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The U.S. Opioid Epidemic: Profit, Risk and Supply Chain Responsibility

(Authors' names blinded for peer review)

This paper gives an unbelievably detailed history of margarine in America. Why then, do you ask, is the title about butter? Well, who ever heard of a far, far margarine place? I mean, come on; you have to give the author some poetic license. Otherwise every paper would read like stereo instructions. And who ever reads stereo instructions? Anyway, the paper is about butter...I mean margarine!

Key words: Opioid Crisis, Pharmaceutical Supply Chain, Supply Chain Integration, Supply Chain Responsibility, Supply Chain Diversification

1. Introduction

The United States has suffered from the painkiller overdose epidemic for years. Increased prescription of Opioid medications led to widespread misuse of both prescription and non-prescription Opioids before it became clear that these medications could indeed be highly addictive. This paper tries to investigate how supply chain structure impacted the prevalence of retail Opioid sales. We focus on studying business acts between retail pharmacies and their upstream partners, such as wholesalers and distributors. Our analysis is based on the ARCOS database that records controlled substances transactions. Big chain pharmacies and their distribution centers were accused of being responsible for the massive proliferation of prescription painkillers abuse (Abelson et al. 2019). Totally, chain retailers processed 53% of Opioids under our setting, among which the top five chain companies managed about 78% of them. These companies are CVS, Walgreens, Kroger, Walmart and Rite Aid. Some counties and states across the nation have already taken legal actions against the companies. However, our results show a different side to this crisis. We believe independent retail pharmacies should also bear the primary responsibility, and chains' partnership with wholesalers played an bad role in fueling the narcotic overdose.

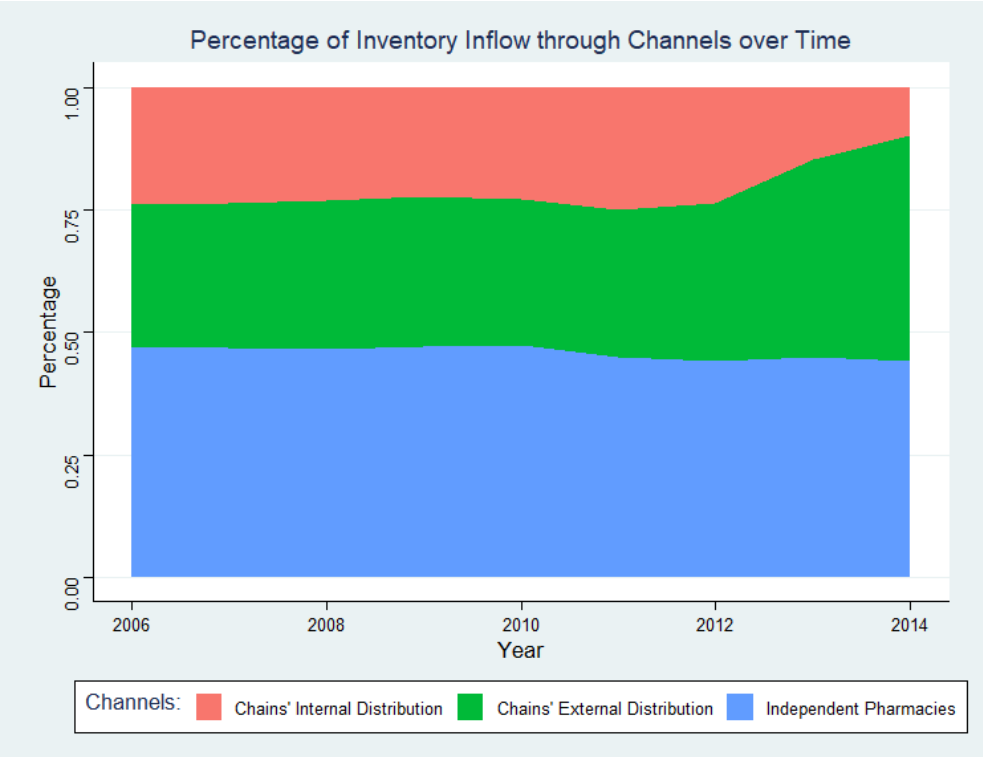

Figure 1 Channels Compete

2. Literature and Hypotheses

The Washington Post has been actively investigating, tracking and reporting the epidemic. The database used by this study was also made available by the Washington Post. Within the pharmaceutical supply chain of Opioid drugs, big pharmaceutical companies played a dominating role, and influenced multiple tiers through growing, processing and supplying the ingredients in painkillers sold by most drug companies. One example is Johnson & Johnson. It imported raw materials, as known as poppy, from foreign countries, and then refined them into Oxycodone and Hydrocodone (Whoriskey 2020). These companies adopted aggressive marketing strategies in order to increased the demand for their pain relievers (Horwitz et al. 2019). People became addicted after using the prescribed products (Rowland 2019). It was reported that main manufacturers, distributors and retailers were indifferent to the evolution of the epidemic (Higham et al. 2019).

The Opioid crisis also drew attention from academic community, and there was a stream of research on this topic from various perspectives. This paper studies the legal practice of prescription Opioids and their overdose, whereas illicit Opioid use was another drive for the epidemic. Legitimate use of Opioids has paralleled by a rise in abuse of prescription drugs (Kuehn 2007). In 2004, 99% of the global supply for Hydrocodone happened in the United States. One reason for the increased prescription was provider-directed payments from drug manufacturers to physicians (Nguyen et al. 2019). It has been argued that physicians who received specific payments prescribed more daily

doses per year than those who did not receive any such payment. The overprescribing may also be due to doctors' lack of awareness of potential harms from anesthesia (Clark and Schumacher 2017).

The pharmaceutical industry can be defined as a complex of processes, operations and organisations involved in the discovery, development and manufacture of drugs and medications (Shah 2004). Multinational companies play a dominating role by covering a large part of the supply chain with a global presence in branded products, which means that primary production is effectively a push process (Shah 2004). Besides distribution of pharmaceutical products, PBM's and insurance providers manage financing part of the supply chain (Dabora et al. 2017). There has published a comprehensive literature review (Narayana et al. 2014). Efforts were made to analyze the supply chain structure. One modeling approach is a generalized network oligopoly setting with arc multipliers for supply chains of pharmaceutical products using variational inequality theory (Masoumi et al. 2012). In the network, each firm selects its product flow paths in a non-cooperative manner, seeking to maximize its own profit, until an equilibrium is achieved.

Retailers are at the bottom stage of the pharmaceutical supply chain. Their business interacts with customers, and meets market demand of prescription pain relievers. Independent pharmacies and chain pharmacies are two main categories. One way to distinguish them is by logistics capabilities. Independent pharmacies rely on wholesalers for warehousing and transportation, but chain pharmacies can directly interact with manufacturers with the help of their internal distribution departments (Brooks et al. 2008). Research found that independent pharmacies are more reliant on prescription sales than chains (Winegar et al. 2009). For independent pharmacies, the prescription department often generates more than 75% of their revenue, whereas this figure may be less than 50% for large retail chains (Doucette et al. 1999). In addition, a higher portion of independent pharmacies offer pain management programs than chain pharmacies do (Doucette et al. 2006). Based on these facts, we believe independent pharmacies were a top driver behind the growth in market supply because their profitability and survival depended more heavily on Opioids that chains did.

HYPOTHESIS 1. *Independent pharmacies were increasingly more active than chain pharmacies to supply Opioids*

Since the relationship with wholesalers is a basic criteria for categorizing pharmacies, we believe supply chain integration influenced the evolution of the overdoes epidemic. To identify the supply chain effect, cost is a standard to measure the performance of structures in terms of their impact on the narcotic crisis. Research shows that more integrated supply chains come with lower operational costs. For example, in a two-stage serial supply chain with stationary stochastic demand and fixed

transportation times, retailers and suppliers could choose to integrate, cooperate or compete. The total optimal cost occurs with supply chain integration, and the other business forms cannot render the optimal base stock levels (Cachon and Zipkin 1999). Similar conclusions are drawn under a dynamic programming setting (Gao 2015). When inventory and transportation operations are managed together as a joint objective, the expected holding and backordering cost are always lower than other scenarios (Büyükkaramikli et al. 2014). "Bullwhip Effect" is one possible explanation for the poor performance of unintegrated stuctures. It is believed that an integrated structure has better information sharing between retailers and wholesalers, which lowers the order variance amplification (Chatfield et al. 2004)

From the data, the number of chain pharmacies that collaborated with wholesalers far exceeds the number of those did not collaborate, which reflects a fact that most chains had insufficient warehousing or transporting capability to survive on their own. Hardly have existed absolutely self-reliant chains. They usually chose to partner with wholesalers even when they owned internally distributing systems. As for this study, the integrating case corresponds to the chains with internal systems, and the opposite case analogizes the chains interacting with wholesalers. To maximize profit, chain pharmacies should allocate their low-cost channel to serve a majority of revenue, and leave the high-cost channel for the remaining small portion of revenue. In this manner, they could optimize the channel allocation programming. Therefore, chain pharmacies should mainly process prescription-related business externally due to only a small portion of profit coming out of it, and other business internally in expectation for a large part of profit to be generated.

HYPOTHESIS 2. *For chains, their external distribution systems were more resistant to lose supply share to independent pharmacies than their internal distribution systems were*

3. Data

Automated Reports and Consolidated Ordering System (ARCOS) is a data collection system in which manufacturers and distributors report their controlled substances transactions to the Drug Enforcement Administration (DEA). It collects transaction information about certain controlled substances, including Opioid drugs. DEA uses the information to determine quota, distribution trends, internal audits, and other analyses. The ARCOS system recorded supply chain activities that directly influenced the epidemic. Through a series of legal processes, the federal court and the Washington Post finally made this database public ((Achenbach 2019),). (**?**)

There are fourteen types of Opioid related drugs from the transaction-level raw data, which are Buprenorphine, Codine, Dihydrocodeine, Fentanyl, Hydrocodone, Hydromorphone, Levorphanol, Meperidine, Methadone, Morphine, Powered Opium, Oxycodone, Oxymorphone and Tapentadol. However, Buprenorphine and Methadone are not a part of our analysis because they are more often

used to treat Opioid addiction and dependence than to relieve pain. In addition, Dihydrocodeine, Powered Opium and Levorphanol are also not included due to their minimal market presence, rarity in prescription use, and abnormal circulation patterns.

3.1. Dependent Variable

To test our hypotheses, we use the annual inventory inflow in each county as the dependent variable, which is the amount of Opioids that wholesalers and distributors delivered to pharmacies. The dependent variable is in morphine milligram equivalents (MME) per capita. MME is a value assigned to Opioid drugs to represent their relative potencies. Each drug can be standardised to an equivalent amount of Morphine in milligram. The ARCOS dataset contains information of MME for each transaction record. The exact market demand for prescription substances is an ideal dependent variable, but such data are unavailable. Given the setting of our model, deliveries from wholesalers and distributors were actually more than 96% of the total drugs processed by pharmacies, and the rest 3% of them left the market for various reasons. Therefore, the shipment amount is a good measure for Opioid supply as it is close to the consumption for prescribed analgesic drugs across the years. To adjust for population, the dependent variable is on a per-capita basis.

We reshape the ARCOS data into a county-level longitudinal format with nine years (i.e., between 2006 and 2014). There are 2965 counties included in the data, and those with incomplete time coverage are discarded in order for a balanced panel.

3.2. Independent Variable

There were three supply chain channels pushing substances to the market. Chain pharmacies partnered with wholesalers. Chains also had internal distribution departments, whereas independent pharmacies can only rely on wholesalers. These three channels constituted the supply of prescription Opioids. Independent retailers selected wholesalers from whom to purchase the products at a price negotiated independently; in contrast, chains were able to negotiate prices directly with pharmaceutical manufacturers (Levitt 2017).

Accordingly, there are three exploratory variables: the percentage of drugs processed through chains' internal/external distribution and independent retailers' distribution. Each represents a proportion of Opioids that were transported to pharmacies in a county through a certain channel for prescription purposes. For example, Baldwin county in Alabama received 26% of their drugs from chains' internal distribution, 46% were handled by independent retailers and the rest 28% were delivered by wholesalers to chains in 2010.

3.3. Control Variables

CDC released data on Opioid prescribing rates that are the total number of Opioid prescriptions dispensed annually at the county level on the per-capita basis. Note that these are prescription

counts, and not converted to morphine milligram equivalents (MME). However, we believe more prescription practice led to higher market demand. The data reflect the true count-level demand of substances between 2006 and 2014. Furthermore, since the dependent variable is the annual inventory inflow that is only the supply, the prescribing rates serve as a proxy of the demand-side information. Controlling for prescribing, we can observe how the annual inventory inflow traveled through the various supply structures. The prescribing rates also contain other information, such as marketing effort made by pharmaceutical companies, and chronic substance abuse.

Narcotic abuse has destroyed many families. People are mentally and physically devastated. As a result, household income becomes a major indicator of the negative social impact. An intuition is that declining economic opportunity may have played a significant role in driving the overdose crisis. Drug abusers eventually become incapacitated due to addiction, and it could lower the median income in a county. Research shows correlations between declining economic and rising death rates among America's working class(Case and Deaton 2017). Another strong negative correlation exists between various measures of prescribing and county median household income (Zhou et al. 2018).

Studies show that counties with worse economic prospects are more likely to have higher prevalence of substance use and Opioid prescriptions. From 2006 through 2016, on average, an increase of 1% in a county's poverty rate was associated with a 1.4% increase in per capita retail Opioid sales (Ghertner and Groves 2018).

Unemployment rate is another widely acceptable social economic measure. Opioid-related deaths and ED visits increased during times of economic weakness. As a proxy for macroeconomic conditions, a 1% increase in the unemployment rate raises predicted Opioid-involved mortality rates by 0.19 per 100,000 for 1999-2014 (Hollingsworth et al. 2017). In terms of prescriptions, an increase of 1% in a county's unemployment rate was associated with a 3.8 % increase in per capita Opioids sales from 2006 through 2016 (Ghertner and Groves 2018).

A wide coverage of insurance can help improve people's health and social well-beings. Research found the uninsured rate has long been higher among individuals with mental and substance use disorders than the general public. Medicaid payment increased by 7.4% for individuals receiving substance use disorder treatment in 2014 (Saloner et al. 2017). Some researchers believe Medicaid is part of the solution to the Opioid crisis. It makes medications like Buprenorphine and Naloxone, which are prescribed to combat opioid use disorders, affordable for beneficiaries (Broaddus et al. 2018). Consequently, the expansion of insurance programs would increase patients' access to treatment, and reduce the overdose.

4. Model and Results

4.1. Setup

To test our hypotheses, we incorporate fixed effects (FE), random effects (RE) and Pooled OLS in the regression equation. The FE approach is that the regression de-means for each individual

county, and then applies OLS to the mean deviations. The benefit of this process is to correct for endogeneity driven by omitted variable bias attributable to time-invariant unobservables. Another benefit is to correct for individual heterogeneity that does not change over time. One downside is that some useful information that did not vary over the 9-year period is mathematically excluded from the analysis. The FE analysis presents how much change of the dependent variable can be explained by the change of the exploratory variables. The RE analysis assumes random intercepts. When the individual heterogeneity is correlated with independent variables, the RE is more efficient the FE; otherwise, the RE is biased. The pooled OLS approach does not take enough county-level information into account. Above all, the FE approach is widely more acceptable than the other two in academia. Overall, this analysis bases on the FE model with robust standard errors clustering by counties, and leaves the rest for purposes of comparison and robustness check. Technically, our conclusions persist after correcting for the within group correlation, cross-sectional correlation and groupwise heteroskedasticity under the FE setting.

$$\begin{aligned} opioid_{i,t} = \beta_1 \cdot percent\_wholesaler\_chain_{i,t} + \beta_2 \cdot percent\_internal\_chain_{i,t} + \\ \beta_3 \cdot percent\_independent_{i,t} + \sum_{j=4}^{8} \beta_j \cdot controls_{j,i,t} + \gamma \cdot \lambda_t + u_i + \epsilon_{i,t} \end{aligned} \tag{1}$$

4.2. Descriptive Statistics

Descriptive statistics and correlations are provided in Table 1. *Opioid per capita* has a positive correlation with *prescribing rate*. *percent_independent* is negatively correlated with *percent_wholesaler_chain* and *percent_internal_chain* as the increase of chains' supply share is equivalent to the decrease of independent pharmacies' supply share. *poverty_rate* and *median_income* are two sides of the same coin that illustrates social well-being in a county. Both collinearity and high correlation issues have been taken into account, and our results are not affected by them.

4.3. Results

To test our hypotheses, we first validate the control variables from Table 2. In the FE setting, the unemployment rate has a positive association with the dependent variable. The poverty rate and the median income associate with the per-capita Opioid supply in a direction that coincides with theoretical predictions. In terms of the uninsured rate, the insurance coverage expansion happened together with overdose treatment programs, which is presented by the positive coefficient. The year fixed effects show an increasing pattern that explains the uprising supply of substances over time. The significantly positive association between the prescribing rate and the annual inventory inflow presents a match between the demand and the supply. Since the controls behave normally and the

Table 1: Descriptive Statistics

		Mean	SDev	1	2	3	4	5	6	7	8	9
1	Opioid	600.20	2.27	1.00								
2	percent_internal_chain	0.17	0.0009	0.04*	1.00							
3	percent_wholesaler_chain	0.25	0.0013	0.08*	0.25*	1.00						
4	percent_independent	0.58	0.0018	-0.09*	-0.69*	-0.88*	1.00					
5	prescribing_rate	0.89	0.0030	0.71*	0.19*	0.05*	-0.13*	1.00				
6	unemployment_rate	7.25	0.0190	0.24*	0.07*	0.02*	-0.05*	0.23*	1.00			
7	uninsured_rate	17.01	0.0340	-0.01*	-0.01*	-0.22*	0.17*	0.07*	0.14*	1.00		
8	poverty_rate	16.28	0.0398	0.13*	-0.05*	-0.21*	0.18*	0.26*	0.48*	0.45*	1.00	
9	median_income	44385.79	73.4447	-0.12*	0.10*	0.33*	-0.30*	-0.26*	-0.31*	-0.44*	-0.75*	1.00

*$p < 0.05$. Displaying statistics for untransformed variables. Opioid per capita, percentage of drugs through chains' internal or external distribution, percent of drugs sold by independent pharmacies, prescribing rate, unemployment rate, uninsured rate, poverty rate, and median income.

Table 2

	Fixed Effects	Random Effects	OLS
	Opioid	Opioid	Opioid
percent_internal_chain	-3.313***	-2.622***	-3.133***
	(0.256)	(0.206)	(0.273)
percent_wholesaler_chain	-2.679***	-1.754***	-0.175
	(0.227)	(0.159)	(0.167)
percent_independent	2.863***	2.024***	1.174***
	(0.220)	(0.148)	(0.148)
prescribing_rate	2.467***	3.182***	5.356***
	(0.147)	(0.132)	(0.133)
unemployment_rate	7.625***	9.503***	17.508***
	(1.107)	(1.091)	(1.872)
uninsured_rate	3.530***	1.730***	-0.529
	(0.583)	(0.492)	(0.779)
poverty_rate	0.847	-0.789*	-7.643***
	(0.587)	(0.479)	(0.873)
year_2007	44.449***	39.863***	27.958***
	(1.319)	(1.307)	(1.668)
year_2008	69.272***	60.056***	33.605***
	(2.170)	(2.114)	(2.836)
year_2009	74.360***	59.353***	9.096
	(5.056)	(4.973)	(7.990)
year_2010	120.787***	105.189***	51.779***
	(5.614)	(5.507)	(8.484)
year_2011	163.637***	148.581***	102.292***
	(5.381)	(5.210)	(7.450)
year_2012	180.930***	164.273***	116.602***
	(5.056)	(4.795)	(6.298)
year_2013	160.411***	146.552***	107.732***
	(4.727)	(4.466)	(5.541)
year_2014	186.054***	168.615***	144.654***
	(4.921)	(4.495)	(5.501)

* p < 0.1; ** p < 0.05; *** p<0.01

within-R^2 is over 0.45, the exploratory variables should render credible results for further analysis and reasoning.

Again, pharmaceutical supply chain is of a push structure, and it is even more so for narcotics according to the background story. This type of structure highlights strategic planning that guides the entire supply chain. Big pharmaceutical companies and manufacturers are the core part that manages supply processes, and they also have a commitment to make marketing efforts. In other words, market demand does not determine production, but instead becomes an outcome of it. As zooming in on the dual-stage subsystem, we believe it was not upon pharmacies to decide the demand of the prescription drugs, and the only decision-making for them was the channel allocation

programming. In terms of the causal direction, the retailers decided their supply channels as a consequence. In this study, the three exploratory variables on the supply side directly illustrate the flow paths of prescription painkiller overdose.

Our results support Hypothesis 1. The coefficient for *percent_independent* is positive in comparison with the negative ones for *percent_wholesaler_chain* and *percent_internal_chain*. Independent pharmacies realized over 75% of their revenue from prescribing medicines (Doucette et al. 1999). Opioids are very unique drugs that become necessities of life as soon as people get addicted to them, and this addiction creates steady demand growth for pharmacies. Consequently, expanding Opioid-related business has the potential for greater relative impact on revenues for independent retailers. One reason chains did not behave as outrageously as independent retailers was their broader business scope. For independent pharmacies, prescription dispensing and professional pharmacist services often dominate their business. However, in other pharmacy settings, the prescription department and pharmacist services are only complementary aspects of their business models, competitive strategies, and positioning in the market (Doucette et al. 2017). In addition, independent retailers relying primarily on the sale of prescriptions, rather than other store items, perceived less fiscal flexibility as prescription profits dropped (Bono and Crawford 2010). Competition between the two types of pharmacies has long been studied. Some independent pharmacies may have closed due to chain competitors (Schommer et al. 2014). It appears that independent pharmacies were not able to keep up with the growth in services shown by the chain pharmacies. This may be due to fewer resources being available to independents compared with larger chain organizations (Doucette et al. 2017). Therefore, the opposite signs of the exploratory coefficients indicate that chain pharmacies did not expand their Opioid prescribing business as hard as independent pharmacies over the nine-year period.

Hypothesis 2 is also supported. For chains, their external distribution appear more resistant to lose their supply share than the internal counterparts. Had chains owned sufficient capacity for their internal systems with an appropriate cost, they would have processed everything through this channel. However, the fact is that absolutely self-reliant chains were very few as we can observe from the data, and almost all chains collaborated with wholesalers. Given the limited capacity, they allocated the large portion of revenue to the low-cost channel to maximize their profit, and assigned the minor portion of revenue, such as Opioid prescribing, elsewhere strategically. Analogously in our study, an internally managed channel was an integrated system, and the dependence on wholesalers corresponded to an unintegrated scheme. Among the two channels, the internal distribution system had a lower cost because of some benefits from supply chain integration. Research shows that the integration of the stochastic dynamics of inventory replenishment and transportation operations performs better than either uncoordinated or coordinated logistics (Büyükkaramikli et al. 2014).

Under a game theoretical setting, no matter to what extent a supplier and a retailer cooperate, an integrated supply chain always outperforms (Cachon and Zipkin 1999). Moreover, whenever transportation plays a role in a distribution process, inventory decisions and transportation decisions would better be made together. If retailers neglect relevant parts of the transportation costs in a multi-echelon inventory, then it may lead to non-optimal safety stock allocations (Tempelmeier and Bantel 2015). When independent retailers became increasingly more progressive to take over supply, chains' internal channel lost more share because it had already handled the large part of revenue, and did not excessively rely on prescription business for profit growth. Prescription service was a minor aspect for chains, and Opioid prescription was even more insignificant. Obviously, chains did not utilize the channel to expand Opioid-related business as heavily as they did externally. In contrast, the loss was not as worse from the partnership with wholesalers because chains always assigned it to primarily process controlled substances, which made this channel keep up a relatively faster pace of the increasing supply while facing aggressions from independent pharmacies.

5. Discussion and Insight

Public opinion and American media blamed chain pharmacies for the overdose epidemic (Abelson et al. 2019). However, our research shows that independent pharmacies should also take the primary responsibility for this crisis because they expanded more aggressively when prescriptions soared the market over the nine years. Surprisingly, the internal distribution was not as actively as chains' wholesaling partnership to fuel the crisis. One takeaway is that supply chain structure matters for this stream of research. Retailers maximize profit by allocating their services to different channels. Those engaging in more diversified business activities rely less on controlled substances for profit growth than the others having more concentrated business scope. A highly integrated supply chain benefits from low operational costs, which reduces reliance on Opioids prescription services.

Efforts have been made to stop the epidemic on the demand side. Toxicosurveillance involves confirmatory Opioid testing in patients presenting to the emergency department (ED) with opioid toxicity, but it is not widely practiced and hard to identify novel drugs (Lucyk and Nelson 2017). Researchers propose a common pain management curriculum for broadly utilization in US medical, dental, pharmacy, or nursing schools, and public education on pain (Clark and Schumacher 2017). Naloxone distribution programs would be another approach (Fairbairn et al. 2017) along with supervised injection facilities (Gilbert and Dasgupta 2017). We believe supply chain responsibility plays an important role in this societal crisis. Independent pharmacies would not have be strongly incentivized to expand their narcotic-related service if they had less narrowly concentrated business scope. Under proper policies, chains could have been unwilling to process Opioids through any of their channels. Consequently, cutting Opioids from the supply side may be as effective as doing so from the demand side.

6. Robustness Check

Simultaneity bias is one potential source of endogeneity. Namely, the dependent variable and the exploratory variables mutually impact each other in each period. More specifically, the demand for the substances reversely influences managers' decision on channel selection. If it is the case, then our estimation is biased and inconsistent. To check for the issue, we use lagged independent variables to interpret the Opioid demand. In this way, the supply side can affect the demand in the next period, but not the other way around. Of course, the pass of the effect is through the current demand.

Table 3 Regression Results with Lagged Exploratory Variables

	Fixed Effects	Random Effects	OLS
	Opioid	Opioid	Opioid
percent_internal_chain	-304.140***	-241.580***	-301.708***
	(26.128)	(20.961)	(27.999)
percent_external_chain	-195.372***	-113.911***	-5.606
	(22.225)	(15.779)	(18.187)
percent_independent	230.550***	157.255***	112.388***
	(21.557)	(15.159)	(15.670)
prescribing_rate	192.751***	291.170***	547.360***
	(17.460)	(15.721)	(14.230)
unemployment_rate	7.860***	9.923***	17.869***
	(1.004)	(1.014)	(1.897)
uninsured_rate	2.887***	1.157**	-0.900
	(0.607)	(0.515)	(0.819)
poverty_rate	0.195	-0.793	-7.365***
	(0.593)	(0.504)	(0.918)
median_income	-0.0004	-0.00007	0.002***
	(0.000)	(0.000)	(0.000)
year_2008	32.869***	27.477***	14.429***
	(1.475)	(1.498)	(1.934)
year_2009	57.465***	46.405***	18.216***
	(2.353)	(2.323)	(3.070)
year_2010	83.702***	65.022***	12.451
	(5.092)	(5.069)	(8.215)
year_2011	109.199***	88.806***	31.989***
	(5.472)	(5.379)	(8.672)
year_2012	134.162***	114.237***	64.822***
	(5.220)	(5.083)	(7.574)
year_2013	107.719***	85.464***	33.855***
	(4.773)	(4.560)	(6.289)
year_2014	110.045***	90.987***	49.316***
	(4.489)	(4.318)	(5.662)

* $p < 0.1$; ** $p < 0.05$; *** $p<0.01$

$$\begin{aligned} opioid_{i,t} = \beta_1 \cdot percent\_external\_chain_{i,t-1} + \beta_2 \cdot percent\_internal\_chain_{i,t-1} \\ +\beta_3 \cdot percent\_independent_{i,t-1} + \beta_{4,5,6,7,8} \cdot controls_{i,t-1} \\ +\gamma \cdot (t-1) + u_i + \epsilon_{i,t} \end{aligned} \tag{2}$$

7. Conclusion

This paper studies the Opioid crisis from the perspective of supply chain structures. Controlling for prescribing rates as a proxy for demand, we take a close look at the supply side of these controlled substances. The "push" structure helps build the causal direction for our analysis, and avoids simultaneity bias. There were three channels delivering inventory inflow, and almost all of the inventory fulfilled demand from prescription holders. As a member at the bottom stage of the supply chain, independent retailers rose to be more active on this business, which resulted in the loss of supply share from chains. However, the prescription department was only a complementary aspect of chains' business activities, and they allocated much of it to wholesaling partners. This explains why the external distribution channel lost fewer supply share than the internal distribution centers. Overall, the two types of pharmacies were both responsible for the current crisis, and supply chain structures determined their impacts. For policymakers, they need to emphasize this subject in order to curb the epidemic.

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