A Quantitative Analysis of the Retail Market for Illicit Drugs

Manolis Galenianos

Alessandro Gavazza

Motivation:

- Many goods traded in illegal markets:
  - Copyrighted media and software;
  - Guns;
  - Alcohol and Tobacco;
  - Drugs (Heroin, cocaine, etc.).

- Key features of these markets:
  1. Search for trading partners (frictions);
  2. Quality uncertainty/non-contractible quality = Sellers' moral hazard;
  3. Penalties on parties;
  4. $\longrightarrow$ Relationships between buyers and sellers.

This paper (1)

EMPIRICAL QUESTIONS:

- How do illicit markets work?
- What is the effect of sellers' moral hazard?
- What are the effects of policy interventions (enforcement)?
- How buyer-seller relationships mitigate moral hazard and affect enforcement?

CRACK COCAINE:

- Ideal ground for testing:
  - One of largest illicit market (estimated to be 85 billion $);
  - Good data (?).

This paper (2):

- Setup a search model with sellers' moral hazard (build on Galenianos, Pacula and Persico, 2012). Sellers' trade off:
  - Moral hazard (i.e., experience good): "cutting."
  - Long-term relationships between buyers and sellers.

- Estimate it using data on crack cocaine.

- Two counterfactuals (towards understanding legalization):
  1. Observable quality
     Quantify the effects of sellers' moral hazard.
  2. Penalties on buyers and sellers
     Quantify the effects of penalties. U.S. versus Europe.

- To our knowledge, first paper to estimate a search model that investigates microstructure and equilibrium of the market of an illicit good.

Data: Sources

- System to Retrieve Information from Drug Evidence (STRIDE):
  - Purchases of drugs by undercover police or informants.
  - Substance, time, place, price, quantity, purity (when applicable).
  - 1982-2007 but focus on 2001-2003.
- Arrestee Drug Abuse Monitoring (ADAM):
  - Interviews with arrestees on past month's drug use.
  - 10,000 crack-cocaine users in 2001-2003.

Drug Purity: Crack Cocaine 2001-2003

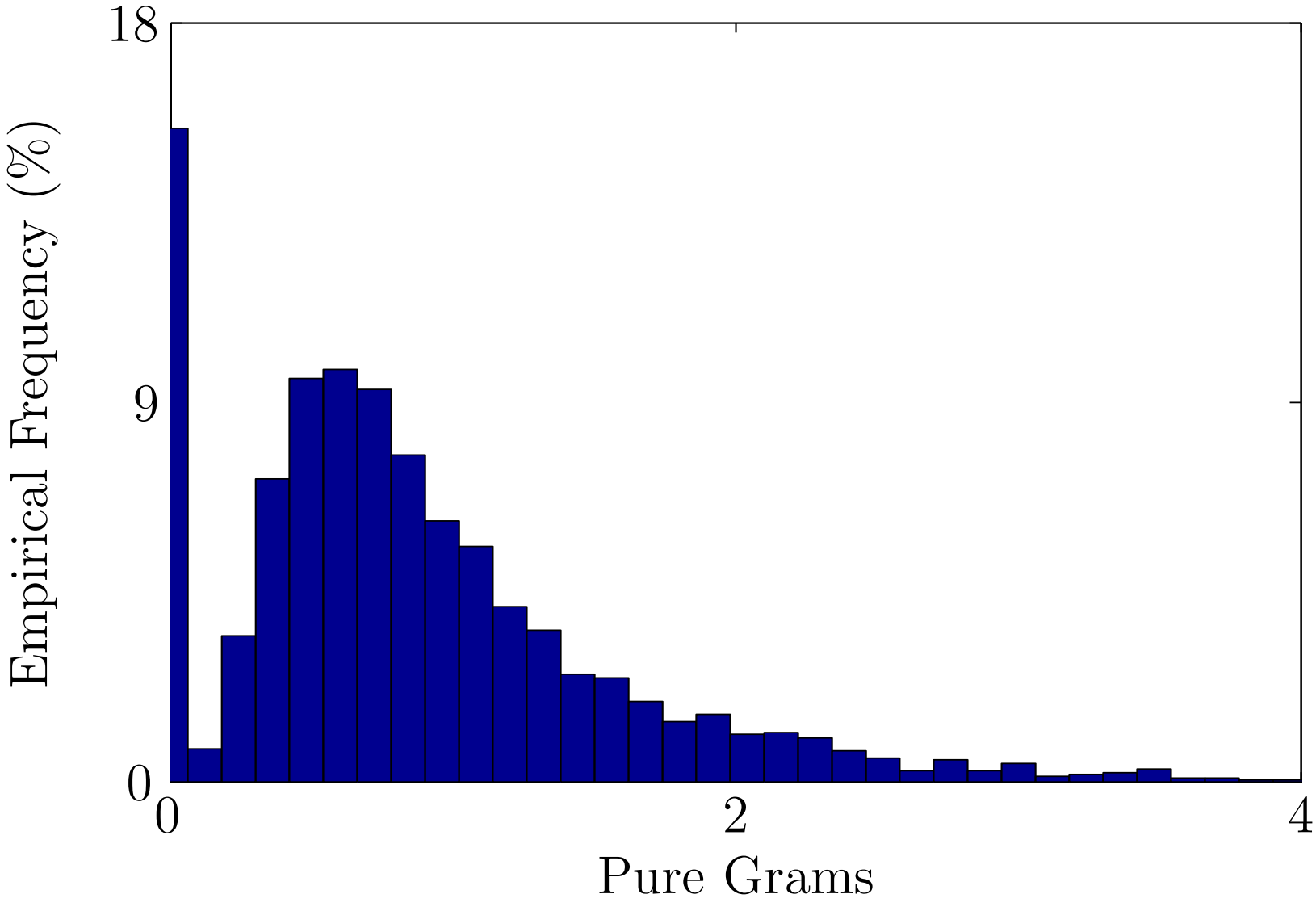

Figure : Histogram of pure grams of crack cocaine per $100.

Data Patterns: Crack Cocaine 2001-2003

Panel A: STRIDE (N=2,321)	Mean	Std. Dev.
Price (2003 dollars)	95.247	48.152
Weight (Grams)	1.120	1.118
Purity (%)	56.313	28.036
Pure Grams	0.658	0.722
Pure Grams per $100	0.622	0.535
Panel B: ADAM (N=64,462)		
Obtained Drug in Last 30 Days (%)	16.899	37.474
Purchased from Regular Dealer (%)	52.481	49.941
Purchases in Last 30 Days, Matched	16.331	11.124
Purchases in Last 30 Days, Unmatched	11.548	10.419
Panel C: Auxiliary Data		
Consuming Crack in NSDUH (%)	0.800	8.908
Arrest Rate (%)	3.700	—

Model

- Continuous time. Infinite Horizon. Discount $r > 0$.

- Buyers:
  - Measure $\bar{B}$. Cost K_B to participate in the market (penalties).
  - Heterogeneous marginal utility of consumption $z \sim M(\cdot)$.
  - Utility of consumption $zq - p$, p fixed (\$100).
  - Maximize inter-temporal discounted utility.

- Sellers:
  - Measure $\bar{S}$. Cost K_S to participate in the market (penalties)
  - Heterogeneous marginal cost of quality $c \sim D(\cdot)$.
  - Choose quality $q(c)$ fixed over time.
  - Maximize steady-state profits.

Meeting, Trading and Matching

- A buyer is either matched with a seller or unmatched.
- "New" meetings:
  - Buyer meets new seller at rate $\alpha_B = \frac{m(B,S)}{B}$.
  - Buyer pays p (exogenous) and receives q.
  - q not observable at purchase; revealed after consumption.
  - Buyer's action: match or not (if already matched, switch).
  - Assumption: same q next time.
- "Repeat" meetings:
  - Matched buyer meets regular seller at rate γ.
  - q is known.
- A match is permanently destroyed at rate δ.

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Buyers' problem

- Given endogenous distribution F, value functions of buyer z :

$$\begin{aligned} r\bar{V}_z &= \alpha_B \left(z \int_0^{\bar{q}} x dF(x) + \int_{R_z}^{\bar{q}} (V_z(x) - \bar{V}_z) dF(x) - p \right), \\ rV_z(q) &= \alpha_B \left(z \int_0^{\bar{q}} x dF(x) + \int_q^{\bar{q}} (V_z(x) - V_z(q)) dF(x) - p \right) + \\ &\quad + \gamma(zq - p) + \delta \left(\bar{V}_z - V_z(q) \right). \end{aligned}$$

- Results:
  - $R_z = \frac{p}{z}$. Higher z has lower reservation value: wants to consume more frequently.
  - Active B buyers with $z \geq z^*$. $B = \bar{B}(1 - M(z^*))$ and distribution $R_z \sim H(\cdot)$ of reservation values.

Sellers' problem

- Given H and F, the steady state profits of type-c seller are:

$$\pi_c(q) = (p - cq)\,(t_N + t_L(q))$$

- $t_N = \frac{\alpha_B B}{S}$ transactions with new buyers, independent of quality.
- $t_L(q) = \gamma l(q) =$ transactions with loyal buyers.
- Steady state number of loyal buyers $l(q)$:
  - Flow out: $\delta + \alpha_B(1 - F(q))$.
  - Flow in: unmatched buyer with $R_z < q +$ matched with $\hat{q} < q$.
  - Flow in = Flow out.

Theoretical results

- An equilibrium exists.
- Necessary conditions for quality distribution:
  - Mass point at $q = 0$.
  - Atomless distribution in $[\underline{q}, \overline{q}]$, $\underline{q} > 0$.
- Given $H(R)$, there is unique c^* such that:
  - $q(c) = 0$ if and only if $c > c^*$.
  - $q(c)$ is strictly decreasing in c for $c < c^*$.
  - Derive ODE that characterizes optimal $q(c)$.

Estimation

- Fix some parameters:
  - Monthly discount rate $r = .01$;
  - Price $p = \$100$;
  - Minimum sellers' profits $K_S = \$1500$ (Levitt and Venkatesh, 2000).

- Buyers' types:
  - fraction λ has $z = 0$;
  - fraction $1 - \lambda$ has $\log z \sim N(\mu_z, \sigma_z) \Rightarrow \log R_z \sim N(\log p - \mu_z, \sigma_z)$.

- Sellers' types: $1/c \sim Pareto \Rightarrow D(c) = \left(\frac{c}{\bar{c}}\right)^{\xi}$.

- Measurement error on drug quality: $q^* = q\epsilon$; $\log \epsilon \sim N(\mu_\epsilon, \sigma_\epsilon)$ with $E(\epsilon) = 1$.

- Measurement error on number of purchases: $\log \nu \sim N(\mu_\nu, \sigma_\nu)$ with $E(\nu) = 1$.

- Selection into ADAM: Buyer z is in ADAM if $\log(z) + \eta \geq 0$; $\eta \sim N(\mu_\eta, \sigma_\eta)$.

Estimation (2)

- Parameters estimated via method of moments:
  - STRIDE: Fraction of ripoffs.
  - STRIDE: First four moments of quality distribution and median.
  - ADAM: Fraction consuming drugs.
  - ADAM: % matched: made last purchase from regular dealer.
  - ADAM: First two moments of past month's consumption (simulated).
- Auxiliary data (Selection into ADAM):
  - NSDUH: Fraction of individuals consuming crack cocaine.
  - FBI: Aggregate number of individuals arrested.

Identification

- Similar to structural search model of labor markets.
- Distributions of sellers' heterogeneity and of the measurement error from quality distribution
- "Zero-probability events" identify measurement errors: gap between $q = 0$ and $\underline{q}$ larger than in the data + heterogeneity of number purchases.
- Rates α, γ and δ, and buyers' heterogeneity from moments of buyers' consumption.
- Fraction λ of individuals that have taste $z = 0$ and unobservable η that determines selection into the ADAM sample from fractions that consume crack cocaine in ADAM and NSDUH and arrest rate.

Estimates

α_B	1.267 [1.217, 1.267]	λ	0.982 [0.980, 0.983]
γ	19.399 [18.868, 20.658]	μ_z	5.118 [5.097, 5.137]
δ	0.731 [0.700, 0.734]	σ_z	0.114 [0.103, 0.125]
K_B	152.639 [112.710, 166.035]	c^*	124.368 [123.597, 128.681]
σ_ϵ	0.526 [0.457, 0.572]	ξ	20.443 [20.443, 31.284]
σ_η	2.803 [2.723, 2.852]	μ_η	-5.237 [−5.329, −5.103]
σ_ν	0.522 [0.479, 0.548]		

- Bootstrapped confidence intervals.

Model Fit

	Data	Model
Fraction of Rip-offs (%)	15.338	15.862
Average Pure Grams per \$100, $\hat{q} > 0$	0.735	0.732
St. Dev. Pure Grams per \$100, $\hat{q} > 0$	0.505	0.416
Median Pure Grams per \$100, $\hat{q} > 0$	0.591	0.635
Skewness Pure Grams per \$100, $\hat{q} > 0$	1.952	1.870
Kurtosis Pure Grams per \$100, $\hat{q} > 0$	8.516	9.521
Obtained Drug in Last 30 Days (%)	16.900	16.899
Last Purchased from Regular Dealer (%)	52.481	52.960
Average No. of Purchases, Matched Buyer	16.331	16.771
Average No. of Purchases, Unmatched Buyer	11.548	10.756
St. Dev. No. of Purchases, Matched Buyer	11.124	11.477
St. Dev. No. of Purchases, Unmatched Buyer	10.419	10.337
Median No. of Purchases, Matched Buyer	15.000	14.000
Median No. of Purchases, Unmatched Buyer	7.000	7.000
Fraction Consuming Drug in NSDUH (%)	0.800	0.800
Arrest Rate (%)	3.776	3.775

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Model Implications: Quality Distributions

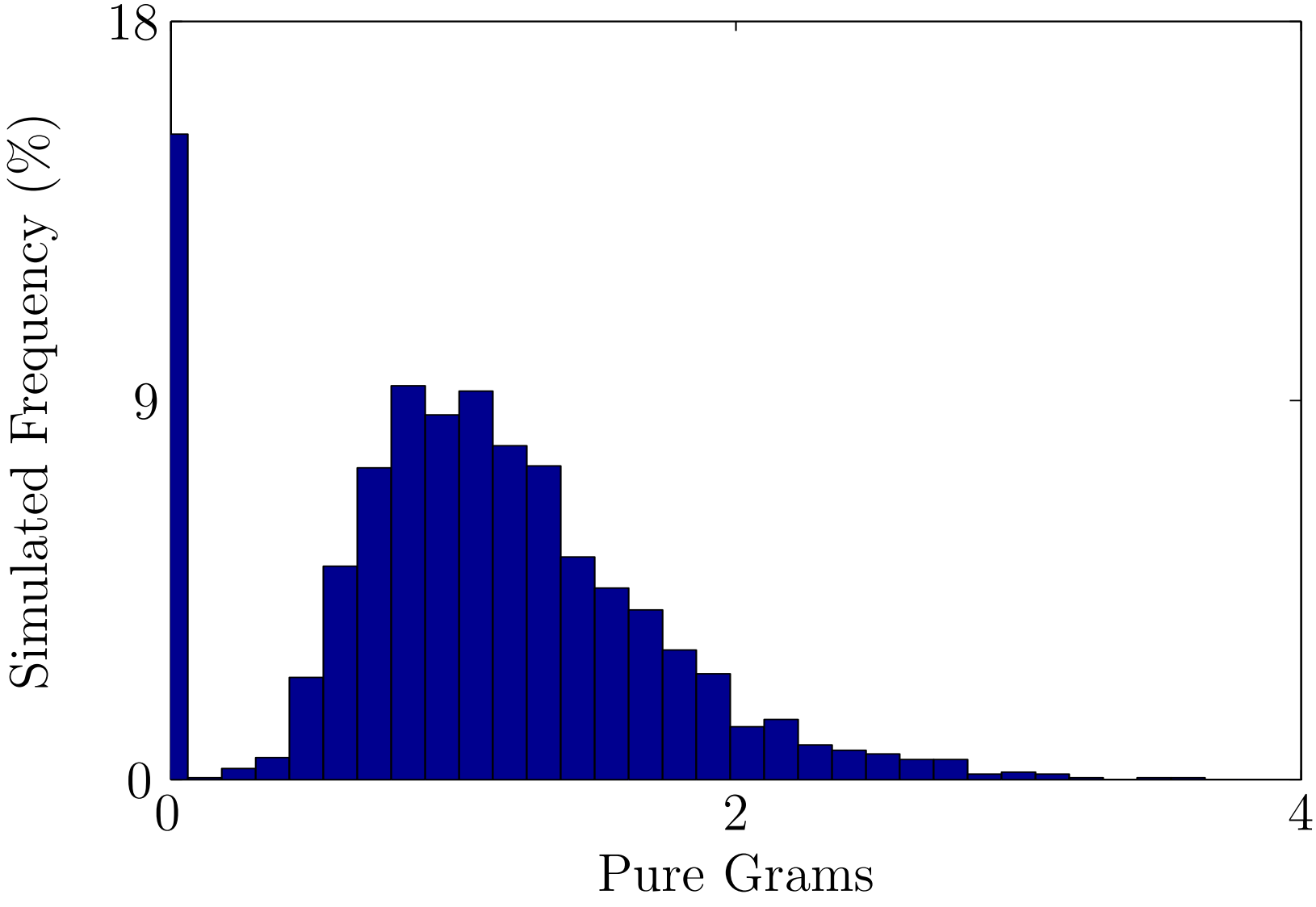

Figure : Histogram of pure grams per $100, simulated data.

Counterfactuals: Observable Quality (1)

- Towards understanding how legal narcotics markets would work.
- Illegality disrupts flow of information about seller's quality.
- Legalization alleviates informational friction.
  - A buyer observes quality before purchasing.
  - Search frictions remain (cannot target the best seller).
    $\Rightarrow$ Quality/Price dispersion but no room for cheating.
    $\Rightarrow$ More search unambiguously improves quality.

Counterfactuals: Observable Quality (2)

- Buyers purchase only if q is high:

$$\begin{aligned} r\bar{V}_z &= \alpha_B(\theta)\int_0^{\overline{q}}\Big(\max\left[z\tilde{q}-p+\max[V_z(\tilde{q})-\bar{V}_z,0],0\right]\Big)dF(\tilde{q}), \\ rV_z(q) &= \alpha_B(\theta)\int_0^{\overline{q}}\Big(\max\left[z\tilde{q}-p+\max[V_z(\tilde{q})-V_z(q),0],0\right]\Big)dF(\tilde{q}) \\ &\quad +\gamma(zq-p)+\delta(\bar{V}_z-V_z(q)) \end{aligned}$$

- Sellers:
  - Flow of first-time buyers depends on q

$$t_N(q)=\alpha_S(\theta)H(q)=\theta\alpha_B(\theta)H(q).$$

  - Therefore, sellers' steady state profits are:

$$\pi_c(q)=\alpha_B(\theta)\theta(p-cq)\Big(H(q)+\frac{\gamma\delta H(q)}{\left(\delta+\alpha_B(\theta)(1-F(q))\right)^2}\Big).$$

Counterfactuals: Observable Quality (3)

	Baseline	Observable q, Partial Eq.	Observable q, General Eq.
Fraction of Rip-offs (%)	15.862	0.000	0.000
	[13.646; 16.812]	[0.000; 0.000]	[0.000; 0.000]
Average Pure Grams per $100	0.616	1.204	1.218
	[0.597; 0.636]	[1.160; 1.261]	[1.166; 1.218]
St. Dev. Pure Grams per $100	0.271	0.184	0.176
	[0.256; 0.279]	[0.156; 0.287]	[0.142; 0.180]
Active Buyers, in Millions	3.431	1.000	1.073
	[3.312; 3.530]	[1.000; 1.000]	[1.042; 1.097]
Active Sellers, in Millions	0.290	1.000	0.822
	[0.271; 0.295]	[1.000; 1.000]	[0.809; 0.844]
Fraction of Matched Buyers (%)	54.040	1.054	1.031
	[52.420; 55.100]	[1.024; 1.109]	[0.985; 1.053]
Avg. No. of Purchases per Month	12.726	1.053	1.013
	[12.228; 13.389]	[1.038; 1.086]	[0.975; 1.028]
Avg. Pure Grams Consumed per Month	9.464	1.082	1.042
	[9.057; 9.990]	[1.063; 1.115]	[1.000; 1.055]

Notes—This table reports market outcomes in the counterfactual cases in which buyers can observe drugs' purity before purchasing.

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Counterfactuals: Penalties

- Penalties affect entry of buyers and sellers.
  - Moral hazard creates counterintuitive interaction between consumption and entry.

- Lower seller penalties may *reduce* drug quality:
  - Higher seller entry, higher α_B and lower match duration.
  - Long-term relationship less attractive relative to rip-off.
  - Increase in rip-offs and reduction in quality.

- U.S. versus Europe: penalties on buyers.

- Potential explanation of interesting trends in the U.S. that seem difficult to reconcile with simple Walrasian market.

Trends in Narcotics: 1) Harsher Penalties

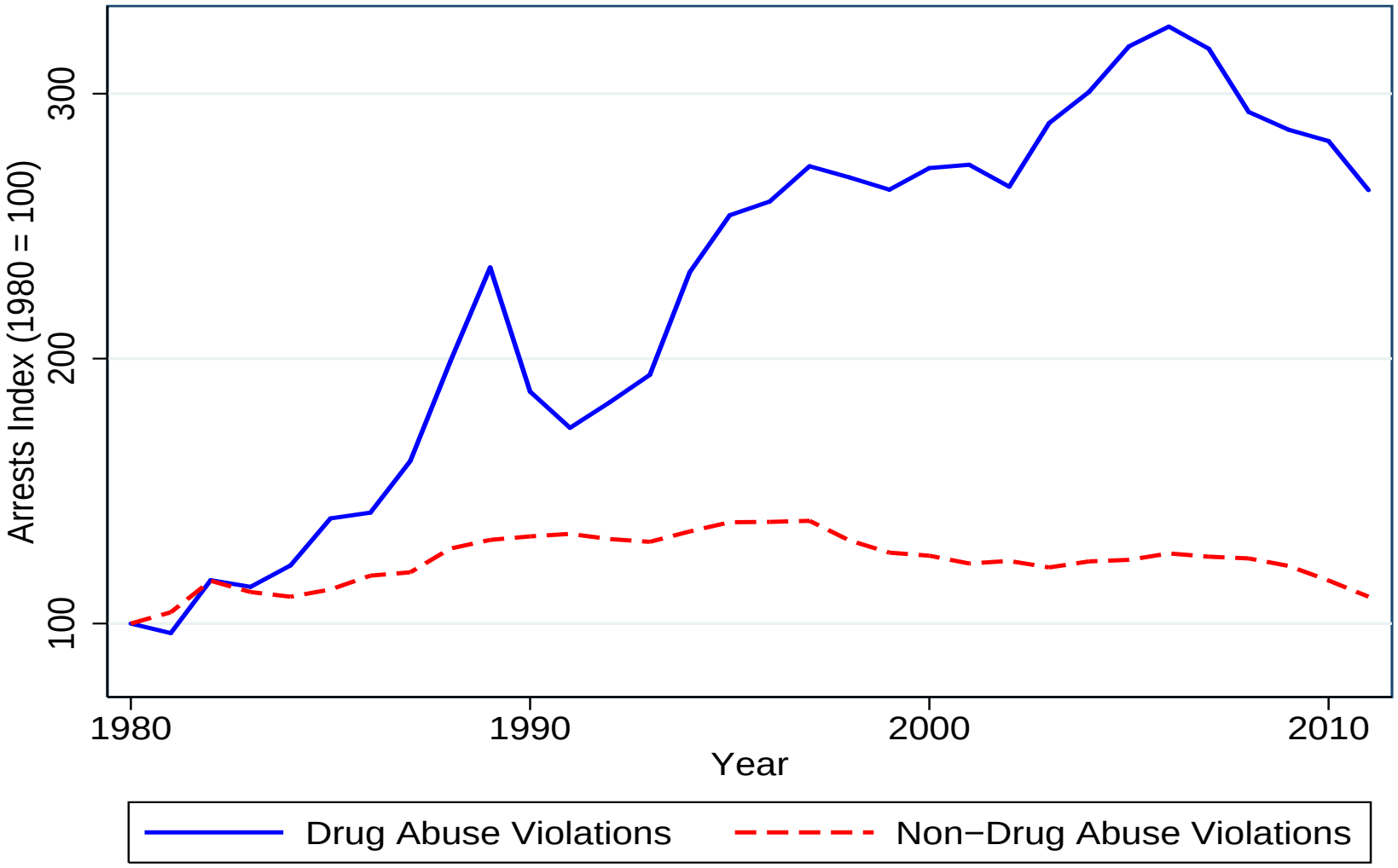

Figure : Number of arrests in the United States in the years 1980-2010, relative to the year 1980.

Trends in Narcotics: 2) Increased Affordability

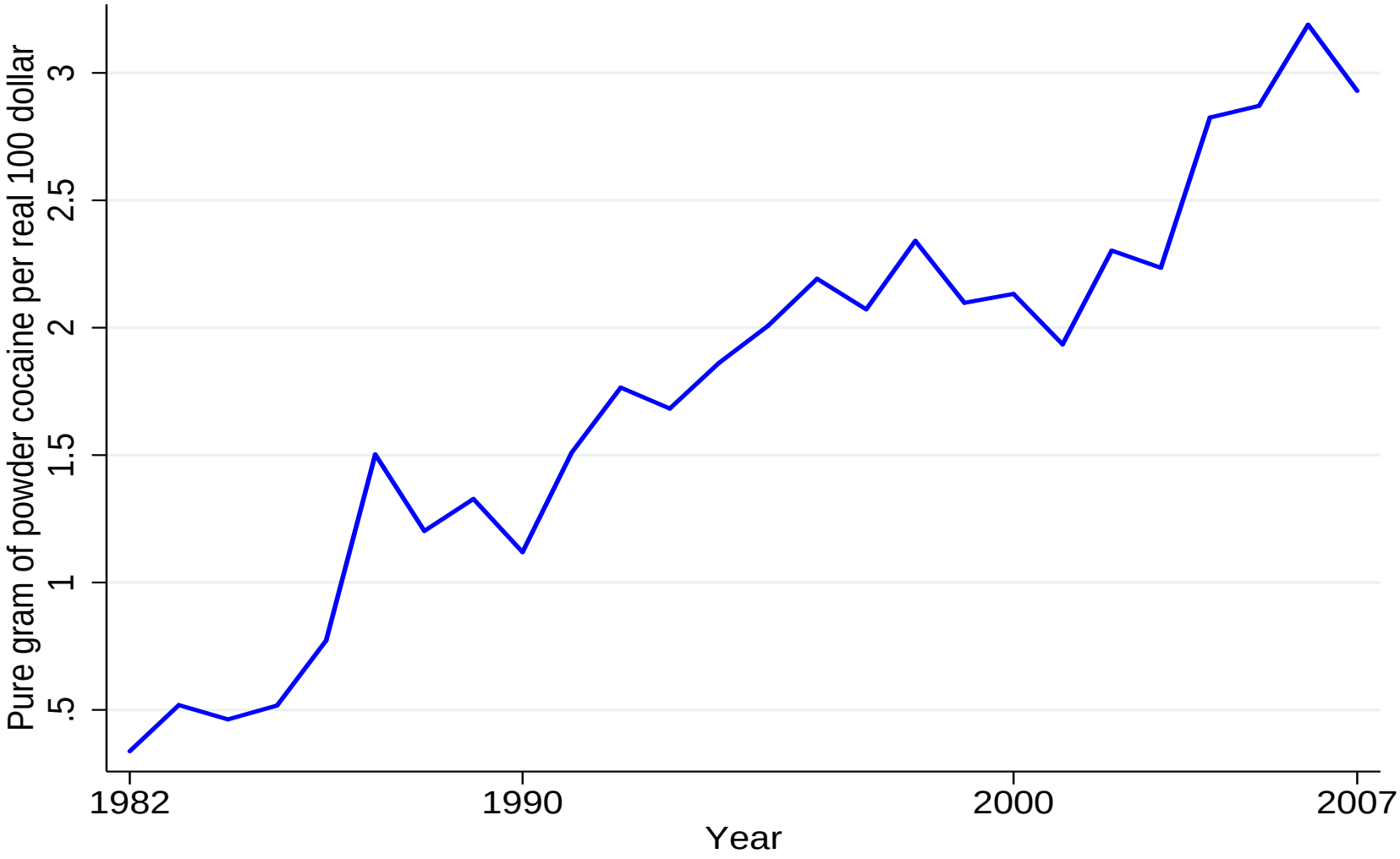

Figure : Average pure gram of powder cocaine per 100 real dollars, retail transactions 1982-2007. The base year is 1983.

Counterfactuals: Lower Penalties

	Baseline	Lower K_S	Lower K_B
Fraction of Rip-offs (%)	15.862	1.678	1.162
	[13.646; 16.812]	[1.596; 1.811]	[1.080; 1.209]
Average Pure Grams per $100	0.616	0.866	0.972
	[0.597; 0.636]	[0.852; 0.877]	[0.950; 0.983]
St. Dev. Pure Grams per $100	0.271	1.195	1.062
	[0.256; 0.279]	[1.172; 1.235]	[1.029; 1.074]
Active Buyers, in Millions	3.431	0.942	1.036
	[3.312; 3.530]	[0.929; 0.957]	[1.008; 1.042]
Active Sellers, in Millions	0.290	1.304	1.036
	[0.271; 0.295]	[1.286; 1.324]	[1.008; 1.042]
Fraction of Matched Buyers (%)	54.040	0.973	0.996
	[52.420; 55.100]	[0.950; 1.032]	[0.955; 1.008]
Average Number of Purchases per Month	12.726	1.028	0.991
	[12.228; 13.389]	[1.000; 1.066]	[0.971; 1.015]
Average Pure Grams Consumed per Month	9.464	1.004	0.988
	[9.057; 9.990]	[0.977; 1.044]	[0.969; 1.016]

Notes—This table reports market outcomes in the counterfactual cases in which buyers' cost K_B and sellers' cost K_S are 15-percent lower than in the baseline case, respectively.

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Conclusions

- Framework useful to empirically analyze markets with quality uncertainty.
- Focus: Moral hazard vs. Long-term relationships between buyers and sellers.
  - Characterization of market in equilibrium.
  - Estimate it using data on crack cocaine.
  - Perform counterfactuals, potential insights into legalization.
- Key limitations:
  - Cross-sectional data.
  - Limited heterogeneity of buyers.
  - Sellers do not discriminate between first-time and repeat customers.