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The Entry of Colombian-Sourced Heroin into the US Market: The Relationship between Competition, Price, and Purity

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Abstract

There have been large structural changes in the US heroin market over the past 20 years. Colombian-sourced heroin entered the market in the mid-1990s, followed by a large fall in the price per pure gram and the exit of Asian heroin. By the 2000s, Colombian-sourced heroin had become a monopoly on the east coast and Mexican-sourced heroin a monopoly on the west coast with competition between the two in the middle. We estimate the relationship between these changes in competitive market structure on retail-level heroin price and purity. We find that the entry of Colombian-sourced heroin is associated with less competition and a lower price per pure gram of heroin at the national level. However, there is wide variation in changes in market concentration across the US. Controlling for the national fall in the heroin price, more competition in a region or city is associated with a lower price per pure gram.

Keywords

Heroin Price; Heroin Purity; Competition; US; Illicit Drug Markets

Introduction

There are four major heroin producing regions for the US market: Mexico, South America (mostly Colombia), Southeast Asia (mostly Burma), and Southwest Asia (mostly Afghanistan), and there have been large changes in the availability of heroin from these regions over time. In particular, in the 1990s there was a dramatic decline in heroin supplied from Asia, while South American heroin increased substantially. Furthermore, as shown by Ciccarone et al. (2009), the US supply of heroin is divided geographically with Mexican-sourced heroin currently having a monopoly in the west, South American heroin having a monopoly in the east, and competition in the middle. We examine two effects: that of entry

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of Colombian-sourced heroin on the US heroin market as well as competition between reduced suppliers.

The competition we measure is that between rival substitute products rather than individual rival businesses. It is likely that competition between drug dealers and along the supply chain has a role to play in the effect of the entry of Colombian-sourced heroin on the US market. Although this would be useful to understand, we are only able to observe changes in the place of origin of heroin, not the dynamics of the many agents in the heroin market. A product like oil is a useful comparison. If we were studying the oil market from a similar perspective, we would be asking what happens to the price of oil if Colombia-sourced oil entered the US market, rather than investigating the rivalry between gas stations or oil tanker companies.

We seek to understand the effects of the changes in market structure after the entry of Colombian-sourced heroin. In standard economic theory, the more competition there is, the better it is for consumers. Industrial organization or international trade theory, which have similar models of imperfect competition and market entry, have various predictions based on imperfect information, product differentiation, uncertainty, economies of scale, price versus quantity (or quality) competition and a variety of other factors (Helpman and Krugman, 1985; Tirole, 1988). We think of the entry of Colombian-sourced heroin into the US market as a low-cost supplier entering a market with a quantity-competition oligopoly, also known as the Cournot model. This model has been used extensively to understand oligopoly behavior (Dixit, 1984; Bresnahan and Reiss, 1991; Lahiri and Ono, 1997). Colombian-sourced heroin is low-cost relative to Asian heroin because of the significantly shorter distance to the US (lower transportation costs), possibly low production costs or low transaction costs by trafficking heroin through already existing networks that sell Colombian-sourced cocaine.

In this model, a low-cost entrant takes over a significant market share and pushes the market share of high-cost incumbents significantly lower. Price falls as greater total quantity is produced. We assume that the heroin market is segmented, in the sense that suppliers do not sell their product in every location and there are only a limited number of potential supplier countries. Paoli et al. (2009), Ciccarone (2009), and Ciccarone (2012) discuss the existence of such segmented markets, where heroin is supplied to particular places by particular suppliers through a limited number of trafficking routes. We assume this segmentation is due to variation in costs (transportation, transaction, production, and law enforcement), enhanced by the promoting forces of globalization and honed by the inhibiting forces of interdiction (Ciccarone, 2012), which make some markets unprofitable to global suppliers. Competitor suppliers of heroin may have tried to deter Colombian-sourced heroin from entering through increased production or by increasing the costs of their competitors through violence. However, Colombian-sourced heroin did enter, which in this model would indicate that Colombian-sourced heroin has lower net costs than at least some of its competitors, in particular Asian-sourced heroin which later exited the market.

To explain the framework using our oil analogy, this model could be used to understand the entry of a new supplier of oil. The supplier can decide on how much to produce, which may affect the market price, but ultimately the global oil market determines the market price which depends on total supply and demand. Thinking about the entry of Colombian-sourced heroin as a legal product in this model, we predict two effects: First, there will be a general fall in price as total supply increases. We call this the *entry effect*. There will be an additional *competition effect*, in that prices within a location will tend to be lower the more competitors there are in a location. Thus, in the short-run, if the entry of Colombian-sourced heroin acts like legal, non-addictive goods, then we should observe a general fall in price through the entry effect and an even greater decline in price where we observe more competitors through the competition effect.

Incorporating the fact that heroin is illegal and addictive would make a theoretical analysis more complex. The theory of addictive goods markets have no general predictions, in that some models predict that increased competition may raise the price while others predict it will lower the price (Driskill and McCafferty, 2001; Richards et al., 2007; Showalter, 1999). On the one hand, competitive pressure may bring prices down. On the other hand, if competition is in the form of violence, then more competition may increase both suppliers' costs, raising the market price (there could be a kind of natural monopoly in heroin). In addition, given that heroin is an addictive good, fewer suppliers can capture a larger share of demand by promoting dependence through lower prices. Thus, assuming policy goals are to both reduce heroin use and lower negative externalities from the heroin market, such as crime and disease, without empirical research it is not obvious that we should prefer fewer suppliers. We contribute to the literature on market competition for illicit and addictive products by providing the first estimates of the relationship of market entry and competition to heroin price and purity in the US retail heroin market from 1990–2008.

Data

Our analysis uses the Drug Enforcement Agency (DEA)'s System to Retrieve Information from Drug Evidence (STRIDE) database. STRIDE includes information from drug seizures and arrests. These observations include the amount and purity, but generally not the price or country of origin. In addition, there is information from law enforcement purchases of heroin, which include price as well as amount and purity. STRIDE includes additional information from the DEA's Domestic Monitor Program (DMP), in which agents purchase illegal drugs and record the price and test those drugs for purity and country of origin. The DMP data is collected to monitor the retail level price and purity of heroin. There is no connection between this data and criminal investigations as in the rest of the STRIDE data. STRIDE also includes data from the Heroin Signature Program (HSP), which tests a sample of heroin seized at borders and from arrests to ascertain the heroin's country of origin. All observations include heroin purity. The 37 percent of observations with a recorded price are used to estimate the price per expected pure gram. The 32 percent of observations with a recorded country of origin (from the DMP and HSP) are used to estimate market competition.

The STRIDE data covers January 1990 through December 2008. There are 100,123 observations. We follow Arkes et al. (2004)'s method to clean the data. We drop observations if the method of acquisition is not by purchase, seizure, or lab seizure (deleting 136 observations). We drop observations that are from U.S. territories (Guam, Puerto Rico, etc.) rather than states (2188 observations). We drop observations where the purity is above 100 percent (6 observations). We keep observations with zero purity, since our price and purity analysis depends on the expected purity, rather than the actual purity of heroin. Actual purity is the objective purity value as tested by the DEA. Expected purity is the subjective belief of the heroin consumer as to the purity of purchased heroin based on multiple purchases in the same heroin market. We assume that expected purity is the average purity of heroin purchased, adjusted for amount, in a given year and location.

Heroin is given a drug code based on the type of heroin. For our main analysis, we use observations for heroin hydrochloride (9200.005) and heroin base (9200.000), which according to Arkes et al. (2004) cannot easily be physiologically distinguished by the consumer. This is likely powder heroin. Heroin hydrochloride and heroin base are used differently by the consumer, in that base needs an addition of acid to make it soluble.

However, they likely have similar effects at similar volumes. These types of heroin account for 82 percent of observations.

We perform a separate analysis for heroin salt undetermined (9200.9), which accounts for 16 percent of observations and may be physically different from heroin hydrochloride and base. The salt undetermined observations are generally not part of the HSP, so one cannot easily determine the original source of heroin. Many of the observations come from Washington, D.C. and are otherwise spread throughout the US.

The remaining 2 percent of observations (heroin citrate, tartrate, and other) are dropped from the analysis. We refer to the combined hydrochloride and hydrochloride base observations as heroin "HCL/B" and the salt undetermined observations as heroin "SU" throughout the paper. Additionally, we focus on retail-level heroin prices. Thus, observations are restricted to amounts of 1 gram or less. In addition, due to the possibility of imprecise purity measures for small amounts of heroin, we remove observations of less than 0.1 gram (22,128 observations). However, all estimates are robust to including observations of less than 0.1 gram. We are then left with 26,348 observations for our analysis (22,091 for heroin HCL/B and 4,257 for heroin SU).

Overview of Global Heroin Production

In this section we examine estimates of the production of opium in the different supply regions in order show whether changes in global supply correspond to changes in the observed regions of heroin origin in the STRIDE database. The STRIDE data has information on four regions of origin: Mexico, South America, Southwest Asia, and Southeast Asia. Figure 1 shows the proportion of retail-level heroin samples from each of these regions. The graph shows that there have been substantial changes in the source of US heroin since 1990. In the early 1990s, Asian heroin represented more than half of the market. By the mid-1990s, South American (i.e. Colombian-sourced) heroin went from zero market share to overtaking Mexico as the dominant supplier of heroin to the US. At the same time, the share of Asian heroin fell to almost nothing.

To show how the changing patterns in the US markets correspond to global opium production, we show yearly estimates of opium production by country of origin from the United Nations Office on Drugs and Crime (UNODC). Figure 2 shows the estimated potential production for Southwest Asian and Southeast Asian heroin, while Figure 3 shows the estimated production for Mexico and Colombia. The graphs show that overall opium production has been rising, with Southwest Asian heroin dominating the global market, an overall rise in production in the Americas (with a decline in Colombian production and rise in Mexican production in the 2000s), and a decline in Southeast Asian production starting in the late 1990s. Given that opium production is illegal, these should be taken as rough estimates of opium supply. The UNODC generally assumes that 10 units of opium can be converted into 1 unit of heroin, although the exact amount of opium that is converted into heroin is unknown.

In trying to understand changes in the sources of heroin for the US, the decline in opium production in Southeast Asia can partially explain what we observe. Laos, Vietnam, and Thailand all had dramatic declines in opium production, however Burma has consistently produced an order of magnitude larger amount of opium than these other countries combined. Although economic development may have led to a reduction in opium production in Laos, Vietnam, and Thailand, the large-scale decline in Southeast Asian opium was likely due to several Burmese states banning opium production between 1997 and 2005 (Paoli et al., 2009).

The decline in supply from Southeast Asia may be able to explain the dramatic decline in Southeast Asian heroin in the US. However, changes in global production patterns cannot explain the fall in the presence of Southwest Asian heroin in the US: There has been a substantial rise in opium production in Southwest Asia, with the exception of the short-term eradication campaign by the Taliban in Afghanistan in 2000–2001 (Gibson et al., 2005; Ciccarone, 2005). The drop in Southwest Asian heroin's US market share may be due to Afghanistan filling the void in Europe and Asia left by the large decline in Southeast Asian heroin. Once Asian heroin left the US market and their trafficking routes were reduced, there could also be substantial barriers to re-entry. Within the context of our model of market entry, we would assume that the fall in the US market share of Southwest Asian heroin since the early 1990s is due to an inability to compete with the lower cost of Colombian-sourced heroin.

The rapid increase in opium production in Colombia (1990–4) can explain Colombian-sourced heroin's take-over of nearly half the US market. However, the UNODC's estimate of a substantial rise in the Mexican opium supply does not explain why the Mexican market share has remained steady and generally below Colombia's since the mid-1990s. One possibility is that the UNODC overestimated Mexican production and underestimated Colombian production in the 2000s. Another possibility is that the recent Mexican Drug War has limited the amount of heroin that enters the US from Mexico.

Market Competition

We use the STRIDE database to estimate location-specific levels of competition based on the yearly proportion of observations from each origin region at the national level, US census region level, and the MSA level as a measure of market share. The 9 census regions are: Pacific (AK, CA, HI, WA, OR), Mountain (AZ, CO, ID, MT, NM, NV, UT, WY), West North Central (IA, KS, MN, MO, ND, NE, SD), West South Central (AR, LA, OK, TX), East North Central (IL, IN, MI, OH, WI), East South Central (AL, KY, MS, TN), South Atlantic (DC, DE, FL, GA, MD, NC, VA, WV), Middle Atlantic (NY, NJ, PA), and New England (CT, MA, ME, NH, RI, VT). We omit the East South Central region from our analysis because of the low number of observations for this region.

We restrict our MSAs to those with at least 400 observations of heroin source region. The 21 MSAs are: Atlanta, Baltimore, Boston, Chicago-Gary-Kenosha, Dallas, Denver-Boulder-Greeley, Detroit-Ann Arbor-Flint, Houston-Galveston-Brazoria, Los Angeles-Riverside-Orange County, Miami-Fort Lauderdale, New Orleans, New York, Newark, Orlando, Philadelphia-Wilmington-Atlantic City, Phoenix-Mesa, San Diego, San Francisco-Oakland-San Jose, Seattle-Tacoma-Bremerton, St. Louis, and Washington, D.C. In addition, we combine the remaining observations by census region to create six additional units. As in the regional analysis we drop the East South Central region. We combine the West North Central and East North Central regions into one location as well as the Pacific and Mountain regions into another location to get a sufficient number of observations.

We construct a Herfindahl Index (HI) from the market shares within a location. The HI is a commonly used measure of market competitiveness, with a higher HI indicating less competitiveness. The HI is calculated by summing the square of each supplier's market share. The HI ranges from 0 to 1, where 0 represents perfect competition and 1 represents monopoly.

Nationally, heroin became more competitive following the entry of Colombian-sourced heroin in the early-1990s (with an HI of 0.3 in 1993 at its nadir) and then grew steadily less competitive to an HI of 0.5 by 2003, where it has leveled off (see Figure 4). The regional trends shown in Figure 5 show changes in the competitive landscape. These trends follow a geographic pattern with wide variation in competitiveness over time. The market has become highly concentrated (HI > 0.8) on the east and west coasts with competitiveness remaining higher and somewhat stable (HI between 0.4 and 0.6) in the center, with the exception of the West North Central region becoming highly concentrated between 1996 and 2002 (HI close to 1), but then becoming significantly more competitive after 2002 with an HI close to 0.5 in 2008. The western part of the US has, for the most part, had a Mexican-sourced heroin monopoly. The east coast lost its supply of Asian heroin, effectively creating a Colombian-sourced heroin monopoly. The center of the country is characterized by the exit of Asian heroin, but the increased presence of Mexican and Colombian-sourced heroin.

The average HI is much larger in the regional and MSA estimates compared to the national estimates. A mathematical example will help to explain why this should be the case. Assume there are only two regions with an equal number of observations and they each have a 50-50 split between Mexican and Colombian-sourced heroin. The HI of each region is 0.5 and the national HI would also be 0.5. If the regions are instead highly concentrated, one with all Mexican-sourced heroin and the other with all Colombian-sourced heroin, they would each have an HI of 1. However, the national HI would remain at 0.5. Thus, a rise in market concentration in a region will have a large effect on that region's HI, but not necessarily the national HI. Note that if a region or MSA flipped from one type of heroin to another, for example from 10 percent Mexican-sourced heroin and 90 percent Colombian-sourced heroin to 90 percent Mexican-sourced heroin and 10 percent Colombian-sourced heroin, the HI would not change. Thus, we measure the availability of multiple types of heroin, rather than the components of these types.

Estimation Strategy

Following Arkes et al. (2004), we use the estimated price per expected pure gram as our measure of market price. Because heroin is unregulated, purchasers do not know the purity of the heroin before it is consumed. Thus, dealers may, purposefully or not, sell low purity heroin to unsuspecting drug users. Given this information asymmetry, we assume that frequent heroin buyers are purchasing heroin with an expectation about the quality of that heroin. As in Arkes et al. (2004), we estimate the price per expected pure gram by using a two-stage estimation. The first stage estimates the purity in a location-year. The second stage estimates the price in a location-year conditional on the estimated purity. We add a third stage in which the estimated price per pure gram is correlated with the level of market concentration.

There are three levels of analysis: national, regional, and MSA level. Arkes et al. (2004) use a two-stage general linear random effects model at the MSA level which allows for general time trends to affect all the MSAs. The regional and MSA level results below are robust to this estimation method, but for simplicity we only report the estimates from an ordinary least squares method. Since we treat each location as a distinct market, when estimating price and purity we only include time effects within location rather than across locations. General time effects are then included in the estimated correlation between competition and the location-specific price per expected pure gram.

Within each market (i.e. the whole country, the census region, or the MSA), purity is estimated as:

$$purity_{it}=\alpha+\beta amount_{it}+\gamma_t+\varepsilon_{it} \quad (1)$$

where $purity_{it}$ is the purity of heroin observation *i* in year *t* in a specific market. $amount_{it}$ is the amount of heroin observed in grams, γ_t are year fixed effects, and ε_{it} is the error term. Price per expected pure gram within a market is then estimated as follows:

$$ln\left(price_{it}\right)=\alpha+\beta ln(\widehat{puregrams}_{it})+\gamma_t+\varepsilon_{it} \quad (2)$$

where $price_{it}$ is the inflation adjusted price and $\widehat{puregrams}_{it}=\widehat{purity}_{it} * amount_{it}$, where $\widehat{purity}_{it}$ is the estimated purity from Equation 1. A location-price-year level dataset is then constructed, where each observation includes the estimated price per pure gram for 0.5 grams of heroin in a given year and location. The choice of 0.5 grams was chosen as a convenient middle point in the distribution, as it is close to the average amount collected between 0.1 and 1 gram. Changing this assumption does not substantially affect the estimates in the third stage.

The last estimation equation correlates the price per pure gram with market competition:

$$ln(\widehat{pricepure}_{jt})=\alpha+\beta HI_{jt}+\psi_j+\gamma_t+\varepsilon_{ijt} \quad (3)$$

where $\widehat{pricepure}_{jt}=\frac{\widehat{price}_{jt}}{\widehat{purity}_{jt} * amount_{jt}}$ evaluated at $amount_{jt} = 0.5$ is the estimated price per pure gram in location *j* in year *t*. HI_{jt} is the location-year HI. We do not separate HI by type of heroin because they are substitutes. ψ_j are location fixed effects.

The national estimates show us the aggregate correlation between market competition and the heroin price. Because there is one location at the national level (the entire US) and one observation per year, location and year fixed effects cannot be included in these estimates as they would absorb all variation in the data. At the national level, the coefficient on market concentration combines both the entry effect and the competition effect of the introduction of Colombian-sourced heroin. These effects go in opposite directions, since the US market became more concentrated (driving up prices through the competition effect), but had access to a new supply of heroin (pushing down prices through the entry effect). Thus, the net effect could go either way, with a positive β meaning the competition effect outweighs the entry effect and a negative β meaning the opposite.

For the regional and MSA estimates, time and location fixed effects control for general time trends in prices across all locations and normalizes each location to its own initial price level. In contrast to the national estimates, these estimates take advantage of the differences in heroin sources across locations. If we assume that the entry effect is similar across the US, then the fixed effects reduce or eliminate the entry effect in the regional and MSA estimates by controlling for the national-level average yearly change in price. In this case, the coefficient on market concentration will show the estimated competition effect on price, which under our assumed model will be a positive correlation between market concentration and price.

Descriptive Statistics and Estimation Results

Descriptive statistics are presented in Table 1. The average estimated purity is similar across specifications, with heroin HCL/B having higher purity than heroin SU. The price per non-pure gram of heroin HCL/B are consistently in the $275–$300 range. Prices are less consistent for heroin SU due to the smaller sample size for this type of heroin and a group of outliers with particularly high prices. These statistics show that HCL/B is a higher quality product with more reliable data. Nonetheless, we provide the SU estimates as a check on the general consistency of our estimation results.

Table 2 shows the estimates of Equation 3. At the national-level, market concentration increased and the price per pure gram fell. The estimated coefficient on HI indicates that an increase in the HI of 0.1 is correlated with a fall in the price per pure gram of 33 percent for HCL/B and 27 percent for SU. Within the context of our model of the heroin market, this fall in price means that the entry effect outweighs the competition effect, driving down prices in spite of a decrease in competition.

We look more closely at the national data in Figure 4, which shows time trends in the estimated heroin prices per expected pure gram and market concentration. Before 1995, market concentration and price were both falling. After 1995 market concentration rapidly increased and prices continued to fall, although more slowly. This pattern fits with the idea of the entry and competition effects. In the early 1990s, both effects were acting together to quickly reduce the price. As market concentration rose in the late 1990s, the competition effect went against the entry effect, causing prices to fall at a slower rate.

The regional and MSA-level estimates include fixed effects that control for national-level changes in the heroin price and, thus, greatly reduce the entry effect from the estimated coefficient on HI. With the entry effect controlled for, market concentration is positively correlated with the heroin price per pure gram. The coefficient for heroin hydrochloride shows that a 0.1 increase in the HI correlates with an 8.4 percent increase in price at the regional-level and a 2.9 percent increase in price at the MSA-level. The opposite signs for the national versus smaller locations show that although prices fell everywhere with the overall increase in market concentration, they fell more rapidly in areas with more competition. That is, Colombian-sourced heroin’s entry is correlated with a general fall in price, but those areas with more competition saw a larger decline in price. Thus, our estimates are consistent with a standard economic model of competition, where entry reduces price, but less competition raises price.

We decompose the effect on the price per pure gram by estimating the correlation between market concentration and the estimated price per non-pure gram (this price is the estimated price in Equation 2 before converting to price per expected pure gram), as well as with the estimated purity (from Equation 1). At the national level, a higher HI is correlated with a lower price: a 0.1 increase in the HI correlates with a 38 percent decrease in the price per non-pure gram of heroin HCL/B. At the regional and MSA levels, which again include fixed effects to reduce the entry effect, a higher HI is correlated with lower purity, but not price: a 0.1 increase in the HI correlates with a 2.8 percentage point decrease in the purity of heroin HCL/B at the regional level and a 0.8 percentage point decrease in purity at the MSA level. Thus, the competition effect appears to occur through increased purity, not a further decline in price. This finding is consistent with the phenomenon of “dime bags”, heroin sold in small quantities for $10. The price of a dime bag has, by definition, not changed over time. The quantity of heroin in a dime bag has not changed much, leaving purity as the dimension along which heroin sellers increase or decrease the price per pure gram.

Limitations

These estimates can only be interpreted as causal if one believes that changes in the measured HI are exogenous with respect to heroin price and purity and that there is no omitted variable bias. Endogeneity may exist because heroin from any given source region may be more likely to enter a high priced market or more likely to exit a low price market, which would bias our estimates towards finding a negative relationship between HI and price. Omitted variable bias may also exist. For example, there may be a drop in price in places with low market concentration because those happen to be places where the economy has been improving relative to the rest of the country and, thus, demand (and price) is lower.

These estimates should be interpreted as rough estimates of the relationship between heroin price and changes in market structure. The nature of illicit drug markets makes it difficult to control for other relevant factors that affect drug prices. For example, our finding of a negative relationship at the national level could alternatively be explained by reverse causality, that the low prices caused Asian heroin to leave, which increased market concentration. However, such reverse causality cannot explain the positive relationship at the regional and MSA level.

There are many unobserved omitted variables that could be driving our results. For example, our model is one of heroin price being driven by the emergence of Colombia as a major heroin supplier. The combined estimated opium production in Colombia and Mexico has more than doubled since the early 1990s, which is a plausible cause of the entry effect which led to a substantial decline in the price per pure gram of heroin. However, we do not know the underlying causes of this increased production, such as a breakdown of drug cartels, which although quite relevant to drug policy, are outside the scope of this article.

Consumer demand is an equally important factor as supply in determining price. We have some evidence that the low prices are not caused by low demand. Figure 6 shows the proportion of high school seniors that report using heroin in the past year. Reported heroin use more than doubled in the mid-1990s, and then slowly declined in the 2000s. Brady et al. (2008) and Tempalski et al. (2013) estimate the prevalence of injection drug use in the overall US population and find a similar pattern. Thus, demand increased after Colombian-sourced heroin entered the American market. That heroin prices fell substantially over the 1990s, indicates that the fall in price was due to an increase in heroin supply rather than a decrease in demand. The low prices of the late 1990s no doubt contributed to the concurrent rise in heroin use.

All heroin HCL/B estimates are robust to including unemployment or poverty rates as controls. (Some of the heroin SU estimates are not robust to the inclusion of these controls, likely due to the lack of precision in these estimates.) The fixed effects estimates remove the effect of any omitted variable that is constant over time or which changes in the same way across the US each year. Nonetheless, there may be location-specific omitted variables changing over time that may bias our estimates such as the availability of drug treatment, degree of police enforcement, or the presence of substitute drugs. Thus, although the estimates use the best available data to give the first evidence of whether changes in the structure of the heroin market are consistent with a standard economic model of entry and competition, we should be cautious about the causal interpretation of the estimates.

Another difficulty in our analysis is that the STRIDE data is unvalidated DEA data in the sense that the data we use is raw, and it is possible that errors remain in the database. We cleaned the data to reduce errors as much as possible. There is disagreement about whether the STRIDE data can be used reliably. Horowitz (2001) argues that the STRIDE data has limited use because the data does not represent a random sample. In particular, Horowitz (2001) finds that the drug observations have different means and time trends within cities depending on the method of acquisition. However, Arkes et al. (2008) further divides the sample by distribution level (low amounts at the retail level; high amounts at the wholesale level) and find that trends are consistent within cities in these subgroups. They argue that although the mean estimate in a given city and time period may not reflect the market's actual price, the city-specific time trends in price and purity can reasonably be estimated with the STRIDE data. In this paper, we follow the general approach outlined in Arkes et al. (2008) to estimate time trends in heroin price, purity, and expected price per pure gram of heroin.

An additional limitation of our analysis is that it is unknown how reliable the STRIDE's country of origin indicator is or whether it is representative, for example, at the city level.

Nonetheless, it is the only such data available. To reduce measurement error, we only use MSAs with a high number of observations. In addition, the data is broadly consistent with ethnographic observation, e.g. Mexican black-tar heroin is prevalent in the west, and Colombian-sourced powder heroin is prevalent in the east (Ciccarone, 2003), and so we have some confidence that our estimates are not driven by measurement error or misidentification.

Discussion

Using newly available data from the DEA, we update and expand on the analysis of Arkes et al. (2004) and Ciccarone et al. (2009), showing that heroin has recently become cheaper and purer in the US. We estimate the correlation between competition and the heroin price per pure gram at the national, regional, and MSA level. Our main finding is that, although the price of heroin has fallen at the national level (the entry effect outweighing the competition effect), it has fallen more quickly in areas where there is a higher degree of competition between supplier regions. This finding is important from a policy perspective because it shows that source country matters and that policy makers may be able to affect heroin price and purity by targeting source regions with the lowest costs of production and transportation. It is also an important finding that the heroin market behaves in a way that we would expect in other licit markets. Thus, reducing the number of sources of heroin within a city can raise prices. Saying this from a different perspective, Mexican-sourced heroin's monopoly on the west coast and Colombian-sourced heroin's monopoly on the east coast is likely causing higher prices than would be the case if both types of heroin were sold in equal shares in every city.

Our estimates are the first empirical evidence of the effect of changes in market structure on heroin prices. The estimates show a distinct pattern, consistent with the following story: Colombia entered the US market in the mid-1990s on the east coast and supplied large amounts of cheap, pure heroin. The low prices (combined with lower production of opium from Southeast Asia) led to the exit of Asian heroin. The supply of heroin from this new source was enough to reduce the price per pure gram of heroin throughout the country. With Mexican and Colombian-sourced heroin as the remaining major sources of heroin, locations with greater availability of both types of heroin, i.e. with more competition, had lower prices. Our findings can help to rule out alternative stories. For example, one could model Mexican and Colombian-sourced heroin suppliers as not competing, but rather as acting as a colluding forward-looking duopoly which keeps the price of heroin low to increase future demand. This may be consistent with the finding of overall lower prices in the US. However, this model would not explain why the price of heroin is lower where both types of heroin are present compared to where they have monopoly control of a market.

Our data and analysis focus on the short-run effects of the entry of Colombian-sourced heroin. It is less clear what to predict in the long-run. On the one hand, the exit of Asian heroin and greater overall market concentration in the US may lead to higher prices as heroin suppliers take advantage of increased market power. On the other hand, prices could remain low if suppliers want to deter new suppliers from entering. Even without external threats, a Mexican-Colombian duopoly could maintain lower prices if they have lower costs than the exiting Asian suppliers. Furthermore, an increase in demand for heroin from external factors, such as a reduction in the supply of substitutes (e.g. prescription opiates, see Unick et al. (2013)) will raise prices; a fall in demand from external factors, such as an increased availability of new addiction treatments (e.g. Suboxone) will lower prices. Thus, we are hesitant to predict the future of the US heroin market due to the possibility of a variety of emerging market factors.

There is considerable evidence that interdiction efforts focused on decreasing supply simply shift production and distribution patterns without substantial effects on consumption. The market evidence presented here is somewhat consistent with that interpretation, namely there are a number of market participants willing and able to compete for the US market, and greater competition for consumers results in an increased quality of heroin. On an international level, Paoli et al. (2009) explain that there is a "balloon effect" where the disruption of heroin from one source/route is somewhat futile because it only causes a new producer/transporter to appear elsewhere. The evidence presented here suggests that heroin product is fungible at a national level as well. All of this is to say that it is difficult to reduce sources of supply without providing incentives for other potential market participants to enter. Furthermore, increased market efficiencies due to globalization and technological advances may be making supply reduction efforts increasingly futile (Ciccarone, 2005, 2009). However, our research also suggests that selectively eliminating suppliers which have particularly inexpensive costs of production and transportation, may cause an increase in price even if new suppliers emerge. If exclusive regional markets (Ciccarone, 2005), aka segmented markets, prove durable, then opportunities for supply reduction may emerge. As evidenced in Southeast Asia, economic development may be an important mechanism to reduce supply. The one obvious avenue that would affect all suppliers would be to reduce consumer demand for heroin.

We are still left with several questions. By what process did Colombian-sourced heroin take over the east coast market? What maintains the geographic segmentation between Mexican-sourced heroin in the west and Colombian-sourced heroin in the east? Did Asian-sourced heroin leave peacefully or was it pushed out through violent competition? Is drug-related crime falling in places with less competition? What are the implications of reduced heroin prices for health and poverty outcomes? Is this era of inexpensive heroin telling us something about resilience to increasing drug demand among vulnerable populations, or the success of new forms of opiate treatment, i.e. buprenorphine? As a beginning of this research agenda, we have shown that competition in the heroin market is not very different than competition in other markets: entry of a low-cost competitor reduces the price and greater competition lowers the price further.

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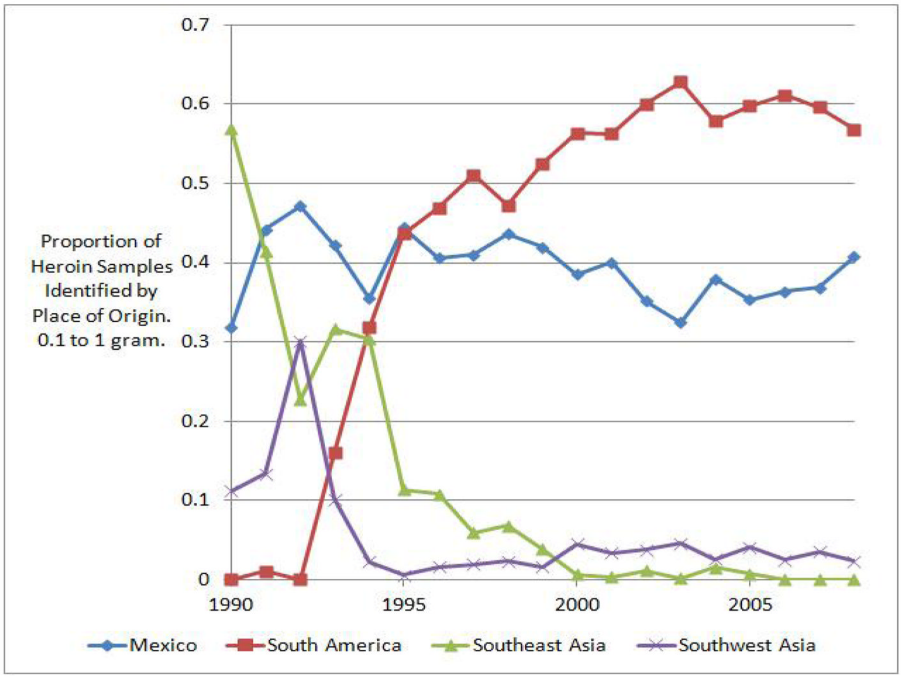

Figure 1.
Change in heroin supplier regions from 1990–2008. Data Source: STRIDE Database.

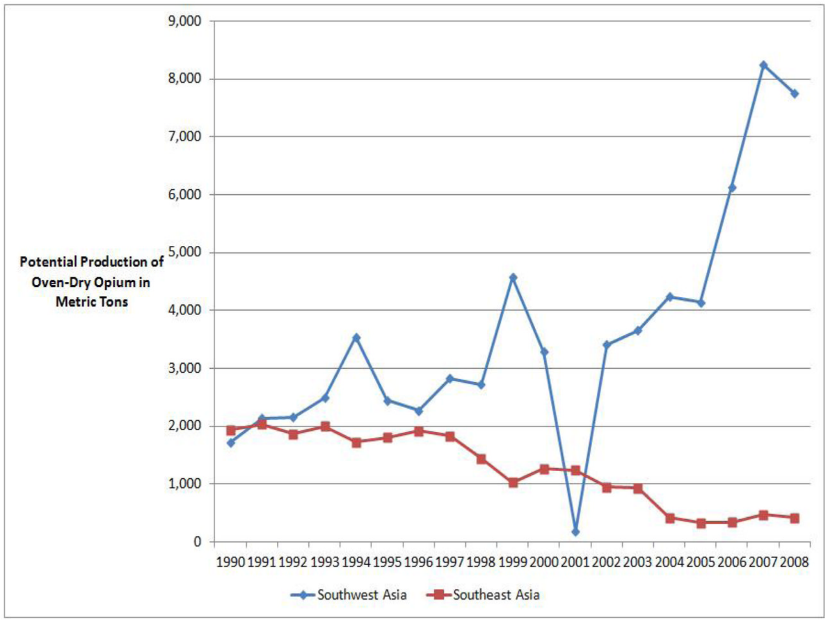

Figure 2.

Potential Asian opium production 1990–2008. Data Source: UNODC (2003) Table 2.1.1 and UNODC (2011) Table 13.

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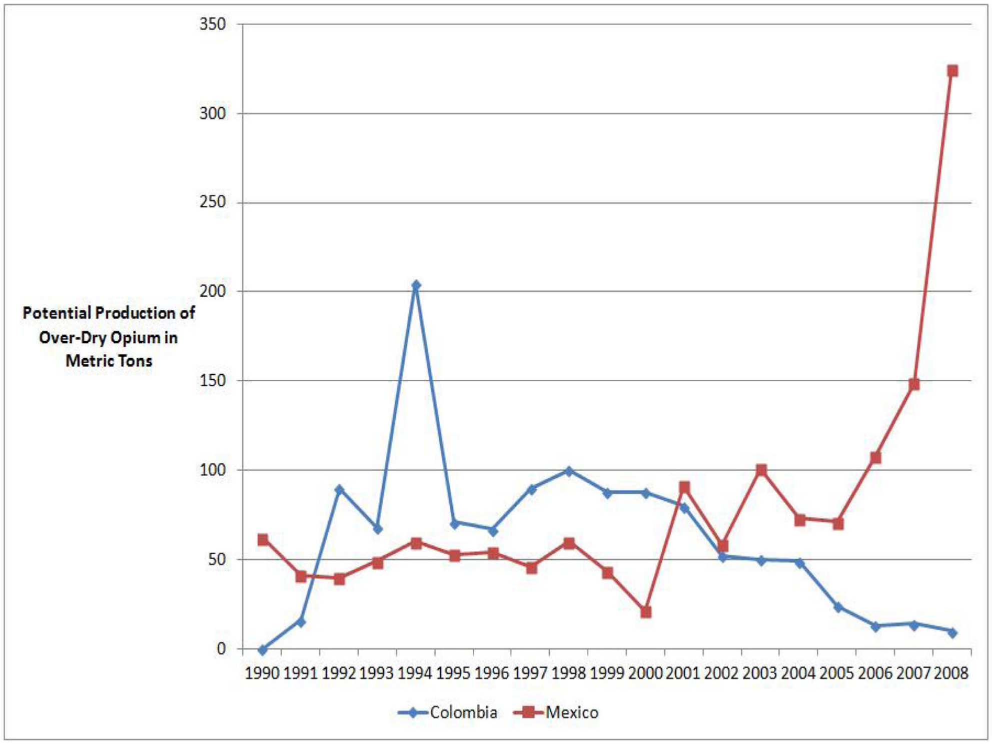

Figure 3.

Potential Mexican and Colombian opium production 1990–2008. Data Source: UNODC (2003) Table 2.1.1 and UNODC (2011) Table 13.

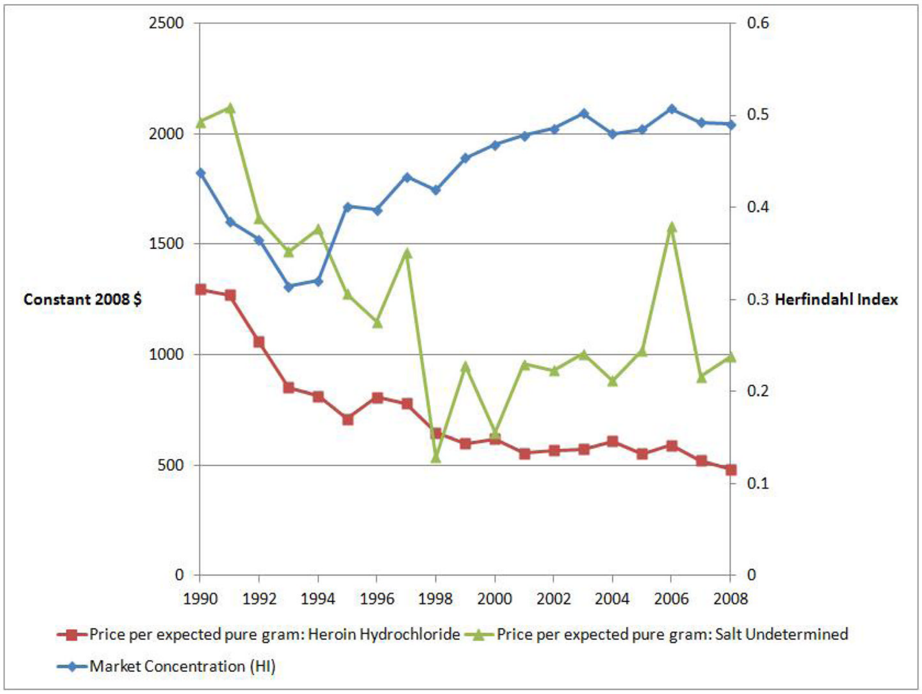

Figure 4.
National estimates of trends in heroin prices and market concentration. Data Source: STRIDE Database

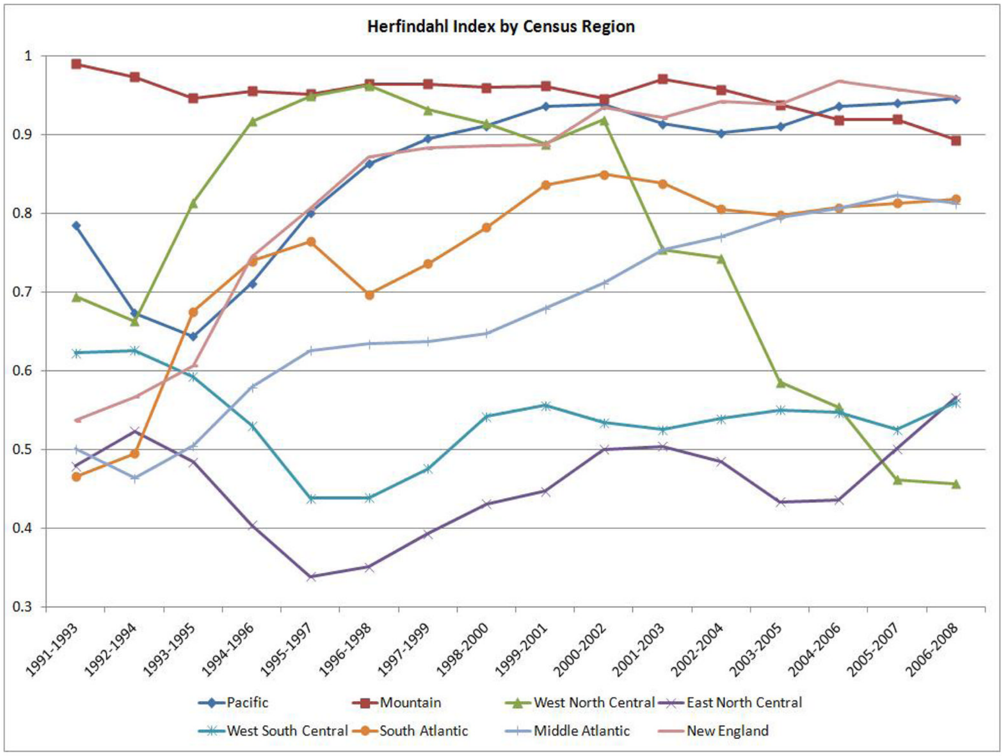

Figure 5.

Herfindahl Index for the heroin market by census region, smoothed 3-year averages. Data Source: STRIDE Database

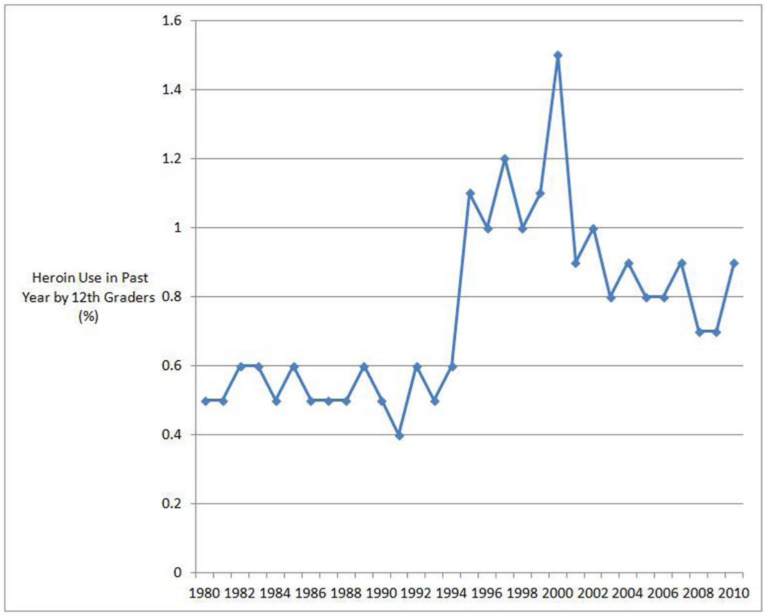

Figure 6.
Proportion of high school seniors reporting heroin use in the past year. Data Source: Johnston et al. (2011), Table 5-2, p. 200.

Table 1

Descriptive Statistics, Mean Values

	National		Regional		MSA
	HCL/B	**SU**	**HCL/B**	**SU**	**HCL/B**
market concentration (HI)	0.44 (0.01)	0.44 (0.01)	0.73 (0.02)	0.73 (0.02)	0.76 (0.01)
$\widehat{purity}$ (percentage points)	38.13 (0.98)	21.82 (0.94)	37.53 (1.20)	27.63 (1.52)	39.74 (0.78)
$\widehat{price}$ (per non-pure gram)	275 (17)	258 (18)	297 (10)	384 (32)	291 (7)
$\widehat{pricepure}$ (per expected pure gram)	731 (55)	1217 (100)	937 (59)	2058 (197)	859 (32)
Observations	19	19	144	144	458

Standard errors in parentheses. Prices in constant 2008 dollars. Purity and price estimated for 0.5 grams of heroin. Regional estimates are from 1991–2008 due to limited observations in 1990. MSA estimates are from 1992–2008 due to limited observations in some MSA's in 1990 and 1991. There were not enough observations of heroin SU to analyze the effect of market concentration on this subgroup at the MSA-level.

Table 2

Effect of Market Concentration on Heroin Price and Purity, 1990–2008

	National Estimates		Regional Estimates		MSA Estimates
	Heroin HCL/B	**Heroin SU**	**Heroin HCL/B**	**Heroin SU**	**Heroin HCL/B**
ln(Price Per Pure Gram)					
Market Concentration	−3.296*** (0.797)	−2.748** (0.853)	0.838*** (0.173)	1.539*** (0.461)	0.290** (0.115)
Regional Fixed Effects	no	no	yes	yes	no
MSA Fixed Effects	no	no	no	no	yes
Year Fixed Effects	no	no	yes	yes	yes
Observations	19	19	144	144	458
R-Squared	0.46	0.21	0.87	0.58	0.69
ln(Price Per Non-Pure Gram)					
Market Concentration	−3.834*** (0.559)	−3.717*** (0.556)	0.022 (0.111)	0.103 (0.413)	0.062 (0.083)
Regional Fixed Effects	no	no	yes	yes	no
MSA Fixed Effects	no	no	no	no	yes
Year Fixed Effects	no	no	yes	yes	yes
Observations	19	19	144	144	475
R-Squared	0.74	0.48	0.86	0.49	0.78
Purity (percentage points)					
Market Concentration	−21.95* (12.57)	−19.56 (11.29)	−28.34*** (5.32)	−22.02** (10.07)	−7.67* (3.43)
Regional Fixed Effects	no	no	yes	yes	no
MSA Fixed Effects	no	no	no	no	yes
Year Fixed Effects	no	no	yes	yes	yes
Observations	19	19	144	144	458
R-Squared	0.09	0.08	0.77	0.53	0.70

Robust standard errors in parentheses. Prices in constant 2008 dollars. Regional estimates are from 1991–2008 due to limited observations in 1990. MSA estimates are from 1992–2008 due to limited observations in some MSA’s in 1990 and 1991. There is one missing MSA data point for Orlando in 1993 due to a lack of data on heroin source for that year. There were not enough observations of heroin SU to analyze the effect of market concentration on this subgroup at the MSA-level. Purity and price estimated for 0.5 grams of heroin.

* $p < 0.1$,

** $p < 0.05$,

*** $p < 0.01$

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