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Supply-side Response to Declining Heroin Purity: The Fentanyl Overdose Episode of 2006

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October, 2009

Abstract

During the past decade, the purity of heroin sold in the Northeastern U.S. declined, while at the same time the availability of prescription opioids increased considerably. In 2006, illicitly produced fentanyl, an extremely potent synthetic opioid, was added to heroin sold in a handful of mostly Northeastern U.S. cities, resulting in over one thousand deaths. We argue that the introduction of fentanyl into the drug markets, the timing of overdose deaths, and the blood concentration of fentanyl in decedents was associated with trends in heroin purity. By the end of 2006, non-pharmaceutical fentanyl had largely disappeared from the drug market, due to several highly publicized busts, enhanced sentencing, and the banning of precursors used in fentanyl manufacture. The fentanyl overdose episode of 2006 can be seen as a supply-side response to declining heroin purity.

Keywords:

JEL Classification:

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1 Introduction

Drug control policy in the United States has tended to prioritize the interruption of supply over demand reduction efforts such as prevention and treatment. Traditionally, interdiction efforts have been focused on relatively small number of popular and potent substances - heroin, cocaine, and to a lesser extent, marijuana. These efforts continue, yet in the last decade, several new developments have complicated drug control efforts. One major shift is the increasing popularity of "non-organic" substances which are manufactured from easily obtained chemicals, most notably methamphetamine, but also XTC and PCP. Another trend is the increasing availability of prescription opioids, which are obtained from many sources, including relatives and friends as well as the illegal drug market.

These more recent developments have increased the sophistication and flexibility of the drug market, and suggest that in this environment, supply interdiction may have new and unintended consequences. We argue that these forces converged to create the fentanyl overdose episode of 2006, in which a sustained decline in heroin purity, brought about in part by enforcement activities, led to the addition of illicitly manufactured fentanyl to the heroin supply by certain drug distributors. The ability to manufacture fentanyl was facilitated by technological change and the use of the internet. The imperative to increase the potency of the heroin supply was heightened by the increased availability of prescription opioids, a close substitute for heroin. The outcome was an eight month period of elevated overdose in a number of U.S. cities, resulting in more than one thousand deaths.

In this paper we describe the economic aspects of this incident and argue that non-pharmaceutical fentanyl overdoses were related to drug suppliers' efforts to respond to declining heroin purity in the context of increasing availability of close substitutes. While the empirical evidence supporting the existence of this relationship in Southern New Jersey is convincing, it should be noted that fentanyl was not universally mixed with heroin in all drug markets in the North East. For example, the pattern we observe in Philadelphia and Camden and the surrounding area does not take place in

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New York City and the Newark area, although the trends in the heroin purity are essentially the same in both markets. We attribute this to differences among drug sellers in access to fentanyl, and perhaps in their predisposition to risk. Market differences in the availability and the use of prescription opioids may also play a role.

The difficulties in evaluating the effect of supply reduction on the consumption of illegal drugs have been addressed in the literature. In general, supply reductions result in moderate declines in supply, which are difficult to assess. Many studies of illegal drug markets focus on evaluating the effect of supply reduction on consumption. Smithson, McFadden, Mwesigye and Casey (2004) used the Australian heroin drought to measure the effect of supply reduction on ambulance calls and enrollment in methadone treatment programs. Weatherburn, Jones, Freeman and Makkai (2003) found that heroin users in Australia during this period substituted cocaine for heroin to a certain extent. A recent paper by Dobkin and Nicosia (2009) studies the effects of government restriction of methamphetamine precursors on the consumption of methamphetamine.

This analysis makes a number of contributions to the literature on drug markets. First, we focus on a sustained and fairly widespread reduction in supply, as the decline in heroin purity was experienced throughout the eastern half of the United States between approximately 2001 and 2007. Second, unlike most of the literature which focuses on demand, this study examines the supply side response to purity decline. Third, unlike much of the previous literature, our analysis includes the consideration of prescription opioids, which are close substitutes for heroin. Fourth, our use of richly detailed unpublished medical examiner data allows us to trace the trend in substances ingested by overdose decedents, allowing the analysis of substitution.

This paper is organized in the following way: Part II will provide some background on heroin markets and prescription opioids. Part III, will describe the fentanyl overdose episode of 2006. Part IV will describe the data, and model, and Part VI will present results. Part V will conclude.

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2 Background

2.1 The market for heroin: purity and price

Over the past several years, there have been two significant trends in the heroin market in the northeastern United States - declining purity and the increasing availability of a close substitute - prescription opioids. Heroin prices and purity depend in part on the origin of the drug. In the east coast of the United States, South American (SA, hereafter) heroin dominates the market, whereas in the west coast Mexican heroin is widely sold. The Drug Enforcement Agency (DEA) conducts the Domestic Monitoring Program, a surveillance project in which they make quarterly street level purchases in most major cities where they monitor the heroin market. This surveillance data shows a decline in the purity of South American heroin for the U.S. as a whole in recent years, (although as mentioned, South American heroin is sold primarily in cities east of the Mississippi). As seen in Table 1, purity declined and the price per milligram pure rose between 2003 and 2006, with the highest price recorded in 2006.

Table 1: South American Heroin: Purities and Prices

	2003	2004	2005	2006
Percent Pure (%)	41.8	32.5	37.3	36.1
Price per pure milligram ($)	0.77	1	0.81	1.04
Number of Samples	470	420	396	418

Source: DEA, 2006 Heroin Domestic Monitor Program, July 2007 unpublished

New York City, New Jersey, and Philadelphia have traditionally had the purest SA heroin in the country, yet data collected under the Domestic Monitoring Program also reveals that even in these areas there has been a decline in purity. The average purity of SA heroin in this region decreased from 65% in 2001 to 50% in 2006. Figure 1 shows the average annual purity in the samples collected in Newark, New York, and Philadelphia. Figure 2.1

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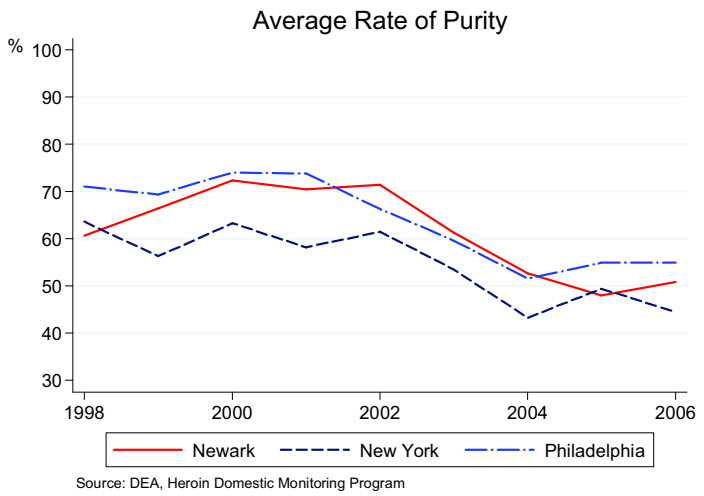
shows the trend in price per pure milligram for these three cities over the same period. Over the last 8 years the price of heroin increased almost 70%. The increase in the price level on the one hand shows the efforts to keep the market price of heroin constant, despite purity decline. However, in some cases like Philadelphia the higher rate of increase in prices relative to the purity level suggest that the price level may also be affected by the scarcity of the heroin in the market.

Figure 1:



The decline in heroin purity is attributed mainly to a reduction in heroin production in Columbia. Additionally, improved interdiction efforts, may have led to changes in trafficking patterns, as SA heroin is increasingly likely to be transported by Mexican drug cartels across the U.S.-Mexican borders rather than arriving on the East Coast. Since approximately 2007, heroin purity has stabilized, as increased production in Mexico has compensated for the continued decline in South American production, although at a level which is below that observed in 2000 or 2001 [1].

[1]See http://www.usdoj.gov/ndic/pubs31/31379/heroin.htm

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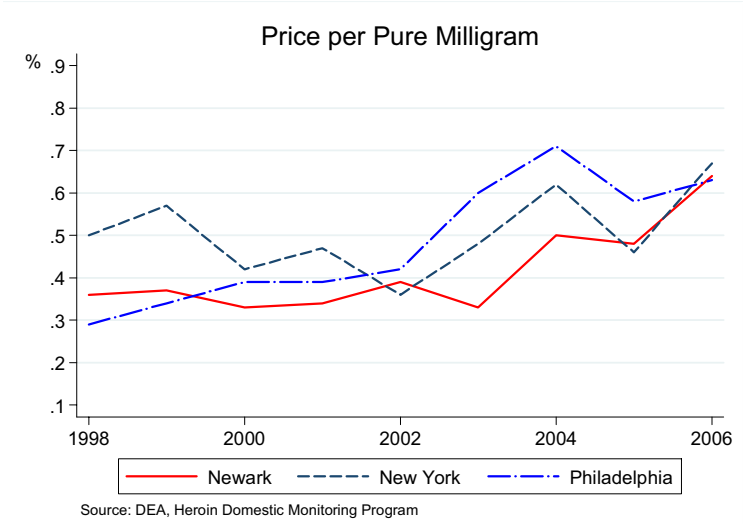

Figure 2:

2.2 Elasticity of Demand for Illegal Drugs and the Role of Prescription Opioids

Most studies on the price elasticity of demand for heroin agree that users respond to price changes in the market. In fact the sign of this response is estimated consistently as negative: if the price of the drug increases a decrease in the demand is observed. However, findings regarding the degree of this response relative to the rate of change in the price are not consistent. The recent price elasticity studies have results ranging from elastic, (i.e. greater than 1 in absolute terms), to inelastic, (i.e. less than one in absolute terms).

Petry and Bickel (2002) study the price and income elasticity of demand among polydrug abusers that are under treatment for heroin addiction. In an experimental setting, participants were asked to spend the given amount of imitation money on the available drugs: heroin, valium, cocaine, marijuana, and alcohol. The price elasticity of heroin was found to range between -0.86 and -1.26, and was more elastic at higher prices. The cross price elasticity results showed that valium was chosen as a substitute for heroin as price level increased. A recent study by Jofre-Bonet and Petry (2006) analyses the

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results of a very similar experimental study and estimate the price elasticity of heroin as -0.917 among heroin addicts. Another study by Saffer and Chaloupka (1999), combined the DEA's STRIDE data with National Household Survey on Drug Abuse for the years 1988, 1990 and 1991, and estimates the price elasticity of heroin as -0.94.

These studies, however, were conducted with two experimental conditions that are not particularly applicable to actual drug markets. The purity of the drug was known to users, and there were no close substitutes available. Unlike most other goods, in the market for illegal drugs, it is fluctuations in purity rather than price which matter most to consumers. Caulkins (2007) provides a good survey about the characteristics of the illicit drug market. Like Levitt and Venkatesh (2000) he also points out that the price of illicit drugs at the retail level is quite stable. The buyer pays a fixed price for a bag which is expected to have some level of purity. The purity of the drug is the most important aspect of its quality, but can only be known after use.

Second, prescription opioids represent a fairly close substitute for heroin. In the study by Jofre-Bonet and Petry (2006), it was shown that heroin addicts chose Valium over other alternatives such as cigarettes, alcohol and cocaine, as a substitute for heroin. While Valium may have been the closest substitute for heroin available to subjects in this study, present day heroin users have closer substitutes such as oxycodone, which would be expected to affect the price elasticity of demand for heroin. In recent years, the availability and use of a variety of prescription opioids has increased dramatically Manchikanti (2007). Paulozzi, Budnitz and Xi (2006) studies the trend in overdose from illicit and prescription drugs, and shows that the share of fatal overdoses from prescription drugs exceeded that from street drugs by 2002. Prescription drug abuse related emergency department visits jumped by 73% between 1999 and 2002, compared to 14% and 18% increase in heroin and cocaine related visits. This would imply that the actual price elasticity of demand for heroin is greater than in an experimental setting with no close substitutes. It would also be expected that heroin suppliers are aware of the increased availability of close substitutes. Yet it should be noted that heroin is also a substitute for prescription opiates, and many users of prescription

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opiates ultimately find that heroin is cheaper and more reliably available. Experts from the treatment community note that once prescription opiates users switch to heroin, they rarely return completely to prescription opiates, due to the greater intensity of the high from heroin, and may continue to use heroin and prescription drugs in combination.

Due to the "experience good" nature of illicit drugs, the relationship between price, which is conventionally measured as dollar per milligram pure and supply is more complicated than in the case of other goods. In general, there is little opportunity to differentiate supply, so that when heroin purity declines it is usually experienced by the entire market. At the same time due to the nature of addiction and the underlying purpose for purchasing heroin, drug sellers cannot compensate addicts for low purity by reducing prices, especially given the presence of substitutes. Therefore sellers have an incentive to try to convince consumers that their product is the most potent on the market. Traditionally, heroin sellers accomplish this attempt at product differentiation through logos on the packages in which the drug is sold. Drug sellers "brand" their baggies with logos suggestive of potency, such as "Die Hard", or "R.I.P.".

In the long run, consumers will know whether or not these marketing claims are accurate. If they are, the use of the logos will help sellers obtain repeat business, and through "word of mouth" communication among drug users, attract new customers who have heard good reviews of the product. The importance of both drug baggie labeling and communication among addicts about drug quality has been described well in Wendel and Curtis (2000). In general, there is not great cross-sectional variation in heroin purity at any given time in the market, and baggies may serve primarily to direct consumers to products that are at the top of the market standard, and to help them avoid products that are particularly bad, or perhaps cut with dangerous substances Wendel and Curtis (2000).

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3 Fentanyl-related overdose

Given the emergence of close substitutes and the conventional attempts at product differentiation in the heroin market, it is understandable that heroin sellers would be motivated to attempt to increase the potency of their product in the face of declining purity. In 2006, the availability of highly potent fentanyl provided such an opportunity.

Fentanyl is a very powerful synthetic opioid that is frequently used in hospital settings for anesthesia. It is estimated to be at least forty times more potent than heroin and other prescription opioids. Since 1990, it has been available with a prescription in various forms like transdermal patches or lollipops for the treatment of serious chronic pain, most often prescribed for late stage cancer patients. Prescription fentanyl has been diverted to the illicit market to a certain extent, although not as widely as much more commonly prescribed substances such as Oxycontin. There have been reported fatal overdoses associated with the misuse of pharmaceutical fentanyl due to crushing, heating and inhaling the patches, or the use of multiple patches. However such cases resulted in only a few dozen overdose deaths a year in New Jersey during the years 2004 through 2006, out of a total of approximately nine hundred overdose deaths per year.

Beginning in approximately April 2006, there was a marked increase in emergency calls received regarding drug overdoses in multiple states including New Jersey, Maryland, Illinois, and Pennsylvania. These overdoses were ultimately found to be linked to non-pharmaceutical fentanyl manufactured by clandestine laboratories in powder form. Packets of heroin mixed with fentanyl were confiscated by the DEA and other law enforcement agents in various locations. During this period Chicago in Illinois and Philadelphia in Pennsylvania observed the highest number of fentanyl related overdoses, 349 and 269 decedents, respectively.

Figure 3 below shows fentanyl related overdose deaths in New Jersey as a percentage of the total number of overdoses between 2004 and 2007. Non-pharmaceutical fentanyl was first identified in the drug market in April 2006, in New Jersey. Fentanyl-related overdoses occurring before then were related

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to misuse of pharmaceutical fentanyl, as described above. As can be seen, starting in April 2006, there was a large increase in the number of fentanyl related overdose deaths. In August 2006, the peak of the fentanyl episode, more than one third of overdose deaths in the State were fentanyl related. Nationally, more than 1000 people died of fentanyl related overdoses in 2006 MMWR (2008).

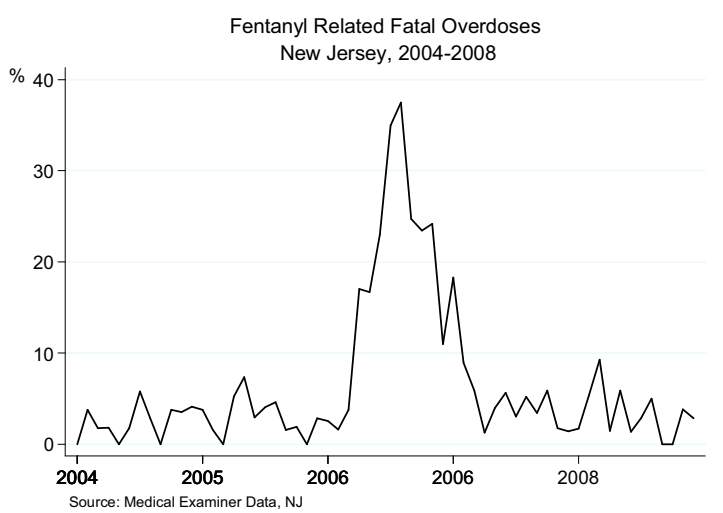

Figure 3:

The retail distribution of "synthetic heroin" comprised of fentanyl or a fentanyl analogue mixed with heroin or perhaps just with a cutting agent has long been a theoretical possibility, and has occurred several times in the past, although on a much smaller scale. In the 1980s a fentanyl-based drug marketed as "China White" caused about a dozen deaths in California. Subsequently, there were several other very small episodes in various places, including New York, Philadelphia, Pittsburgh and New Jersey. These cases resulted in very few deaths, and were connected to corrupt chemists attempting to manufacture synthetic heroin, but were not connected with major drug distribution operations.

Previous episodes of synthetic heroin overdoses were small in scale in part due to difficulties in manufacturing large quantities of fentanyl. The extent

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of the episode in 2006 was mostly due to the ready availability of the inputs and the development of a new, relatively simple method of fentanyl production - "The Siegfried method" - which was disseminated on the internet[2]. This method does not require special equipment or a high degree of technical knowledge. Before the 2006 incident, the distribution of N-phenethyl-4-piperidone (NPP), the main substance used to produce fentanyl, was not regulated. However, despite the ease of production, the correct dosing of fentanyl does require professional equipment and knowledge. It is extremely difficult to dose fentanyl correctly, as one gram of fentanyl is equivalent to about seven thousand street doses (MMWR, 2008). Due to this high potency the street sale of fentanyl mixed with other drugs or a cutting agent creates a high potential for overdoses, as evidenced in the episode of 2006.

Initially, sellers of heroin enhanced with fentanyl marketed their product using distinctive baggie logos, and distributed free samples to consumers in some cities. The publicity surrounding the overdose deaths paradoxically attracted users to the product, making public health messages relatively ineffective in containing the episode. Ultimately, pressure from law enforcement in the form of enhanced sentencing laws, bans in the availability of ingredients, and raids on fentanyl labs led to the suspension of this practice and thus the spate of fentanyl-related overdose deaths came to a fairly abrupt halt in the late fall of 2006.

4 Empirical Results

4.1 Data

While both declining heroin purity and fentanyl overdose were characteristic of a number of Northeastern states and cities, our empirical analysis focuses on New Jersey, due to the availability of detailed data. Our information on trends in heroin purity in New Jersey comes from the DEA. In addition to

[2]See http://opioids.com/fentanyl/synthesis.html , a very dedicated website on Fentanyl production using Siegfried Method. It includes the links to off-shore pharmacies. First suggested link on Google (by March 4, 2009)

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the Domestic Monitoring Program data, which has already been described, we additionally have access to unpublished DEA purity data which provides detail on individual buys. During the 2006 fentanyl episode, DEA conducted supplemental heroin surveillance in Camden, New Jersey, which is not usually part of the DMP sampling frame. Data on individual buys from Camden and Newark were used, although surveillance in Camden was only conducted in 2006.

Our main source of information on fentanyl consumption comes from New Jersey medical examiner data. It is acknowledged that fatal overdoses represent only a sample of drug use, and probably not a representative sample. Yet in the case of fentanyl use mortality data are comparatively rich. Non-fatal fentanyl overdoses treated in the hospital are difficult to identify, due the lack of detailed toxicological testing. Hospitals as a rule do not engage in extensive testing in the event of drug overdoses, since the mode of treatment (administration of Narcan) is unlikely to vary as the result of testing, and many overdose patients do not have generous insurance payers.

Medical examiner data, on the other hand, provides complete toxicological results for all substances found in the decedent, and includes the blood concentration of most substances found. Additionally medical examiner data provides basic demographic information about the decedent, the time and place where the body was found, and includes a brief narrative synopsis that describes the scene, and often includes information about drug paraphernalia found. Table 2 provides some basic information about characteristics of drug overdoses in New Jersey. In 2006 there were 980 fatal overdoses in total, of which 19% involved in either fentanyl alone or fentanyl combined with heroin.

4.2 Model and Results

Our goal is to show that the distribution and consumption of non-pharmaceutical fentanyl was related to heroin purity. Our measure of consumption comes from medical examiner data on fatal overdoses, while our measure of purity comes from DEA surveillance conducted in two New Jersey cities, Camden

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Table 2: Characteristics of fatal drug overdoses, New Jersey 2006

	Total	Fentanyl Only	Fentanyl & Heroin	Heroin Only
	N ([a]Rate)	N	N	N
South	538 (17.8)	84	84	152
North	442 (9.26)	9	2	202
Mean Age	39.8	37.3	33.8	38.9
Sex				
Male(%)	77	84	87	81
Race				
Non-Hispanic White (%)	71	76	79	70
Non-Hispanic Black (%)	20	12	11	19
Other				
Positive for Cocaine (%)	50	53	57	43
Positive for Oxycodone (%)	25	22	22	20
nanograms fentanyl/ml blood	-	17	23	-

Source: New Jersey Medical Examiner data. Includes all cases meeting case definition occurring between Jan 1 and December 31. South New Jersey counties are; Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Mercer, Monmouth, Ocean, and Salem.
Nanograms fentanyl/ml blood shows the averages. Age, 5 cases missing information. Race, 6 cases missing information.

[a]Rate calculated per 100,000 resident population

and Newark during the year 2006. Due to the relatively short duration of the fentanyl overdose outbreak, we are constrained to using data from 2006.

Our dependent variable shows the number of non-pharmaceutical fentanyl related overdoses observed in a month. We have a panel of 21 counties of New Jersey. Since the fentanyl episode was first observed in April and all New Jersey counties did not begin testing for fentanyl until that period, there are nine months of data.

The general approach to estimate the expected number of count data is to use Poisson regression, which has the strict requirement of mean and variance being equal. In our data average number of overdoses in a given month is about 0.78 whereas the variance is 3.8 people. Hausman, Hall

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and Griliches (1984) show that this requirement could be broken by adding a county specific random effects, exponential of which has gamma distribution.

A second option is to use a random effects negative binomial model, which is obtained by assuming that the expected value of the number of overdoses in a given month and county is random variable with gamma distribution. The cumulative distribution of non-pharmaceutical fentanyl related overdoses is shown in the Figure 5,below. In nine month period about 70% of the observations are zero. This rate drops down to 50% if we only focus on the south of New Jersey.

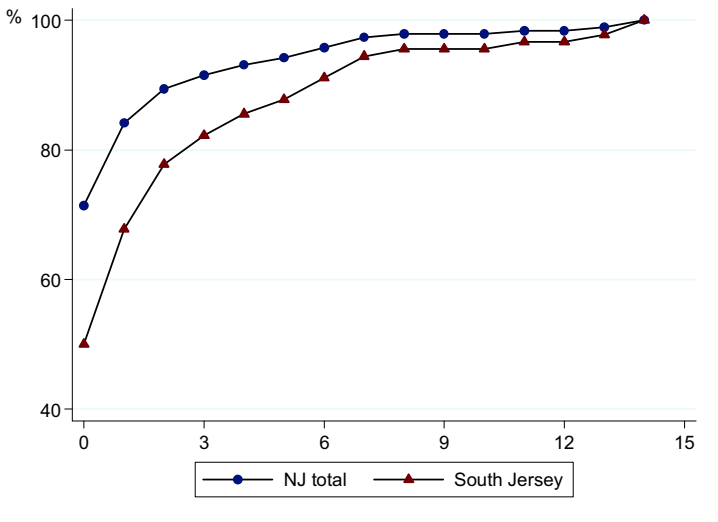

Figure 4:

The excess number of zeros hints to the overdispersion in our data. The likelihood ratio tests on overdispersion coefficent also comes out significantly different than zero. Some of the counties of New Jersey have low rates of overdose cases in a given year or month. The past data of New Jersey, however, shows that every county has heroin overdose cases during a year. So, there is a positive probability to observe a heroin overdose in every county in a year. This probability varies from county to county.

The expected number of Fentanyl related cases in a month will be modeled as a linear function of the race distribution within the county, the median

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income relative to the median income of New Jersey, and the average heroin purity level observed within that month. To avoid multicollinearity, the proportion of non-hispanic white population is left out of our regression.

In order to control for the availability of the substitutes we will use two different variables; a simple dummy variable where it takes one if the county is in the south, and the number of prescription and illicit drugs combined overdoses observed between the ages 10 and 65 in 2004 per 100,000 population. The reason for picking the year 2004 is simply because we believe that some of the cases in the last months of 2005 might be due to non-pharmaceutical fentanyl related and might bias the significance.

The data shows that overdoses from prescription opioids is more prevalent in South Jersey, where South Jersey includes the following counties; Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Mercer, Monmouth, Ocean, and Salem. The difference between North and South Jersey in terms of prescription drug related overdoses over the last 4 years can be observed in Figure 5 below.

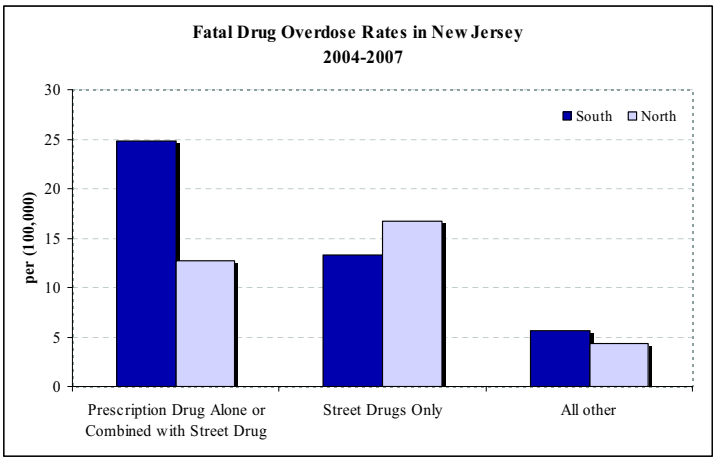

Figure 5:

The rate of prescription drugs related overdoses in south New Jersey is about 25 per 100,000 population, which is almost twice as much as the rate

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observed in the north. The illicit drug overdoses on the other hand is more frequently observed in the north, compared to the rates in south.

Table 3 shows the poisson and negative binomial regression results with random effects specification. Estimated coefficients are quite similar between the two specification. The first column and third columns show uses the dummy variable to compare the South and the North. The estimated contribution of dummy variable to county effect is significantly different than zero in both estimations. This actuall shows that we observe more fentanyl related overdoses in the south compared to north. In Table 2, above we see that only 5% of the fentanyl cases happened in the northern New Jersey. So this significance is not suprising.

Table 3:

Dependent Variable: $Fent_{it}$	Poisson		Negative Binomial	
$\ln Pure_{t-1}$	-1.781**	-1.781**	-1.781**	-1.748**
	(0.61)	(0.61)	(0.63)	(0.64)
$ProportionHispanic_i$	0.003	-0.091*	0.002	-0.064+
	(0.05)	(0.04)	(0.05)	(0.04)
$ProportionBlack_i$	0.041	0.113*	0.04	0.06
	(0.04)	(0.06)	(0.04)	(0.06)
$MedianIncRate_i$	0.016	0.001	0.016	-0.001
	(0.01)	(0.01)	(0.01)	(0.01)
$Dsouth_i$	3.169**		3.134**	
	(0.94)		(0.94)	
$POD04_i$		0.462*		0.433**
		(0.23)		(0.16)
Const	-5.996**	-3.447	-2.332	-0.324
	(2.31)	(2.11)	(4.24)	(3.05)

Notes: $+, *,$ and $**$ show 10%, 5% and 1% significance, respectively. The standard errors are in parenthesis'.The dependent variable $Fent_{it}$ is the monthly overdose counts in a country. $ProportionHispanic_i$ and $ProportionBlack_i$ are the control for rate of race per 100,000 population in each county. $MedianIncRate_i$ controls for the median income rate relative to the median income in New Jersey.$POD04_i$ is the rate of prescription and illicit drugs combined overdoses per 100,000 population

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The second columns in each regression includes the second control variable, $POD4_i$. This variable aims to distinguish the counties with high prescription and illicit drug related overdoses from the others, because as discussed above the availability of the alternative drugs was the main motivation of the sellers to mix fentanyl in their product. The coefficient of this varaible estimated around significantly as 0.43. Which means everything else constant having a higher rate of prescription overdose history increases the expectations about 1.5 times higher than the ones without.

The coefficient of previous months average heroin purity is estimated significantly different than zero. This result is robust different specifications. Everything else constant, 10% decrease in purity is pushes up the expected number of overdoses by 18% .

The contribution of distribution of the different races is minor. In this analysis, we have five different race groups, which are non-hispanic white, non-hispanic black, hispanic, asian pacific islander and other. Asian pacific islander and other groups combined together does not reach more than 8% of the population. So, excluding both does not rule out the perfect multicollinearity problem. In addition to that there is a strong correlation between hispanic and white populations in New Jersey. If proportion of hispanic population is high in one county, the proportion of white populatin is significantly lower. Therefore, we excluded the proportion of the white population.

The coefficient shows that in counties where hispanic population is lower we have higher expectations for fentanyl related overdoses. Negative binomial regression estimates the coefficient significant at 10% level. This significance can be explained by the strong negative correlation between hispanic population and white population, which is about 80%. This coefficient actually captures that a county where the share of white population is higher tend to have higher overdoses, which is consistent with the fact that more than 75% of the heroin overdoses are white.

The next table, Table 4, shows the results for the effect of purity when substitute is available. The first regression shows that in the north New Jersey, the purity level has no significant effect on the expected number of overdoses. Purity levels effect kicks in when we switch to the south. As-

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suming that in south New Jersey heroin substitutes are easily accessible this suports our argument that the quality of the heroin sold becomes relevant when the supplier is concerned about losing customer and hence profit.

As in the previous table we see that the negative binomial regression estimates the effect of race significantly. Different than the previous table, however, we see that proportion of the black population also has a significant effect on the expected number of fentanyl overdoses.

Table 4:

Dependent Variable: $Fent_{it}$	Poisson		Negative Binomial	
$\ln Pure_{t-1}$	1.832		1.792	
	(1.28)		(1.29)	
$ProportionHispanic_i$	-0.012	-0.095*	-0.012	-0.095*
	(0.05)	(0.04)	(0.05)	(0.04)
$ProportionBlack_i$	0.048	0.121*	0.046	0.116*
	(0.04)	(0.06)	(0.04)	(0.06)
$MedianIncRate_i$	0.012	-0.001	0.012	-0.001
	(0.01)	(0.01)	(0.01)	(0.01)
$\ln Pure_{t-1} \times Dsouth_i$	-3.856**		-3.836**	
	(1.18)		(1.16)	
$\ln Pure_{t-1} \times POD04_i$		-0.425**		-0.427**
		(0.14)		(0.15)
Constant	-2.719	-1.586	0.59	1.926
	(1.71)	(1.91)	(3.31)	(3.58)

Notes: $+, *,$ and $**$ show 10%, 5% and 1% significance, respectively. The standard errors are in parenthesis'.The dependent variable $Fent_{it}$ is the monthly overdose counts in a country. $ProportionHispanic_i$ and $ProportionBlack_i$ are the control for rate of race per 100,000 population in each county. $MedianIncRate_i$ controls for the median income rate relative to the median income in New Jersey.

The second and third columns estimate that the effect of past months low purity levels is bigger when the county has a past history of higher prescription related illegal drug overdoses. The combined effect is estimated to be negative and significant at 1%.

In order to do a sensitivity analysis these regressions are also computed

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using the number of prescription related illegal overdoses observed in a county in year 2008. Again, 2007 is avoided not to bias the estimation. The results (not shown) are the same. So, the easy availability of the prescription opioids problem is still prevalent in some counties in the south New Jersey.

The question why the fentnayl episode ended suddenly in 2007, could be answered by the increase in the law enforcement and the control over the distribution of fentanyl precursor. The data on purity shows that after the end of 2006 purity level of heroin in the market moved to back to earlier levels. So, we could argue that this could have been removed the pressure from the sellers to find a another alternative that is going to balance the quality of their product.

5 Conclusion

We argue that the enhancement of heroin with illicitly manufactured fentanyl in 2006 was a supply side response to both declining heroin purity and the growing availability of a close substitute, prescription opioids. While this response may have been economically rational, the consequences were tragic, as more than one thousand fatal overdoses occurred.

Enhanced sentencing and bans on precursors ultimately contributed to the cessation of the illegal manufacture and distribution of fentanyl, yet suppliers' incentives to minimize the cost of bringing drugs to the illegal market will undoubtedly remain. The combination of declining heroin quality, growing competition from a close substitute, and the dissemination of a technological innovation led some drug distributors to risk the manufacture and sale of a product whose potency they could not successfully control.

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References

Caulkins, Jonathan P., "Price and purity analysis for illicit drug: Data and conceptual issues," *Drug and Alcohol Dependence*, 2007, *90.*

Dobkin, Carlos and Nancy Nicosia, "The War on Drugs: Methamphetamine, Public Health, and Crime," *American Economic Review*, March 2009, *99* (1), 324–349.

Hausman, Jerry, Bronwyn Hall, and Zivi Griliches, "Econometric Models for Count Data with an Application to Patents-R&D Relationship," *Econometrica*, July 1984, *52* (4), 909–938.

Jofre-Bonet, Mireia and Nancy M. Petry, "Trading apples for oranges?: Results of an experiment on the effects of Heroin and Cocaine price changes on addicts polydrug use," *Journal of Economic Behavior & Organization*, May 2006, *66* (2), 281–311.

Levitt, Steven D. and Sudhir A. Venkatesh, "An Economic Analysis of a Drug-Selling Gang's Finances," *The Quarterly Journal of Economics*, Aug. 2000, *115* (3), 775–789.

Manchikanti, Laxmaiah, "National drug control policy and prescription drug abuse: facts and fallacies.," *Pain Physician*, May 2007, *10* (3), 399–424.

MMWR, "Nonpharmaceutical Fentanyl-Related Deaths — Multiple States," *Center for Disease Control and Prevention, Morbidity and Mortality Weekly Report*, July 2008, *57* (30), 793–796.

Paulozzi, Leonard J., Daniel S. Budnitz, and Yongli Xi, "Increasing deaths from opioid analgesics in the United States," *Pharmacoepidemiology and Drug Safety*, Jul. 2006, *15* (9), 618–627.

Petry, Nancy M. and Warren K. Bickel, "Polydrug abuse in heroin addicts: a behavioral economic analysis," *Addiction*, May 2002, *93* (3), 321–335.

Saffer, Henry and Frank Chaloupka, "The Demand for Illicit Drugs," *Economic Inquiry*, Aug. 1999, *37* (3), 401–411.

Smithson, Michael, Michael McFadden, Sue-Ellen Mwesigye, and Tony Casey, "The impact of illicit drug supply reduction on health and social outcomes: the heroin shortage in the Australian Capital Territory.," *Addiction*, March 2004, *99* (3), 340–348.

visited on 09/9/2011

Weatherburn, Don, Craig Jones, Karen Freeman, and Toni Makkai, "Supply control and harm reduction: lessons from the Australian heroin 'drought'.," *Addiction*, January 2003, *98* (1), 83–91.

Wendel, Travis and Ric Curtis, "The Heraldry of Heroin: "Dope Stamps" and the Dynamics of Drug Markets in New York City," *Journal of Drug Issues*, Spring 2000, *30* (2), 225–260.