (0.177)
2018	0.333** (0.073)	0.292** (0.087)	0.292** (0.087)	0.537** (0.100)	0.567** (0.117)	0.567** (0.117)	1.090** (0.201)	0.886** (0.192)	0.886** (0.192)
2019	0.302** (0.074)	0.227* (0.091)	0.227* (0.091)	0.567** (0.101)	0.553** (0.130)	0.553** (0.130)	1.073** (0.181)	0.793** (0.204)	0.793** (0.204)
2020	0.314** (0.073)	0.241** (0.085)	0.241** (0.085)	0.574** (0.100)	0.542** (0.135)	0.542** (0.135)	0.961** (0.160)	0.700** (0.199)	0.700** (0.199)
Average elasticities									
2009-12	0.048 (0.029)	-0.019 (0.037)	-0.019 (0.037)	0.076 (0.056)	0.019 (0.072)	0.019 (0.072)	0.090 (0.078)	-0.074 (0.115)	-0.074 (0.115)
2013-16	0.186** (0.045)	0.136* (0.060)	0.136* (0.060)	0.319** (0.064)	0.319** (0.076)	0.319** (0.076)	0.640** (0.139)	0.422** (0.136)	0.422** (0.136)
2017-20	0.317** (0.070)	0.259** (0.084)	0.259** (0.084)	0.553** (0.095)	0.554** (0.118)	0.554** (0.118)	1.049** (0.174)	0.809** (0.182)	0.809** (0.182)
R-squared	0.310	0.885	0.885	0.301	0.879	0.879	0.615	0.893	0.893
Controls									
Year fixed eff.	X	X	X	X	X	X	X	X	X
State fixed eff.		X	X		X	X		X	X
Covariates			X			X			X

Notes: * denotes p < 0.05, ** denotes p < 0.01. The table shows the robustness of the estimates to including fewer controls in equation (1) for all drug overdoses (columns 1-3), opioid overdoses (columns 4-6), and fentanyl overdoses (columns 7-9). For each set of results, the first column shows the estimates and standard errors when state fixed effects and covariates are excluded; the second shows the results once state fixed effects are added; the third 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 The relationship between overdoses and different import measures

	All drug overdoses			All opioid overdoses			Fentanyl overdoses		
	Baseline model	With oil & gas	Import weight	Baseline model	With oil & gas	Import weight	Baseline model	With oil & gas	Import weight
Average elasticities									
2009-2012	-0.019 (0.037)	-0.019 (0.032)	-0.001 (0.020)	0.019 (0.072)	-0.014 (0.066)	0.017 (0.026)	-0.074 (0.115)	-0.080 (0.105)	0.036 (0.049)
2013-2016	0.136* (0.060)	0.099 (0.053)	0.026 (0.024)	0.319** (0.076)	0.218** (0.068)	0.073** (0.028)	0.422** (0.136)	0.309** (0.121)	0.144** (0.049)
2017-2020	0.259** (0.084)	0.186* (0.080)	0.075* (0.031)	0.554** (0.118)	0.410** (0.118)	0.143** (0.050)	0.809** (0.182)	0.617** (0.179)	0.250** (0.076)
R-squared	0.886	0.875	0.874	0.879	0.867	0.861	0.893	0.884	0.878

Notes: * denotes $p < 0.05$, ** denotes $p < 0.01$. The table shows estimates using different measures of imports per state resident for all drug overdoses (columns 1-3), all opioid overdoses (columns 4-6), and fentanyl overdoses (7-9). All of the estimates are based on equation (1). For each set of results, the first column shows estimates using our main import measure (the value of imports excluding oil and gas); the second column shows estimates using the value of imports inclusive of oil and gas imports; and the third column shows estimates using the weight of imports in kilograms, which are recorded for sea and air imports (but not land or mail imports). The summary estimates here are averages of single-year coefficients, with standard errors calculated using the delta method. Each regression uses 650 observations. See the notes in Table 2 and the text for more details.

Table A4 The relationship between imports and police seizures of fentanyl

	All states [ln(case rates +0.01)]		State always with positive rates (40 states)			
			ln(case rates)		ln(case rates + 0.01)	
	Fentanyl	Fentanyl & analogs	Fentanyl	Fentanyl & analogs	Fentanyl	Fentanyl & analogs
Average elasticities						
2011-2012	0.181 (0.182)	0.176 (0.183)	0.154 (0.196)	0.147 (0.198)	0.143 (0.188)	0.137 (0.189)
2013-2016	1.266** (0.331)	1.254** (0.334)	0.869** (0.327)	0.859** (0.323)	0.843** (0.320)	0.834** (0.312)
2017-2020	1.601** (0.385)	1.646** (0.384)	1.232** (0.369)	1.274** (0.367)	1.210** (0.364)	1.248** (0.363)
R-squared	0.876	0.882	0.900	0.908	0.901	0.908
Observations	550	550	440	440	440	440
Mean cases / 100,000 pop.	11.6	13.9	12.2	14.6	12.2	14.6

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 real value of imports per state resident. We use the number of fentanyl cases excluding and including 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). The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. The annual estimates for columns (1) and (2) are plotted in Figure 5. See the notes to Table 2 and the text for more details.

Table A5 The relationship between imports and overdoses by opioid type

	Fentanyl	Heroin	Oxycodone	Methadone	Other & unspecified opioids
Average elasticities					
2009-2012	-0.031 (0.104)	0.383 (0.250)	0.070 (0.076)	0.014 (0.104)	0.198 (0.188)
2013-2016	0.385 (0.141)	0.491 (0.258)	0.278** (0.089)	0.280** (0.106)	0.030 (0.222)
2017-2020	0.789** (0.181)	-0.340 (0.340)	0.323* (0.128)	0.554** (0.169)	0.248 (0.281)
R-squared	0.887	0.753	0.784	0.733	0.602
Mean deaths / 100,000 pop.	3.17	1.47	2.88	0.861	0.522

Notes: * denotes $p < 0.05$, ** denotes $p < 0.01$. This table summarizes the estimated elasticities and standard errors for different types of fatal opioid overdoses when only one type is reported on the death certificate. The respective ICD-10 drug identification codes on the death certificates are: fentanyl (T40.4); heroin (T40.1); oxycodone (T40.2); methadone (T40.3); and other/unspecified opioids (T40.6). The estimates are based on equation (1), where 0.01 is added to the deaths per 100,000 residents before we take the natural log (as some of these outcomes have zero deaths for some state-year observations). The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. Each regression uses 650 observations. See the notes to Table 2 and the text for more details.

Table A6 The relationship between imports and police seizures of other opioids

Elasticity estimates	Heroin	Oxycodone	Methadone
2011-2012	0.186 (0.163)	0.257* (0.126)	0.233 (0.234)
2013-2016	0.331 (0.244)	0.140 (0.185)	0.572 (0.321)
2017-2020	0.029 (0.268)	0.309 (0.256)	0.721 (0.414)
R-squared	0.825	0.816	0.728
Mean cases per 100,000 population	2.85	1.47	4.35

Notes: * denotes $p < 0.05$, ** denotes $p < 0.01$. This table summarizes the estimated elasticities and standard errors of police forensic seizures of heroin, oxycodone and methadone per 100,000 state residents to the real value of imports per state resident. 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). For all outcomes, 0.01 is added before we take the log as some observations are zero. Each regression has 550 observations. The summary estimates presented here are averages of single-year coefficients, with standard errors calculated using the delta method. The annual estimates are plotted in Figure 6. See the notes to Table 2 and the text for more details.

Table A7 Relationship between overdoses and imports using 2008 values

	All drug overdoses		All opioid overdoses		Fentanyl overdoses	
Elasticity estimates	Annual value of imports	2008 value of imports	Annual value of imports	2008 value of imports	Annual value of imports	2008 value of imports
2009-2012	-0.019 (0.037)	-0.034 (0.036)	0.019 (0.072)	0.007 (0.073)	-0.074 (0.115)	-0.093 (0.120)
2013-2016	0.136* (0.060)	0.143* (0.061)	0.319** (0.076)	0.310** (0.076)	0.422** (0.136)	0.410** (0.133)
2017-2020	0.259** (0.084)	0.284** (0.082)	0.554** (0.118)	0.545** (0.108)	0.809** (0.182)	0.786** (0.169)
R-squared	0.886	0.875	0.879	0.880	0.893	0.894

Notes: * denotes $p < 0.05$, ** denotes $p < 0.01$. The table shows the main estimates compared to estimates using the 2008 import values for all drug overdoses (columns 1-2), all opioid overdoses (columns 3-4), and fentanyl overdoses (5-6). All of the estimates are based on equation (1). The summary estimates here are averages of single-year coefficients, with standard errors calculated using the delta method. Each regression uses 650 observations. See the notes in Table 2 and the text for more details.

Table A8 The relationship between imports and other causes of death

	"Deaths of despair"		Other causes of death			
Elasticity estimates	Non-drug suicide	Alcohol cirrhosis	All causes except drug overdoses	Heart disease	Lung cancer	Traffic fatalities
2009-2012	-0.015 (0.019)	0.014 (0.034)	-0.004 (0.004)	-0.010 (0.010)	0.005 (0.010)	-0.001 (0.022)
2013-2016	-0.002 (0.021)	0.023 (0.043)	-0.005 (0.006)	-0.015 (0.012)	-0.007 (0.008)	-0.041 (0.021)
2017-2020	-0.037 (0.020)	0.002 (0.052)	-0.002 (0.006)	-0.009 (0.013)	-0.011 (0.013)	-0.017 (0.028)
R-squared	0.964	0.946	0.990	0.986	0.989	0.954
Mean deaths / 100,000 pop.	13.7	6.79	863	262	50.3	13.2

Notes: * denotes $p < 0.05$, ** denotes $p < 0.01$. This table summarizes the estimated elasticities and standard errors for different underlying causes of death reported on death certificates. The respective 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); and 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 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 7. See the notes to Table 2 and the text for more details.

Table A9 Heterogeneity using the value of imports by import type

	2009-12	2013-16	2017-20	Ave. imports ($K per person)
Country/region of origin				
China	0.121 (0.152)	-0.204 (0.138)	-0.187 (0.143)	0.82
Mexico	-0.020 (0.079)	0.010 (0.089)	0.071 (0.112)	0.48
Canada	-0.165 (0.113)	0.074 (0.147)	0.0003 (0.168)	0.79
Europe	-0.016 (0.123)	0.278* (0.135)	0.337* (0.145)	1.26
Asia (except China)	-0.153 (0.123)	-0.065 (0.149)	0.064 (0.164)	0.93
South & Central America	0.037 (0.08)	0.101 (0.079)	0.234** (0.078)	0.19
Africa and Oceania	-0.044 (0.102)	0.032 (0.087)	0.012 (0.129)	0.08
Mode of transport				
Sea	-0.033 (0.113)	0.273* (0.118)	0.443** (0.164)	2.09
Air	0.074 (0.089)	0.027 (0.099)	0.130 (0.126)	1.16
Land / packages: Canada & Mexico	-0.113 (0.095)	0.144 (0.179)	0.180 (0.145)	1.08
Packages: Rest of world	-0.017 (0.075)	-0.071 (0.096)	0.018 (0.098)	0.20
Industry (NAICS code)				
Computer & electronic product manufacturing (334)	-0.031 (0.063)	0.030 (0.081)	0.053 (0.08)	0.73
Transportation equipment manufacturing (336)	0.013 (0.089)	-0.133 (0.117)	0.048 (0.131)	0.64
Chemical manufacturing (325)	0.033 (0.091)	-0.007 (0.09)	0.219* (0.089)	0.54
Primary metal manufacturing (331)	-0.052 (0.15)	0.012 (0.175)	-0.095 (0.176)	0.40
Machinery manufacturing (333)	-0.016 (0.082)	0.118 (0.076)	0.109 (0.067)	0.22
Agriculture, forestry, fishing & hunting (11)	-0.042 (0.064)	0.094 (0.068)	0.250* (0.097)	0.14
All other imports	-0.100 (0.133)	0.163 (0.203)	0.025 (0.236)	1.85

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. The estimates come from modified versions of equation (1), where the annual value 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 the text for more details.

Table A10 The relationship of import characteristics to all opioid overdoses

	2009-12	2013-16	2017-20	Share of imports
<u>Country/region of origin</u>				
Value of imports	0.032 (0.079)	0.356** (0.100)	0.560** (0.116)	--
Shares: China	0.106 (0.089)	-0.011 (0.078)	-0.078 (0.089)	18.0%
Canada	0.035 (0.108)	0.297** (0.108)	0.280** (0.105)	17.4%
Mexico	0.020 (0.047)	0.071 (0.051)	0.037 (0.082)	10.5%
Europe	0.116 (0.091)	0.365** (0.095)	0.466** (0.138)	27.7%
Asia (except China)	-0.011 (0.083)	0.100 (0.098)	0.095 (0.135)	20.4%
South & Central America	0.129 (0.111)	0.254* (0.124)	0.384** (0.115)	4.2%
<u>Mode of transport</u>				
Value of imports	-0.008 (0.072)	0.243** (0.093)	0.448** (0.123)	--
Shares: Sea	0.144 (0.124)	0.050 (0.115)	0.038 (0.143)	46.1%
Air	0.173* (0.070)	0.029 (0.073)	0.038 (0.119)	25.6%
Land / packages: Canada & Mexico	0.064 (0.102)	0.006 (0.097)	0.001 (0.123)	23.8%
<u>Industry (NAICS code)</u>				
Value of imports	-0.014 (0.078)	0.312** (0.085)	0.505** (0.103)	--
Shares: Computer/electronic product manufacturing (334)	-0.021 (0.045)	-0.069 (0.047)	-0.044 (0.068)	16.2%
Transportation equipment manufacturing (336)	0.065 (0.056)	-0.039 (0.063)	0.055 (0.083)	14.2%
Chemical manufacturing (325)	0.070 (0.045)	0.036 (0.054)	0.172* (0.074)	11.9%
Primary metal manufacturing (331)	-0.094 (0.100)	0.057 (0.079)	-0.038 (0.101)	8.8%
Machinery manufacturing (333)	-0.018 (0.042)	0.061 (0.055)	0.085 (0.057)	4.9%
Agriculture, forestry, fishing & hunting (11)	-0.041 (0.049)	0.028 (0.038)	0.158** (0.059)	3.1%

<u>Notes:</u> * denotes p<0.05, ** denotes p<0.01. The table shows the relationship between different import characteristics and fentanyl overdoses at the state level. The estimates come from modified versions of equation (1), where the annual value 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 A11 LASSO selections for interaction of country/region and mode of transport

Period	Import type		LASSO	Post-OLS
		Fentanyl overdoses		
2013-2016	Value of imports		0.331	0.349
	Shares:	Sea imports from Europe	0.176	0.221
		Air imports from Europe	0.071	0.108
		Air imports from Africa	0.060	0.100
		Air imports from South/Central America	0.010	0.028
		Sea imports from Mexico	0.011	0.018
		Land imports from Mexico	-0.030	-0.060
		Air imports from China	-0.043	-0.086
		Sea imports from Asia (except China)	-0.084	-0.190
		Sea imports from China	-0.169	-0.192
2017-2020	Value of imports		0.561	0.540
	Shares:	Air imports from Europe	0.374	0.467
		Air imports from Africa	0.116	0.175
		Sea imports from South/Central America	0.127	0.157
		Sea imports from Canada	0.014	0.022
		Sea imports from Europe	0.040	0.007
		Sea imports from Mexico	0.005	0.004
		Land imports from Canada	-0.026	-0.068
		Sea imports from Oceania	-0.023	-0.087
		Air imports from Oceania	-0.063	-0.090
		Air imports from China	-0.048	-0.097
		Air imports from Mexico	-0.055	-0.102
		Air imports from Asia (except China)	-0.166	-0.220
		Sea imports from China	-0.202	-0.272
		All opioid overdoses		
2013-2016	Value of imports		0.158	0.239
	Shares:	Sea imports from Europe	0.036	0.097
		Air imports from China	-0.010	-0.042
		Sea imports from China	-0.011	-0.079
2017-2020	Value of imports		0.279	0.293
	Shares:	Air imports from Europe	0.134	0.218
		Sea imports from Europe	0.092	0.113
		Sea imports from South/Central America	0.064	0.093
		Air imports from Canada	-0.007	-0.038
		Air imports from Oceania	-0.033	-0.064
		Sea imports from China	-0.077	-0.102
		Air imports from China	-0.056	-0.117
		Sea imports from Asia (except China)	-0.082	-0.152

Notes: This table shows the types of imports selected by the LASSO procedure, including their LASSO and Post-OLS estimates. For each overdose type and time period, the import types are ordered by Post-OLS magnitudes. All models included state and year fixed effects, which 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 imports per capita and country/region-by-mode 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 18.76 for fentanyl and 20.17 for all opioids. See text for more details.

Table A12 LASSO selections for interaction of country/region and industry type

Period	Import type (NAICS codes in brackets)		LASSO	Post-OLS
		Fentanyl overdoses		
2013-2016	Value of imports		0.174	0.385
	Shares:	South/Central American machinery manufacturing (333)	0.001	0.022
		Chinese computer & electronic manufacturing (334)	-0.039	-0.244
2017-2020	Value of imports		0.274	0.388
	Shares:	European chemical manufacturing (325)	0.374	0.467
		European machinery manufacturing (333)	0.039	0.082
		European agriculture, forestry, fishing & hunting (11)	0.026	0.070
		African agriculture, forestry, fishing & hunting (11)	0.005	0.013
		African machinery manufacturing (333)	0.002	0.008
		Chinese computer & electronic manufacturing (334)	-0.060	-0.293
		All opioid overdoses		
2013-2016	Value of imports		0.092	0.217
	Shares:	Canadian machinery manufacturing (333)	0.008	0.046
		European chemical manufacturing (325)	0.002	0.044
2017-2020	Value of imports		0.170	0.251
	Shares:	European chemical manufacturing (325)	0.108	0.164
		European machinery manufacturing (333)	0.022	0.033
		European agriculture, forestry, fishing & hunting (11)	0.013	0.031
		African agriculture, forestry, fishing & hunting (11)	0.005	0.007
		Oceanian computer & electronic manufacturing (334)	-0.024	-0.048
		Chinese transportation equipment manufacturing (336)	-0.028	-0.079
		Chinese computer & electronic manufacturing (334)	-0.047	-0.089

Notes: This table shows the types of imports selected by the LASSO procedure, including their LASSO and Post-OLS estimates. For each overdose type and time period, the import types are ordered by Post-OLS magnitudes. All models included state and year fixed effects, which 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 imports per capita and country/region-by-industry 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 75.7 for fentanyl and 34.05 for all opioids. See text for more details.