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Impact of South American heroin on the US heroin market 1993–2004

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Abstract

Background—The past two decades have seen an increase in heroin-related morbidity and mortality in the United States. We report on trends in US heroin retail price and purity, including the effect of entry of Colombian-sourced heroin on the US heroin market.

Methods—The average standardized price ($/mg-pure) and purity (% by weight) of heroin from 1993 to 2004 was from obtained from US Drug Enforcement Agency retail purchase data for 20 metropolitan statistical areas. Univariate statistics, robust Ordinary Least Squares regression and mixed fixed and random effect growth curve models were used to predict the price and purity data in each metropolitan statistical area over time.

Results—Over the 12 study years, heroin price decreased 62%. The median percentage of all heroin samples that are of South American origin increased an absolute 7% per year. Multivariate models suggest percent South American heroin is a significant predictor of lower heroin price and higher purity adjusting for time and demographics.

Conclusion—These analyses reveal trends to historically low-cost heroin in many US cities. These changes correspond to the entrance into and rapid domination of the US heroin market by Colombian-sourced heroin. The implications of these changes are discussed.

Keywords

Heroin; Heroin supply; Heroin distribution; Medical consequences of heroin use; Heroin economics; Illicit drug history

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1. Introduction

In the United States (US), heroin users suffer persistently high rates of drug related harm. Heroin related emergency department visits have been rising. Between the years 1995 and 2002, the number of heroin-related emergency department visits increased 34% nationwide (Substance Abuse and Mental Health Services Administration: Office of Applied Studies, 2003). In a number of cities, heroin-related overdose deaths have risen dramatically (Fernandez, Hackman, McKeown, Anderson, & Hume, 2006; Oxman, Kowalski, Drapela, Gray, & Fafara, 2000; Solet, Hagan, Nakagawara, Plough, & Ball, 2000). Several major cities experience hundreds of overdose deaths every year (Bryant *et al.*, 2004) (Substance Abuse and Mental Health Services Administration: Office of Applied Studies, 2005). Bacterial complications from injection drug use are also increasing. Injection-related soft tissue infection was a leading cause of medical or surgical admission at one large county hospital (Ciccarone *et al.*, 2001) and hospitalizations for endocarditis are increasing (Cooper *et al.*, 2007). Injection drug users experience much chronic illness as well; they now constitute the majority of new hepatitis C infections (Wasley, Miller, & Finelli, 2007).

What changed about US heroin consumption to make it more dangerous? Analyses of heroin market trends may facilitate an understanding of these changes. As economists have repeatedly demonstrated a relationship between the price of an item and demand for it, that a similar relationship exists between heroin price, consumption and associated dangers, seems probable (J. Caulkins & Reuter, 1996). Moreover, a major goal of drug supply control efforts is to increase the street price of a drug by shifting the supply curve; this in turn reduces the quantity demanded by consumers as the market reaches a new equilibrium. (For a primer on illicit drug economics, see (Moore *et al.*, 2005).

Illicit drug consumers adjust their purchase behaviours in response to price fluctuations (A. L. Bretteville-Jensen & Biørn, 2003; Grossman & Chaloupka, 1998). The ways and extent to which price influences heroin purchase and consumption are additionally affected by gender and whether or not the consumer also deals drugs (A. L. Bretteville-Jensen, 1999). A model of drug price effects showed drug purity-adjusted price fluctuations to predict more than 95% of the variation in drug-related emergency department visits (J. P. Caulkins, 2001). An economic study of data from 21 US cities found a significant inverse relationship between purity adjusted heroin price and emergency episodes (Dave, 2006).

Some of the increase in heroin-related emergency department (ED) visits may be attributable to rising heroin purity. A study of epidemic level heroin-related deaths between 1979 and 1982 in Washington, DC, found that street heroin purity was significantly associated with overdose deaths (Ruttenber & Luke, 1984). An Australian study, conducted at two-week intervals over a two-year period, found a significant relationship between average heroin purity and number of overdose deaths (Darke, Hall, Weatherburn, & Lind, 1999).

The US Drug Enforcement Agency (DEA) maintains several administrative databases of heroin acquisitions. These include the Domestic Monitor Program (DMP), the Heroin Signature Program and System to Retrieve Information from Drug Evidence II (STRIDE). The DMP collects data from street-level heroin purchases made by undercover DEA agents in a number of major US cities, with the explicit goal of monitoring heroin trends. The Heroin Signature Program is responsible for determining the relationship between chemical composition and country of origin such that each heroin-producing region is associated with a specific chemical “signature.” The DMP and other DEA programs then utilize these signatures (US Department of Justice: National Drug Intelligence Center, 2000; US Drug Enforcement Administration, 1996a). In contrast to the DMP, STRIDE is a forensic database from street-level and larger scale seizures of all drugs, not solely heroin, to support enforcement and judicial proceedings

(Office of National Drug Control Policy, 2004; US Drug Enforcement Administration, 1998).

These programs greatly inform any attempt to understand historical and current trends in the US heroin market. Prior to 1990, the Heroin Signature Program and DMP data reveal the top three sources of heroin to the US market as Southwest Asia (SWA), Southeast Asia (SEA), and Mexico (US Drug Enforcement Administration, 2000a). SEA and SWA heroin historically captured the largest share of the global market (United Nations Office on Drugs and Crime, 2007; US Department of Justice: National Drug Intelligence Center, 2007), while heroin from Mexico has significant distribution only in the US (Bucardo *et al.*, 2005; US Drug Enforcement Administration, 2000b). In the early 1990s, seizure and intelligence data revealed entry of a novel heroin – sourced from Colombia – that appeared to be poised for rapid expansion in the US (US Drug Enforcement Administration, 1993).

We examined DEA DMP data on price and purity for all four sources of heroin coming into the US from 1993–2004 for up to 20 metropolitan statistical areas (MSAs). While heroin market trends are reported by governmental agencies, this report represents an independent analysis of US heroin price and purity trends and the effects of Colombian-sourced heroin on the US heroin market.

2. Methods

The DEA designs, funds and executes the DMP to track the US retail heroin market. The DMP makes undercover, street-level heroin purchases. They compile price information and analytic data of the purity, chemical signature, composition, adulterants and diluents for each purchase. (The chemical signature identifies the heroin's region of origin, as determined by the Heroin Signature Program.) Although useful for drug supply and demand studies in general, we did not use STRIDE data for several reasons. Since drug acquisitions are made to support criminal investigations, the criteria for drug purchase or seizure varies by local priorities leading to less consistent sampling across time and geography (Horowitz, 2001; Office of National Drug Control Policy, 2004). Criminal investigations often require multiple purchases from the same dealer leading to clustering of price data (Horowitz, 2001).

Finally, since STRIDE studies drugs seized from all market levels, including large border seizures and minor possession arrests, there are proportionally fewer at the level of highest interest: retail or street-level (Horowitz, 2001; Office of National Drug Control Policy, 2004). In contrast, DMP purchases focus on sampling heroin exclusively – and only at the retail/street level. Additionally, DMP is not collected for the purpose of criminal prosecution, only for monitoring price and purity trends.

We obtained the DMP data for the years 1993–2004 through Freedom of Information Act requests to the DEA. These multiple requests yielded mostly yearly composite data, and not data on individual samples, for many of the years requested. Data prior to 1993 is either too sparse or contains too many unclassified or misclassified samples to contribute to these analyses. The identified source regions were SEA, SWA, Mexico, South America or, unclassified. Unclassified samples did not match any of the existing regional chemical signatures. These samples were included in the analyses. The South American heroin signature was developed in 1993 and government documents from 1993 forward state that Colombia is the source of South American heroin.

2.1 Analyses

We included 240 MSA-years of DMP heroin data in our analyses. Of the 23 possible MSAs, Orlando, El Paso, and San Juan were excluded because of extensive missing price and purity

data (total 36 MSA-years) leaving 20 MSAs for this analysis. The DMP calculates the mean price per milligram-pure for all the samples collected in each MSA-year. The mean heroin price for each of 20 different MSAs was then adjusted for inflation: for each year, the mean was divided by the Bureau of Labor Statistics Consumer Price Index for year 2000 US dollars. The percent of heroin from a source region was determined as a percent of all samples purchased in an MSA that originated from one of the four regions (South America, Mexico, SEA, SWA) or categorized as unknown.

The price/purity and source region sample data make some assumptions about the representiveness of the sample collection in each MSA. First, that the samples collected in each MSA are representative of the price and purity of the heroin available for street purchase in that MSA. Second, that the source region of the samples is representative of the heroin available in that MSA. The mean number of samples over all MSA-years was 32/MSA-year and the range of the mean number of yearly samples in each of the MSAs was 25 (New Orleans) to 53 (New York). The reasonable number of samples contributing to the mean MSA-year price and purity calculations provides some assurance that changes in these values are aligned with changes in the larger heroin market in each of these MSAs.

The price and purity of heroin may be confounded with the size of the market, thus with the number of IDUs in the MSA. We included demographic covariates to serve as proxy variables for the number of IDUs or consumption patterns that would affect the price and purity of heroin within an MSA (Dave, 2006). The population, percent at a given education level, ethnic/racial composition and age distribution of a given MSA for each year between 1993 and 2004 was collected from the National Cancer Institute SEER database. Information on the percentage of individuals living in poverty in a given MSA-year was collected from the Consumer Population Survey March Supplement. Data on percent of the population arrested was gathered from the Uniform Crime Reporting data for each MSA in each year.

Fifteen MSA-years had missing covariate data. Specifically, the source region of the heroin was missing for 6 different MSA-years. Miami was missing data on arrests for 9 years (1996–2004). These MSA-years were excluded from the random effects models, but included in all other analysis. An additional four MSA-years had extreme price data. Because price in the DMP data is adjusted for purity, and therefore confounded with purity, our price estimates are sensitive to sham samples with very low amounts of heroin. These 4 MSA-years were each 3 standard deviations above the mean of their MSA (over all years) and also had full model standardized residuals above 3. We elected to eliminate these 4 MSA-years from all analysis.

All data coding and statistical analysis was conducted in Stata 10.0 (StataCorp, 2007). Univariate statistics, robust Ordinary Least Squares (OLS) regression and mixed fixed and random effect growth curve models were used to predict the price and purity data in each MSA over time. Robust OLS regression was used to model the mean yearly change in the geographic origin of heroin separately for each MSA. Standard errors used in robust OLS regression are more precise when outcomes are not normal as is the case with the percent of heroin originating from the various source regions. Because the price and purity of heroin is not independent of the MSA where the samples were collected, a multilevel modelling approach was used to model the price per mg-pure and the purity models. Specifically, growth curve models were estimated with Stata's XTMIXED procedure. Random effects allow for each MSA to have a different baseline for the price and purity of heroin and to adjust for an exchangeable correlation structure within MSA price and purity observations. Evaluations of the correlation structure suggest a single fixed estimate of the correlation within MSAs for price and purity is appropriate and has more statistical power. To make the price model coefficient more interpretable, dollars were converted to cents. The price data was, as is typically the case, skewed to the right. Two different methods were compared to account for the skewed price data. One strategy to deal

with the right-skewed price data was to take the log of the price creating an approximately normal distribution. This strategy satisfied the distributional assumptions of the model, but made the coefficients difficult to interpret because they are now in logged cents. The second strategy was to use bootstrap standard errors, an effective alternative to logging the price data (Afifi, Kotlerman, Ettner, & Cowan, 2007; Efron & Tibshirani, 1993). The bootstrap method allows for the price data to be kept in its original dollar units while accounting for the non-normal distribution by empirically estimating the standard errors with resampling techniques. The results for these two methods were very similar and led to the same inferences. Only the bootstrapping approach is shown.

The purity data was also skewed to the right, but was approximately normal when transformed with a square root function of the original purity data. Similarly, the bootstrapping approach was also used and the results of the two approaches were very similar. Again, only the bootstrap approach is shown.

For both the price and purity random effects growth curves, 4 different models were used. The first model for each outcome was the means model, estimating only an intercept and two random effects: the standard deviation for the between MSA residuals and the standard deviation for the within MSA residuals. The second set of models included parameters specifying the relationship between time and the outcome. The third set of models added parameters for the percent of heroin originating from South America or Mexico. Given the small percent of heroin originating from SWA and SEA, these percents were not included. Their effect is still represented in the model because of the mutually exclusive nature of percentages. The final set of models added covariates for other potentially confounding MSA attributes such as demographic differences, law enforcement activity and economic characteristics.

3. Results

Over all cities and years, the cluster-adjusted mean price for heroin was 1.09 (se=0.12) US dollars ($) per milligram-pure (mg-pure). Seattle had the highest mean price at $4.68/mg-pure, while San Diego had the lowest mean price at $0.22/mg-pure. Table 1 lists the mean price, maximum price and minimum price for each MSA along with the years that those prices occurred. With the exception of San Francisco, each MSA's maximum price was recorded before the minimum price. The smallest change between the maximum price and the minimum price was a 60% reduction in the cost of heroin recorded in Dallas. San Diego saw the largest decrease, with the purity-adjusted price of heroin falling 89% between 1996 and 1999. Over the course of the study period, the mean inflation-adjusted price of heroin dropped 62% from $1.67 to $1.03/mg-pure.

Table 1 also displays information on the changes in the purity of heroin in each of the MSA regions between 1993 and 2004. The cluster-adjusted mean purity of heroin was 34.33 (se= 3.56) percent heroin by weight (%). Changes in the purity of heroin by MSA were less consistent than changes in the price of heroin during the study period. Half of the MSAs had minimum purity values occurring before the maximum purity during this time. However, the other half of the MSAs saw reductions or wide fluctuations in the purity of samples collected: Boston, Chicago, Houston, Los Angeles, New Orleans, New York, Philadelphia, San Francisco, Seattle, and St Louis.

Figure 1 shows the changes in the price and purity of heroin averaged per year. Consistent with the results presented in Table 1, the price of heroin decreased dramatically between 1993 and 1997 and stabilized thereafter. The yearly averaged purity graph shows a substantial increase from 1993 to 1998 with a subsequent decline.

Table 2 shows the changes in the percent of heroin coming from South America, SWA, SEA and Mexico. MSAs were organized into two regions based on predominance of specific heroin sources: east and west of the Mississippi River. East of the Mississippi River, heroin from South America predominates and the median percent of heroin from South America grew at a significant rate of approximately 7% per year in absolute terms across all eastern MSAs. Percent of samples from SEA and SWA declined significantly in several eastern cities. West of the Mississippi, Mexican heroin predominates with three cities showing small, but significant increases in percent of Mexican heroin. No South American, SEA, or SWA heroin was recorded in cities west of the Mississippi.

Figure 2 shows the yearly changes in the geographic origin of heroin collected by DEA agents. This graph visually displays the results presented in table 2. The percent of South American heroin in the US market increased remarkably between 1993 and 2004, while the percent of SEA heroin decreased almost to 0% of the US market. Mexican heroin stayed relatively constant.

In order to test if time and percent South American heroin predict price and purity nationally, multilevel growth curve models with years nested in MSAs were estimated. Out of a possible 240 units of MSA-years, 221 units had complete price and covariate data (mean: 11.1 years per MSA). Table 3 shows the results for the 4 models predicting the inflation-adjusted price of heroin controlling for other MSA covariates. Of the four models, the full model is the best fitting. These models suggest that both the effect of time and the percent of heroin from South America are quadratic and statistically significant independent predictors of lower heroin prices. These models confirm that the quadratic price curve presented in figure 1 is statistically significant. The full model suggests that price of heroin decreased $0.26/mg-pure per year on average, but that this effect tailed off as time increased. Similarly, for each 1% increase in heroin coming from South America the price of heroin decreased $0.01/mg-pure (e.g., each 10% increase in South American heroin produced a $0.13/mg-pure price decline). This effect also asymptotically tailed off as the percentage of South American heroin increased. None of the other MSA level covariates had a significant effect on the price of heroin, including the percentage of heroin originating in Mexico.

In an analysis not shown, we restricted the full price model to the years 1993 to 1999 when the largest increase in percent of SA heroin and decrease in prices occurred. During this time, each 10% increase in SA heroin resulted in a $0.20 ($p < 0.01$) decrease in the price per mg-pure. For these 7 years, the percent of heroin originating from SA increased by 34%, resulting in a model-imputed decrease of $0.66/mg-pure due to changes in the geographic origin of heroin alone.

Table 4 shows the models predicting the change in purity. Out of a possible 240 units of MSA-years, 221 units had complete purity and covariate data (mean: 11.1 years per MSA). From 1993 to 2004, the purity of heroin did not show a statistically significant linear or quadratic change over time after adjusting for the percent of heroin originating from South America and other covariates. Increases in the percent of heroin originating from South America resulted in a linear increase in the purity of heroin in US markets. Each 10% increase in the amount of heroin originating in South America produced an absolute increase of 1.7% in the purity of heroin. Unlike the price model, the effect of South American heroin on the purity of heroin was not quadratic. Again, the percentage of heroin originating from Mexico had no effect on the purity of heroin. The percentage of adults and males in an MSA had a statistically significant effect on the purity of heroin, but no other MSA covariates showed effects on the purity of heroin in an MSA.

4. Discussion

During the 12 years studied, street-level heroin in the US became significantly less expensive. In the US cities sampled, the price of heroin declined 60–89%, with an overall yearly decrease of $.26 per pure mg. These changes are significantly related to the introduction of new Colombian-sourced heroin. National market share of Colombian heroin grew by approximately 7% per year during the period of study. For each 10% increase in Colombian heroin market share, a corresponding $0.13/mg-pure decline in price and an absolute 1.7% increase in purity were seen in our models. The successful market share capture of Colombian heroin effectively reduced the number of heroin sources from three regions to one in the eastern US. By the end of the study period the nationwide heroin market is divided with the western and eastern US receiving predominately Mexican heroin and Colombian heroin, respectively.

4.1 Colombian heroin trade history

The first substantial poppy crop yields in Colombia (although minor in size compared with coca) are estimated to have appeared in 1991. According to the United Nations Office of Drugs and Crime, opium poppy cultivation in Colombia was estimated to be 1,160 hectares in 1991 and reached a peak of 15,091 hectares in 1994 before falling to 6, 500 hectares in 2000 (United Nations Office on Drugs and Crime, 2005). Aspects of Colombian drug trade history help illustrate why Colombian traffickers were capable of quickly and effectively entering the US heroin market (for more details see, (Ciccarone, 2008) and for an extensive history see, (Thoumi, 2003). These factors can be summed as: 1) lack of government control over the drug cartels and drug producing regions; 2) product (drug) diversification; 3) cooperation between Colombian-Mexican drug traffickers and the incorporation of heroin into new and existing cocaine distribution systems; and 4) collapse of the big cartels and rise of independent traffickers.

Coca was first processed into cocaine for export during the 1970s (US Drug Enforcement Administration, 2005b). Early successes with both cocaine and marijuana trafficking catalyzed the development of the Colombian drug cartels and put systems in place for large-scale drug production and distribution.

Diversification of the drug trade, with the production and exportation of heroin, was initiated while the large cartels were still powerful (US Drug Enforcement Administration, 2000a, 2005b). Heroin, by weight, was considered more profitable than cocaine (US Drug Enforcement Administration, 1995). The huge success of the cocaine trade eventually led to excess supply and diminishing profits (US Drug Enforcement Administration, 1995, 2005b). Trafficking agreements, made out of necessity with Mexican smugglers, also cut into profits (Constantine; US Drug Enforcement Administration, 2000a).

Collaboration between Colombian and Mexican drug traffickers is a key development in the US geographic distribution of cocaine and heroin (US Drug Enforcement Administration, 2000a, 2002). US interdiction operations in the Caribbean and Florida in the 1980s interfered with cocaine shipments originating from Colombia. Agreements allowing for cocaine smuggling through Mexico ultimately accounted for 50% of all South American wholesale cocaine entering the US. Further agreements in the 1990s led to 50% profit sharing with Mexican traffickers and their subsequent control of a large share of the US bound cocaine trade (Constantine; US Drug Enforcement Administration, 2000a). The enrichment of Mexican drug lords from the cocaine trade led to investment in new distribution strategies (US Drug Enforcement Administration, 2000a). Eventually, two US distribution networks developed: Mexican-sourced heroin and Colombian-sourced cocaine is distributed to the Midwest and West; Colombian traffickers, relying on long-established trading routes (US Drug Enforcement Administration, 1996b), distribute Colombian-sourced heroin and cocaine to the eastern US

(US Drug Enforcement Administration, 2000a). Of note, while the evidence for smuggling cooperation is strongest for cocaine, the geographic distribution of heroin confirmed by our data (Table 2) is likely more than historical accident.

By the 1980's, the enormous success of the drug trade, coupled with continuing government weakness, allowed smaller drug organizations to evolve in the wake of the larger ones (Constantine, 1996; US Drug Enforcement Administration, 1996b, 2000a; Vargas, 2002). By the end of the decade, the largest cartel, Medellin, had come under increasing political, judicial and enforcement pressure. A decade of violence and political tumultuousness culminated in the dismantling of the Medellin Cartel leadership: Carlos Lehder (extradited to the US), Jose Gonzalo Rodriguez Gacha (killed) and the Ochoa brothers (surrendered to Colombian authorities to avoid extradition). This was followed by the assassination of the Medellin Cartel's Pablo Escobar – a former member of Colombia's Congress and a key Cartel leader – in 1993 (US Drug Enforcement Administration, 2005b). The Cali cartel, which became more powerful after the dismantling of the Medellin Cartel, was known for its sophisticated trading practices that mimicked successful legitimate international business strategies in conjunction with the compartmentalization and secrecy strategies of criminal cells (US Drug Enforcement Administration, 2000a). The toppling of the Cali Cartel followed the capture of five key leaders in 1995 (US Drug Enforcement Administration, 2005b). The drug trade became decentralized as power was passed to experienced traffickers seizing opportunities to increase their share of the drug trade, including through diversification and production of the new crop – heroin (US Drug Enforcement Administration, 2000a).

4.2 Consequences of US heroin market changes

What effect did the novel entry of Colombian-sourced heroin have in the US? One might predict that the steady influx of inexpensive heroin lasting over a decade would have led to an upswing in heroin use. The US has experienced two documented heroin "epidemics" since WWII: late 1940s to early 1950s; and 1960s to mid 1970s. Early observations from these cycles appeared to fit economic supply-demand theories and led to current national control policies (Hughes & Rieche, 1995). According to studies on price elasticity, heroin consumption does respond significantly to price (Moore *et al.*, 2005) in both international (Darke, Topp, Kaye, & Hall, 2002) and US settings (Saffer & Chaloupka, 1999). During the period of 2001, now referred to as a heroin "drought" in Australia, heroin users modified their use in response to changes in availability and price. Heroin use declined while cocaine and methamphetamine use increased (Topp *et al.*, 2002). The percentage of injectors reporting heroin as their primary injection drug fell 27% from the period preceding the drought (Maher *et al.*, 2007). Of heroin users who felt heroin had become more expensive, less available, or of poorer quality, 56% reported using more of other drugs to compensate (Weatherburn D., 2003). Heroin related consequences also declined; fatal and non-fatal heroin overdoses decreased dramatically following the supply reduction (Degenhardt, Reuter, Collins, & Hall, 2005). In the US, a study of heroin-related emergency department visits and heroin prices, during the period of 1981–1996, revealed a significant negative correlation between the two. This study found that long-term changes in price have a larger effect on emergency department visits than abrupt price changes (J. P. Caulkins, 2001).

The emergence of Colombian heroin in the US coincides with an increase in heroin related consequences. Emergency department mentions rose almost 50% from 63,158 in 1994, (Substance Abuse and Mental Health Services Administration: Office of Applied Studies, 2002) to 93,519 in 2002 (Substance Abuse and Mental Health Services Administration: Office of Applied Studies, 2003). Numerous reports document increasing incidences of heroin-related overdose (Bryant *et al.*, 2004; Fernandez *et al.*, 2006; Landen *et al.*, 2003; Oxman *et al.*, 2000; Solet *et al.*, 2000) and soft tissue infections (Binswanger, Kral, Bluthenthal, Rybold, &

Edlin, 2000; Ciccarone *et al.*, 2001; Werner, Passaro, McGee, Schechter, & Vugia, 2000) during this period. While the aging of the injection drug using population seeking treatment (Broz & Ouellet, 2008) may account for some of the rise in consequences, Drug Abuse Warning Network data reveal the highest increase in heroin related ED visits was for 18–25 year olds (Substance Abuse and Mental Health Services Administration: Office of Applied Studies, 2002, 2003).

The rise in heroin initiation and experimentation among youth during the 1990's does raise concern. The Monitoring the Future Study reported a doubling of the rate of first heroin use among 12–17 year olds, from less than 1 per 100 person-years in the late 1980s, to almost 2 per 100 person-years in 1998 (Johnston, O'Malley, Bachman, & Schulenberg, 2006). There is anecdotal evidence of market "innovations," which appear aimed at new and/or young users. "Chiva," slang for "black tar" heroin, was highlighted as causing numerous overdoses – because of its high purity and ability to be smoked –among naïve high school students in suburban Plano, Texas (Cropper; Gray, 1999). More recently, "cheese," a mixture of acetaminophen, diphenhydramine and heroin was reported as readily available in middle and high schools in Texas with doses costing as little as $2.00 (Maxwell, 2007; Office of National Drug Control Policy, 2007; US Drug Enforcement Administration, 2006). Increased heroin purity also allows for the promotion of alternative routes of administration. A review of heroin-use data from New York City found large, concomitant increases in intranasal heroin use and heroin purity (Frank, 2000). Intranasal use of heroin increased among those entering treatment during the 1990s (Substance Abuse and Mental Health Services Administration: Office of Applied Studies, July 20, 2001; April 26, 2007); of note, this is the preferred route for using "cheese" (Office of National Drug Control Policy, 2007).

Complicating the consequences of a heroin uptrend is the fact that different global sources of heroin produce substantially different products. Colombian heroin is almost always a light-coloured powder. Most heroin from Mexico is viscous, black and solid at room temperature and thus called "black tar" (BTH) (US Drug Enforcement Administration, 1986). Furthermore, these heroin products are regionally distributed in the US: South American heroin predominates in the Eastern US, while heroin from Mexico is found almost exclusively in the Western US. Powdered heroin (South American and Asian) and BTH from Mexico differ in several physical and chemical characteristics (Ciccarone & Bourgois, 2003). Patterns of use also vary, e.g., unlike powdered heroin, BTH is almost always heated in water to make it soluble prior to use. These differences appear to result in disparate health consequences for users. BTH has been associated with wound botulism (Passaro, Werner, McGee, Mac Kenzie, & Vugia, 1998; Werner *et al.*, 2000), necrotizing fasciitis (Kimura *et al.*, 2004), tetanus (Bardenheier, Prevots, Khetsuriani, & Wharton, 1998) and soft tissue infections (Binswanger *et al.*, 2000; Ciccarone *et al.*, 2001; Harris & Young, 2002; Murphy *et al.*, 2001). HIV prevalence among injection drug users is much higher in cities with powder heroin than in cities where BTH is endemic (Ciccarone & Bourgois, 2003). The plateau of heroin purity nationwide, at about 30 percent, may be due to the influence of BTH, which may have a purity limit based on manufacturing. Refinements in Mexican heroin are plausible given cooperation between Colombian and Mexican traffickers and labs, but given the lack of competition this seems unlikely. The regional distribution of heroin sources/types affects the risk environment for heroin users and results in geographic variation in risk/disease distribution (Ciccarone, 2008). Further surveillance and research is needed on the distribution, use patterns and consequences, over time, of different sources of heroin in the US.

4.3 Limitations

A number of limitations in our analyses should be noted. The lack of data at the level of individual purchases limits our ability to make more detailed intra- and inter-MSA or regional

comparisons. For example, more detailed MSA drug data would permit stratified analyses of the distinct eastern and western US heroin markets. In addition, we are not able to adjust for systematic differences, e.g., changes in purchase volume, *within* MSAs across the study time. The mixed models approach we use does allow us to adjust for differences in the purchase volume *between* MSAs, assuming that the DMP purchase volume remains relatively constant or at least randomly different within each MSA. The US General Accounting Office has published a critique of the DEA DMP (United States General Accounting Office, 2002). The DMP sampling of retail heroin may be based on policing patterns or convenience. The DEA's control of their samples and data is such that there is no real opportunity for alternative sample analysis. In addition, the small number of MSAs in the DMP sampling frame limits statistical analyses (US Drug Enforcement Administration, 2005a).

Another potential source of bias in this study is that the percentage of heroin of unknown origin decreased over the study period. One possible explanation is that South American heroin was initially classified as unknown (US Drug Enforcement Administration, 1994) thus raising the concern of misclassification bias. Improvement of the heroin signature over time could contribute to this bias. In a sensitivity analysis, we found that price is sensitive to the inclusion of unknown samples into the South American samples, but purity was not. This is not surprising for several reasons. Reviewing data from the 1980s through 2000 there is a wide range in the percent of unknown samples, but as a general rule about 20% of all samples have been from unknown sources. Historically, heroin samples that were not analyzable, i.e., of unknown origin, were of very low quality, or "bunk." The discovery of high quality samples led to the development of the South American signature. Reclassifying the unknown samples as South American randomly combines both bunk and good samples with the South American signature data; this may have the same effect as introducing stostatic noise. Furthermore, unknown samples of high quality, which might be misclassified, flatten the curve of South American heroin market prevalence during the period of study thus reducing its correlation with heroin price. It cannot be ascertained if this is a valid point without examining the period prior to 1993 to model the effect of growth of the unknown category. This cannot be reliably done as the DEA data prior to 1993 are too sparse and lack the South American signature on which to extend the analysis. Finally, Figure 2 is somewhat misleading in that the drop off in unknown samples after 2000 is due to cessation of DEA reporting rather than an improvement in lab procedures or the signature. Thus, while some degree of misclassification is likely present, the most plausible explanation for the relationship between price and the percent of heroin originating from South American is the role of this new market participant and not just a monitoring effect.

4.4 Conclusion

Heroin prices also declined steadily in Europe during the period of study (Gibson, Degenhardt, Day, & McKetin, 2005; United Nations Office on Drugs and Crime, 2008). This may be evidence of international heroin supply exceeding demand (Ciccarone, 2005). Perhaps demand is down worldwide, but no evidence exists that it is so low as to be deflationary. Increasingly, heroin sources and markets are intertwined and exclusive; this, combined with increases in efficiency spurred on by globalization may have led to heroin price declines (Ciccarone, 2008). That this glut is happening globally doesn't detract from forming specific regional explanatory models. The findings presented in this paper argue that, *in addition,* a new source of heroin has contributed to historic heroin trends in the US market.

Despite the rhetorical, financial and militaristic manifestations of the US "war on drugs," – now in its fourth decade (Nixon, 1971) – Colombian drug producers successfully marketed a new drug – heroin – in the United States during the 1990s. The rise of purity and decline in price of US retail heroin during the 1990s appears directly related to Colombian-sourced heroin

effectively competing with and collapsing the Asian-sourced heroin market in the US. The resulting restricted market of Mexican- and Colombian-sourced heroin is geographically defined, with reduced competition and unpredictable future implications. Market shifts could produce supply shocks or redistribution of heroin source/type. Further research is needed on the medical consequences of different sources/types of heroin, and changes in supply, by geographic area. Surveillance is particularly necessary in areas where Colombian heroin potentially replaces Mexican heroin as this may impact HIV rates.

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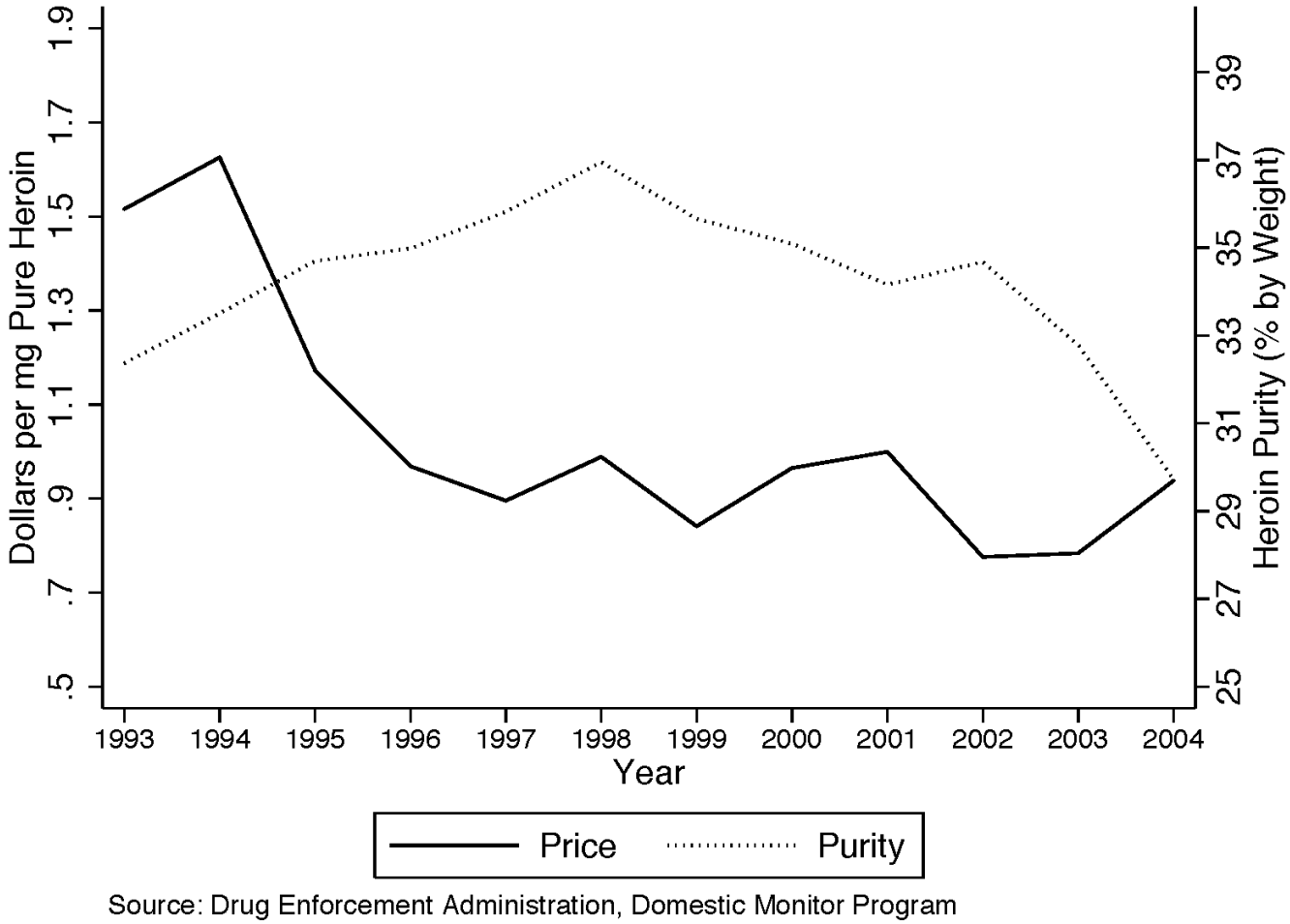

Figure 1.
Mean price and purity of heroin samples between 1990 and 2004

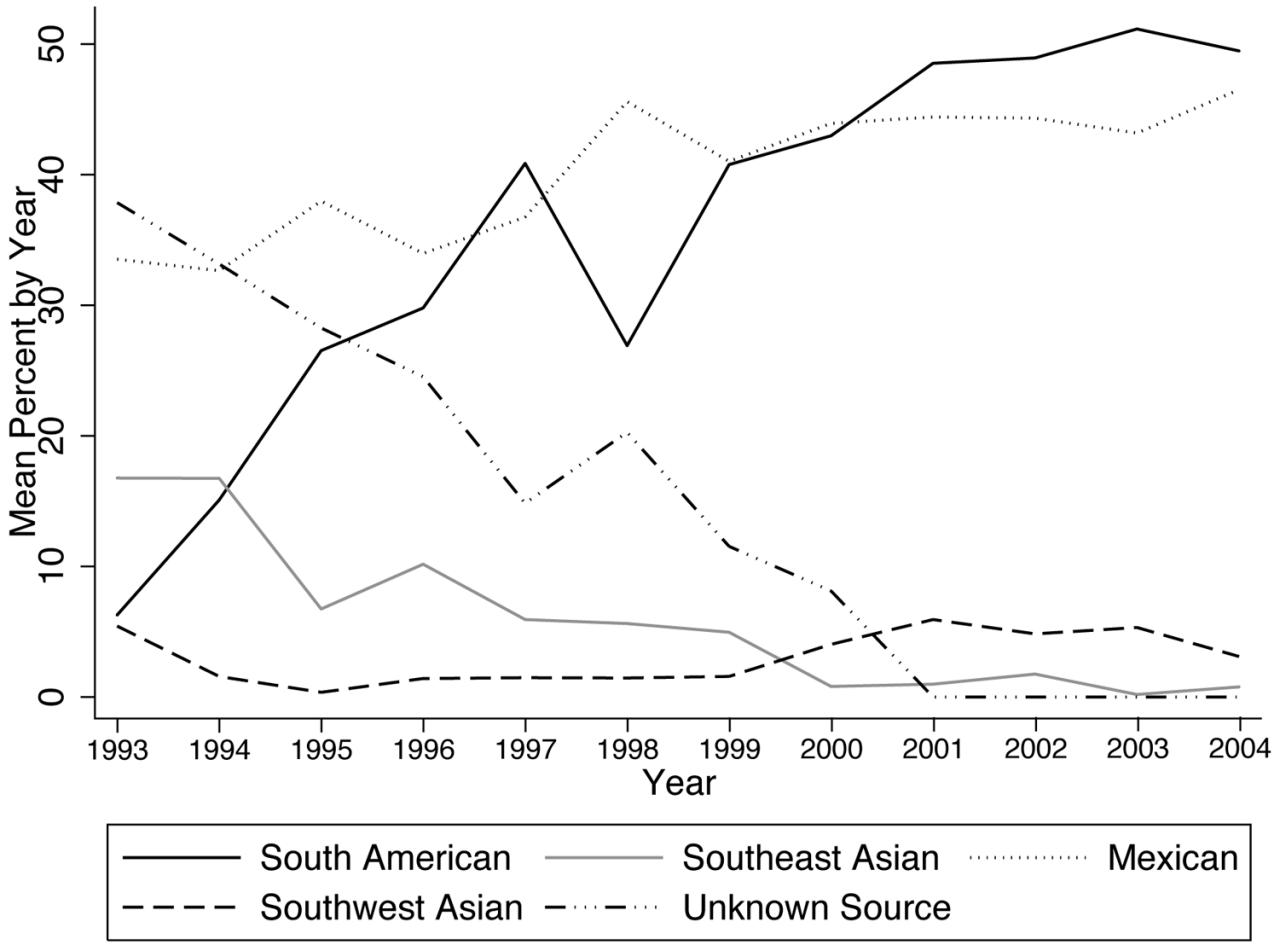

Figure 2.
Geographic source of heroin samples between 1990 and 2004

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Table 1

Price and purity of heroin, 1993 – 2004

MSA	Mean Price (SD)	Min Price (Year)	Max Price (Year)	Mean Purity (SD)	Min Purity (Year)	Max Purity (Year)
Atlanta	1.69 (0.66)	0.77 (1999)	2.74 (1993)	48.62 (9.01)	29.92 (1993)	64.89 (1999)
Baltimore	0.54 (0.21)	0.25 (2001)	0.94 (1993)	25.56 (9.29)	10.83 (1993)	41.96 (1997)
Boston	1.05 (0.26)	0.48 (2003)	1.44 (1993)	54.53 (11.02)	27.8 (2004)	65.23 (1993)
Chicago	0.88 (0.50)	0.49 (2002)	2.2 (1994)	25.14 (9.46)	12.1 (2004)	46.76 (1997)
Dallas	1.18 (0.36)	0.73 (2002)	1.86 (1995)	13.02 (2.98)	8.55 (1995)	17.30 (2002)
Denver	1.35 (0.73)	0.51 (2004)	2.71 (1994)	26.32 (10.48)	15.7 (1995)	47.24 (1997)
Detroit	1.01 (0.36)	0.59 (1999)	1.79 (1995)	42.24 (8.94)	29.11 (1994)	54.57 (1999)
Houston	1.27 (0.59)	0.48 (2004)	2.31 (1997)	22.91 (10.20)	10.99 (2001)	42.77 (1997)
Los Angeles	0.56 (0.25)	0.25 (2004)	1.01 (1997)	27.39 (6.69)	14.64 (1998)	36.94 (1997)
Miami	1.26 (0.50)	0.43 (1995)	2.07 (1993)	17.85 (7.93)	7.63 (1993)	29.40 (2002)
New Orleans	2.15 (0.79)	0.81 (1999)	3.28 (1993)	30.78 (5.19)	24.44 (2004)	40.63 (1997)
New York City	0.58 (0.23)	0.37 (2000)	1.18 (1993)	56.74 (12.83)	24.95 (1997)	70.05 (1995)
Newark	0.53 (0.27)	0.33 (2002)	1.24 (2001)	58.82 (13.69)	22.6 (1997)	72.06 (2000)
Philadelphia	0.56 (0.20)	0.35 (1997)	1.01 (1996)	62.91 (12.79)	29.13 (1997)	74.31 (1993)
Phoenix	0.68 (0.55)	0.35 (1999)	1.99 (1994)	40.22 (7.32)	23.03 (1997)	48.90 (2002)
San Diego	0.45 (0.51)	0.22 (1999)	1.95 (1996)	47.10 (9.58)	18.81 (1997)	57.89 (1998)
San Francisco	1.02 (0.41)	0.36 (1998)	1.74 (2001)	19.94 (8.74)	10.1 (2001)	34.46 (1995)
Seattle	1.51 (1.06)	0.93 (1997)	4.68 (1993)	18.34 (8.26)	10.4 (2003)	35.33 (1997)
St Louis	2.39 (0.83)	1.01 (2002)	4.02 (1995)	16.59 (6.71)	8.71 (2004)	30.69 (1997)
Washington, DC	1.16 (0.44)	0.67 (2001)	1.92 (1994)	24.60 (6.65)	17.09 (1995)	41.74 (1997)
US overall	1.09 (0.12)	0.81 (2002)	1.67 (1993)	34.33 (3.56)	29.72 (2004)	36.95 (1998)

Price: USD per milligram pure heroin

Purity: Percent heroin by weight

Source: DEA – DMP

Table 2

Geographic origin of heroin and percent change (absolute) between 1993 and 2004

MSA	South American Heroin (Median %)	Change South American Heroin (Mean Yearly %)	Mexican Heroin (Median %)	Change Mexican Heroin (Mean Yearly %)	Southeast Asian Heroin (Median %)	Change Southeast Asian Heroin (Mean Yearly %)	Southwest Asian Heroin (Median %)	Change Southwest Asian Heroin (Mean Yearly %)
Eastern cities								
Atlanta	43.47%	8.70%***	0.00%	ns	11.72%	−3.53%***	4.55%	1.44%*
Baltimore	78.57%	7.31%***	0.00%	ns	3.22%	ns	3.85%	ns
Boston	74.29%	7.93%***	0.00%	ns	0.00%	−1.20%**	0.00%	ns
Chicago	46.01%	7.61%***	0.00%	ns	17.75%	−6.66%***	4.00%	2.00%*
Detroit	64.50%	6.96%***	0.00%	ns	6.47%	−4.02%***	9.29%	2.11%**
Miami	62.50%	7.36%***	0.00%	ns	0.00%	ns	0.00%	ns
New Orleans	69.63%	6.95%**	0.00%	ns	0.00%	ns	0%	ns
New York City	84.78%	7.14%***	0.00%	ns	0.00%	ns	1.43%	ns
Newark	85.15%	5.83%***	0.00%	ns	1.47%	−1.35%*	0.00%	ns
Philadelphia	90.46%	5.17%**	0.00%	ns	0.00%	ns	0.00%	ns
Washington, DC	59.26%	6.08%***	0.00%	ns	5.88%	−3.58%*	6.45%	ns
Western Cities								
Dallas	0.00%	ns	86.96%	ns	0.00%	ns	0.00%	ns
Denver	0.00%	ns	92.24%	3.65%***	0.00%	ns	0.00%	ns
Houston	0.00%	ns	94.33%	ns	0.00%	−0.37%**	0.00%	ns
Los Angeles	0.00%	ns	91.63%	ns	0.00%	ns	0.00%	ns
Phoenix	0.00%	ns	100%	3.98%*	0.00%	ns	0.00%	ns
San Diego	0.00%	ns	98.81%	ns	0.00%	ns	0.00%	ns
San Francisco	0.00%	ns	97.30%	4.28%***	0.00%	ns	0.00%	ns
Seattle	0.00%	ns	95.00%	2.52%*	0.00%	ns	0.00%	ns
St Louis	0.00%	ns	91.67%	ns	0.00%	ns	0.00%	ns

*** p< 0.001

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** $p<0.01$

* $p<0.05$

ns no significant change

Table 3

Price of heroin (cents/mg) between 1993 and 2004

	Means Model Cents (SE)	Quadratic Growth Model Cents (SE)	Geographic Source Model Cents (SE)	Full Model Cents (SE)
Fixed Effects				
Intercept	114.63*** (3.53)	247.94*** (26.72)	248.92*** (29.07)	969.78 (1267.33)
Year		−24.40*** (5.74)	−20.56** (7.09)	−25.62*** (7.49)
Year[2]		0.96*** (0.29)	0.72* (0.33)	0.79* (0.32)
Percent Heroin from South America			−1.19* (0.47)	−1.26* (0.50)
Percent Heroin from South America[2]			0.01** (0.00)	0.01** (0.00)
Percent Heroin from Mexico			−0.13(0.19)	−0.03 (0.19)
Percent Male				−21.64 (19.06)
Percent Adult				9.07 (6.31)
Percent below Poverty Line				0.39 (1.14)
Percent White				0.41 (4.10)
Percent African American				1.78 (3.77)
Percent Hispanic				0.27 (4.39)
Percent Arrested				−6.65 (4.27)
Random Effects				
Within MSA Residual Standard Deviation	48.91*** (4.08)	42.49*** (3.26)	41.68*** (3.39)	41.09*** (3.87)
Between MSA Residual Standard Deviation	60.84*** (3.68)	60.16*** (3.38)	61.95*** (3.36)	68.67*** (10.06)
Interclass Correlation	0.61	0.67	0.69	0.74
Log Likelihood	−1197.93	−1167.95	−1169.45	−1150.32

*** p< 0.001

** p<0.01

* p<0.05

[2] Indicates that the term was squared to form a quadratic function

Table 4

Purity of heroin between 1993 and 2004

	Means Model Purity (SE)	Quadratic Growth Model Purity (SE)	Geographic Source Model Purity (SE)	Full Model Purity (SE)
Fixed Effects				
Intercept	33.72*** (0.67)	25.64*** (4.80)	28.82*** (5.41)	530.47** (201.12)
Year		2.24(1.14)	0.67(1.49)	3.35(1.83)
Year^2		−0.13* (0.06)	−0.08(0.07)	−0.10(0.08)
Percent Heroin from South America			0.16** (0.06)	0.17** (0.06)
Percent Heroin from Mexico			0.03(0.07)	0.03(0.07)
Percent Male				−6.56* (2.85)
Percent Adult				−4.88** (1.67)
Percent below Poverty Line				−0.20(0.24)
Percent White				−0.07(0.49)
Percent African American				−0.55(0.56)
Percent Hispanic				−0.40(0.65)
Percent Arrested				0.80(0.74)
Random Effects				
Within MSA Residual Standard Deviation	9.35*** (0.72)	9.26*** (0.70)	8.95*** (0.60)	8.86*** (0.63)
Between MSA Residual Standard Deviation	16.02*** (0.71)	15.98*** (0.70)	14.08*** (0.94)	13.99*** (1.51)
Interclass Correlation	0.75	0.75	0.71	0.71
Log Likelihood	−839.65	−839.32	−834.05	−824.81

*** p< 0.001

** p<0.01

* p<0.05

^{2} Indicates that the term was squared to form a quadratic function