SEX UNDER THE INFLUENCE: THE EFFECT OF ALCOHOL POLICY ON SEXUALLY TRANSMITTED DISEASE RATES IN THE UNITED STATES*

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ABSTRACT

This article presents evidence that sexually transmitted disease (STD) rates are responsive to increases in alcohol taxes and in the drinking age. The presumed relationship is that a more restrictive alcohol policy reduces alcohol consumption, which in turn decreases risky sexual activity. Reduced-form regressions of STD rates on state alcohol taxes for the years 1981–95 (with controls for state and year) indicate that a $1 increase in the per-gallon liquor tax reduces gonorrhea rates by 2.1 percent, and a beer tax increase of $.20 per six-pack reduces gonorrhea rates by 8.9 percent, with similar though more pronounced effects on syphilis rates. Quasi-experimental analysis of alcohol policy changes supports these findings and offers evidence that increases in the drinking age reduce STD rates among youth. The estimated external cost of alcohol-attributable STDs exceeds $556 million annually, a factor that could be considered in determining optimal alcohol policy.

I. Introduction

SEX, drugs, and rock and roll: while evidence for the inclusion of rock and roll in this phrase may be anecdotal, an abundance of research suggests an association between substance use and risky sexual behavior. This correlation between drug use and risky sexual behavior is not limited to illegal drugs, as the use of alcohol is a well-documented predictor of sexual activ-

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While the link between alcohol consumption and sexual activity is well documented, there is little evidence that this link is causal, rather than merely associational.

The issue of alcohol taxation and risky sex has two important policy implications. First, if alcohol does promote risky sexual activity, then alcohol taxation might be an effective tool in reducing the incidence of sexually transmitted diseases (STDs), including HIV/AIDS. Second, the tax levied on alcoholic beverages should in part reflect the external social costs of the alcohol-related STD transmissions, a potential externality of alcohol consumption that has yet to be addressed in the literature. These external costs might be substantial, as the annual direct cost of STDs (including HIV/AIDS) exceeds $12.5 billion in the United States.

In this paper we present strong evidence that gonorrhea and syphilis rates are sensitive to changes in state alcohol taxation. We estimate that a $1 increase in the per-gallon liquor tax reduces gonorrhea rates by 2.1 percent and a beer tax increase of $.20 per six-pack reduces gonorrhea rates by 8.9 percent, with similar though more pronounced effects on syphilis rates. These estimates are based on a fixed-effects model of annual state-level STD incidence rates, which includes the state excise tax on alcohol as an independent variable. We present a variety of robustness checks (including an analysis of changes in the federal alcohol tax as well as quasi-experimental analysis of state-level alcohol tax and drinking-age increases), all of which support the finding that a more restrictive alcohol policy can reduce STD rates.

II. Alcohol Taxes and Consumption

A number of economists have offered evidence that alcohol consumption is sensitive to price. While there is no consensus on the exact magnitude

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1 For reviews of this literature, see Barbara C. Leigh & Ron Stall, Substance Abuse and Risky Sexual Behavior for Exposure to HIV: Issues in Methodology, Interpretation, and Prevention, 48 Am. Psychol. 1035 (1993); and Catherine Donovan & Robert McEwan, A Review of the Literature Examining the Relationship between Alcohol Use and HIV-Related Sexual Risk-Taking in Young People, 90 Addiction 319 (1995).


3 Institute of Medicine, The Hidden Epidemic: Confronting Sexually Transmitted Diseases 59 (Thomas R. Eng & William T. Butler eds. 1997).

of the response to changes in the price of alcohol, there is overwhelming support for the conclusion that an increase in the taxation (price) of alcohol causes a reduction in consumption. Reductions in consumption in response to higher taxes are often discernable, and more restrictive alcohol policies have been associated with decreases in automobile fatalities, liver cirrhosis mortality, and violent crime, including domestic violence.

III. ALCOHOL AND RISKY SEX

Leif Crowe and William George review the controlled laboratory experiments of the effects of alcohol consumption on human responses to sexual stimuli. Their review suggests that the sexual disinhibition associated with alcohol consumption is both pharmacological and psychological. That is, alcohol itself and the socially learned expectancies about alcohol both play a role in sexual responses under the influence of alcohol. Thus, there is a scientific basis for the belief that alcohol consumption might increase the likelihood of participating in a risky sexual encounter.

Barbara Leigh and Ron Stall review the published studies of the relationship between substance use and risky sexual behavior and conclude that there is an association that may or may not be causal. Most of the research of Alcohol-Related Problems (Michael E. Hilton & Gregory Bloss eds. 1993), reviews this literature, which provides estimates of the price elasticity of demand for alcoholic beverages ranging from $0.1$ to more than $-1.0$. Willard Manning, Linda Blumberg, & Lawrence Moulton, The Demand for Alcohol: The Differential Response to Price, 14 J. Health Econ. 123 (1995), suggests that these elasticities may differ between light, moderate, and heavy drinkers. Philip J. Cook & George Tauchen, The Effect of Liquor Taxes on Heavy Drinking, 13 Bell J. Econ. 379 (1982), offers evidence that even heavy drinkers are sensitive to the price of alcohol.


7 Cook, supra note 6; and Cook & Tauchen, supra note 4.


11 Leigh & Stall, supra note 1.
in this area is based on self-reported data. Since a person’s participation in one potentially risky activity (such as drinking) is likely to be correlated with his or her participation in another potentially risky activity (such as unprotected sex), it is difficult to determine from survey data whether this correlation reflects a causal, rather than associational, relationship between alcohol consumption and risky sexual behavior.\(^{12}\)

IV. THE DATA AND THE VARIABLES

The data set covers a 15-year period (1981–95) but differs depending on whether the focus is beer taxes or liquor taxes. The sample contains 50 states and the District of Columbia for the beer tax; for the liquor tax only the 32 states, plus the District of Columbia, that do not have state monopolies in wholesale or retail liquor commerce are used. State drinking-age regulations and excise taxes on alcohol are reported by the Distilled Spirits Council of the United States.\(^{13}\) In instances of a tax increase we used the tax level that was in effect for the majority of the calendar year. The Consumer Price Index is used to transform dollar values to June 1998 price levels. Gonorrhea and syphilis rates (calculated per 100,000 population) are obtained from the Centers for Disease Control and Prevention, which records state surveillance reports of these cases.

Gonorrhea and syphilis are bacterial diseases that (besides mother-to-infant) are almost always transmitted through vaginal, anal, and/or oral sex.\(^{14}\) Gonorrhea and syphilis are the only sexually transmitted diseases for which long-term surveillance data are available. In the United States in 1996 there were a reported 326,000 gonorrhea cases and 53,000 syphilis cases.\(^{15}\) These diseases can have serious consequences, such as infertility or ectopic pregnancy in women. Further, the presence of syphilis or gonorrhea

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\(^{12}\) Recently, Richard A. Scribner, Deborah A. Cohen, & Thomas A. Farley, A Geographic Relation between Alcohol Availability and Gonorrhea Rates, 25 Sexually Transmitted Diseases 544 (1998), found an association between an area’s STD rate and its number of alcohol outlets. Harvey A. Siegal \textit{et al.}, Under the Influence: Risky Sexual Behavior and Substance Abuse among Driving under the Influence Offenders, 26 Sexually Transmitted Diseases 87 (1999), found that among drunk-driving offenders, having sex while high was associated with an increased risk of acquiring an STD.

\(^{13}\) Distilled Spirits Council of the United States (DISCUS), History of Beverage Alcohol Tax Changes, 1996 (1996); and DISCUS, Minimum Purchase Age by State and Beverage, 1933–Present (1996).

\(^{14}\) See Control of Communicable Diseases Manual (Abram S. Benenson ed. 1995); and Institute of Medicine, \textit{supra} note 3.

\(^{15}\) Division of STD Prevention, Sexually Transmitted Disease Surveillance, 1996 (1997). The 53,000 syphilis cases reported include all stages of syphilis. Our analysis focuses on recently acquired syphilis cases (primary and secondary syphilis, of which there were a reported 11,300 cases in 1996) and does not include latent syphilis cases.
can facilitate the transmission of HIV.\textsuperscript{16} Gonorrhea and syphilis have short incubation periods, usually less than 1 week and 4 weeks, respectively.\textsuperscript{17} Thus, a reduction in risky sexual activity would be expected to be followed closely by a reduction in gonorrhea and syphilis rates.

Gonorrhea is our preferred outcome measure for two main reasons. First, gonorrhea is much more common than syphilis. Reported gonorrhea cases in 1996 were sixfold the number of reported syphilis cases. Second, gonorrhea is more evenly distributed across states than syphilis, which is highly concentrated in a few areas. Some states have little or no syphilis incidence, and recently 31 counties (out of the nation’s 3,115) accounted for more than half of the nation’s new syphilis cases.\textsuperscript{18}

V. Methods and Results

A. The Model

We proceed with direct estimation of the response of state-level STD rates to changes in state alcohol taxes. We use fixed-effects estimators to control for the influence of omitted variables.\textsuperscript{19} In particular, dummy variables for each state account for constant cross-state differences in the STD rate, and dummy variables for each year capture national trends in STD rates. Thus the basic model of interest is given as

\[ \log(R_{it}) = \beta_0 + \beta_1 \text{TAX}_{it} + \beta_{2-51} \nu_i + \beta_{52-65} \gamma_t + \epsilon_{it}, \]

where \( R \) is the STD rate, \( i \) indexes states and \( t \) indexes years, \( \text{TAX} \) is either the per-gallon liquor tax or the per-gallon beer tax in 1998 dollars, \( \nu \) is the state dummy variable, and \( \gamma \) is the year dummy variable. State-specific time-varying factors are reflected in the \( \epsilon \) term. The estimation of this simple model is complicated by the dynamic structure of the dependent variable. In particular we find severe autocorrelation. This persistence is to be expected as the incidence rate of a communicable disease depends in part on the prevalence rate of that disease. Also, the persistence could be attributable to unobservable factors or differences in state reporting practices. To

\textsuperscript{16} For example, see Judith N. Wasserheit, Epidemiological Synergy: Interrelationships between Human Immunodeficiency Virus Infection and Other Sexually Transmitted Diseases, 19 Sexually Transmitted Diseases 61 (1992); and William J. Kassler \textit{et al.}, Seroconversion among Patients Attending Sexually Transmitted Disease Clinics, 8 AIDS 351 (1994).

\textsuperscript{17} Benenson ed., \textit{supra} note 14.


\textsuperscript{19} Our general approach is based on that of Cook & Tauchen, \textit{supra} note 4, and Michael J. Moore, Death and Tobacco Taxes, 27 Rand J. Econ. 415 (1996).
further control for these dynamic differences across states, we examine the richer specification of including the previous year’s STD rate as a covariate:

\[
\log(R_{it}) = \beta_0 + \beta_1 \log(R_{i,t-1}) + \beta_2 \text{TAX}_{it} + \beta_{3,t-2} V_i + \beta_{3,t-6} Y_i + \epsilon_{it}.
\]  

(2)

Finally, we will modify equation (2) to allow for a large number of robustness checks.

B. Estimation

We use ordinary least squares to estimate equations (1) and (2), using both gonorrhea and syphilis rates as dependent variables. The alcohol tax coefficient is negative and significant for both equations, regardless of whether the dependent variable is gonorrhea or syphilis and whether the tax variable is liquor or beer (Table 1). The estimates based on equation (1), which do not include the lagged dependent variable, might be considered unreliable owing to the presence of statistically significant serial correlation (shown on the row labeled “residual test”) as indicated by the Breusch-Godfrey chi-square test for residual autocorrelation.20

The lagged dependent variable is included in equation (2) to model the dynamic structure of STD rates and to control for the serial correlation.21 All of the estimations of equation (2) easily pass the Breusch-Godfrey test, which is robust in the presence of lagged dependent variables. Further, we calculate the standard errors using the White22 correction for heteroskedastic robust standard errors. Allowing for the Newey-West23 correction for standard errors robust to heteroskedasticity and autocorrelation does not change the results.

This result, that higher alcohol taxes are associated with lower STD rates, also holds for each gender (Table 2). The gonorrhea rate for women is less responsive than the male rate to alcohol tax changes, while for syphilis the pattern is reversed.

These alcohol tax parameter estimates can be interpreted as the approxi-

20 See William H. Greene, Econometric Analysis 426–29 (2d ed. 1993). The 5 percent critical value for rejecting no autocorrelation is 3.84.

21 Results from the standard generalized least squares (GLS) correction to model 1 are qualitatively consistent with the results presented for model 2, but the lagged dependent model appears superior on the basis of goodness of fit, and the GLS correction does not eliminate the serial correlation problem.

22 Hal White, A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity, 48 Econometrica 817 (1980).

### TABLE 1
STD Rates and Alcohol Taxes, 1981–95, Fixed-Effects Estimates of Equations (1) and (2)

<table>
<thead>
<tr>
<th></th>
<th>Gonorrhea Rate (log)</th>
<th></th>
<th>Syphilis Rate (log)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Liquor tax</td>
<td>–.055** (.019)</td>
<td>–.021+ (.012)</td>
<td>–.102* (.059)</td>
<td>–.099** (.034)</td>
</tr>
<tr>
<td>Beer tax</td>
<td>–.979** (.175)</td>
<td>–.254* (.102)</td>
<td>–1.75** (.397)</td>
<td>–.933** (.293)</td>
</tr>
<tr>
<td>Lagged STD rate (log)</td>
<td>.765** (.053)</td>
<td>.829** (.029)</td>
<td>.766** (.038)</td>
<td>.715** (.035)</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>424</td>
<td>383</td>
<td>675</td>
<td>615</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>.914 (.968)</td>
<td>.905 (.976)</td>
<td>.754 (.885)</td>
<td>.655 (.780)</td>
</tr>
<tr>
<td>Sum of errors</td>
<td>29.8</td>
<td>75.7</td>
<td>17.7</td>
<td>293.5</td>
</tr>
<tr>
<td>Residual test</td>
<td>251</td>
<td>471</td>
<td>.302</td>
<td>292</td>
</tr>
</tbody>
</table>

**Note.** The dependent variables are gonorrhea rate (log) and syphilis rate (log). The column headings 1 and 2 denote estimations of equations (1) and (2). Covariates include the alcohol tax measure, state and year dummy variables, and (in equation (2)) the lagged STD rate. Gonorrhea rates include all age groups; syphilis rates include ages 25 and higher. The residual test is the Breusch-Godfrey chi-square test for residual autocorrelation; the 5% critical value for rejecting no autocorrelation is 3.84.

* Statistically significant, .10 level, two-tailed test.
* Statistically significant, .05 level, two-tailed test.
** Statistically significant, .01 level, two-tailed test.
## TABLE 2

**Fixed-Effects Estimates of Equation (2) by Gender**

<table>
<thead>
<tr>
<th></th>
<th>Gonorrhea Rate (log)</th>
<th>Syphilis Rate (log)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Liquor tax</td>
<td>−.033**</td>
<td>−.006</td>
</tr>
<tr>
<td></td>
<td>(.012)</td>
<td></td>
</tr>
<tr>
<td>Beer tax</td>
<td>−.344**</td>
<td>−.167</td>
</tr>
<tr>
<td></td>
<td>(.113)</td>
<td>(.105)</td>
</tr>
<tr>
<td>Lagged STD rate (log)</td>
<td>.761**</td>
<td>.816**</td>
</tr>
<tr>
<td></td>
<td>(.049)</td>
<td>(.029)</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>383</td>
<td>615</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>.969</td>
<td>.976</td>
</tr>
<tr>
<td>Sum of errors$^2$</td>
<td>10.7</td>
<td>19.7</td>
</tr>
<tr>
<td>Residual test</td>
<td>.000</td>
<td>2.72</td>
</tr>
</tbody>
</table>

Note: The dependent variables are gonorrhea rate (log) and syphilis rate (log). Covariates include the alcohol tax measure, state and year dummy variables, and the lagged STD rate. Gonorrhea rates include all age groups; syphilis rates include ages 25 and higher. The residual test is the Breusch-Godfrey chi-square test for residual autocorrelation; the 5% critical value for rejecting no autocorrelation is 3.84.

** Statistically significant, .01 level, two-tailed test.
mate percentage change in the STD rate associated with a $1 (June 1998 prices) increase in the excise tax on a gallon of liquor or a gallon of beer. Using equation (2) as our preferred model, this implies that a $1 increase in the per-gallon liquor tax (beer tax) is estimated to decrease gonorrhea rates by 2.1 percent (25.4 percent) and syphilis rates by 9.9 percent (93.3 percent). These estimated effect of a beer tax increase might be interpreted more reliably for smaller changes in the beer tax. A $.35 increase in the tax per gallon of beer (which represents roughly $.20 per six-pack) would be expected to reduce gonorrhea rates by 8.9 percent and syphilis rates by 32.7 percent. We note again that we have more confidence in the estimates based on gonorrhea rates because gonorrhea is more common and more evenly distributed across states than syphilis. In the diagnostic tests and robustness checks that follow, we focus primarily on equation (2) with gonorrhea rates as the outcome measure.

VI. Diagnostic Tests and Robustness Checks

A. National Trends

The largest change in the excise tax on beer during the period of analysis was a doubling of the federal excise tax on beer that took effect on January 1, 1991. It is an important validation of our hypothesis that this major national tax increase be associated with a corresponding nationwide reduction in STD rates in 1991 as compared to 1990. The impact of such a change, of course, is not picked up by our alcohol tax coefficient, since the tax increase would be common across states. However, the change should appear as a discontinuity in the year dummy variable estimates in our model. We therefore investigate the movement in the estimated year fixed effects (Figure 1). The coefficients are estimated relative to 1982, which is the omitted year, and by construction these estimates control for state-specific effects as well as for the lag in the STD rate and a state-specific trend in the STD rate (a specification addressed in more detail later) to isolate the year effect. The line for the alcohol tax increase is drawn just to the right of 1990, as STD cases after 1990 occurred when the higher tax rate was in effect. As shown in the figure, STD rates fell sharply from their 1988–90 levels in 1991 and 1992. The estimates imply that nationwide gonorrhea rates (controlling for state effects) fell by about 10 percent between 1990 and 1991.

24 This federal beer tax increase (from $9 to $18 per 31-gallon barrel in nominal terms) was accompanied by an increase in the federal liquor excise tax from $12.50 to $13.50 per proof gallon.

25 We thank an anonymous referee for suggesting this particular robustness check.
Figure 1.—Year fixed-effects estimates before and after federal alcohol excise tax increase.

(as the alcohol tax was implemented) and almost 30 percent between 1990 and 1992, and these differences are significant at much less than the .01 level. The reduction in syphilis rates is even more striking as the estimated nationwide rate fell almost 30 percent between 1990 and 1991 and close to 40 percent between 1990 and 1992. While this in no way proves that the increase in federal tax had an effect on national STD rates, the findings are at least consistent with the assertion that alcohol tax increases can reduce STD rates.

B. Lagged Effects

The results presented so far might understate the true effect of alcohol taxation on STD rates since our model ignores the effect of alcohol taxation in previous years on current alcohol consumption. We estimate equation (2) using lagged values of the alcohol tax to allow for the possibility that alcohol taxation might influence alcohol consumption beyond a time horizon of a single year. Including lags of the beer tax actually leads to a stronger result, while including lags of the liquor tax leads to results that are only mar-

26 These estimated percentage changes are calculated from the coefficients of the year dummy variables according to the expression $e^\theta - 1$, where $\theta$ represents the year dummy coefficient, as described in Peter Kennedy, A Guide to Econometrics (4th ed. 1998).
alcohol policy and STD rates

originally significant (Table 3). This difference might be attributable to the different samples (recall that the regressions with the liquor tax exclude states with state liquor monopolies) or to the fact that beer is the choice of alcohol among youth, who are more at risk of gonorrhea and syphilis than older adults. The combined estimated effect of alcohol taxes on STD rates when the model includes the current alcohol tax and two lags of the tax is larger than the alcohol tax coefficient of equation (2) when only the current tax level is included as a covariate: \(-.451\) versus \(-.254\) for beer and \(-.027\) versus \(-.021\) for liquor.

C. Exogeneity

The robustness of our findings is supported by the fact that the lagged tax rate is often significant in predicting STD rates as detailed above. We also conduct reverse causality tests\(^{27}\) to establish the exogeneity of the alcohol tax, since our identification strategy requires that decisions to change alcohol policy are not based on STD rates. We find that in our model, the previous year’s STD rate has no significant effect on the current tax rate (Table 4). In other words, this year’s alcohol tax affects next year’s STD rate (as shown in Table 3), but this year’s STD rate does not affect next year’s alcohol tax rate (Table 4), which supports our assumption that the alcohol tax rate is exogenous.

D. State-Level Trends

The alcohol tax rate (through inflation) and the STD rate (perhaps reflecting improvements in STD control programs or an increase in awareness of the risks of STDs, including HIV/AIDS) both exhibited downward movement, in general, over the time period of our analysis. Thus, it is possible that there is some positive feedback effect between STD rates and alcohol taxes due to the general reduction over time in STD rates and alcohol taxes. These trends over time may dampen our observed effect of alcohol taxes on STD rates, and our results may actually be stronger than reported. To control for these trends (and other unobserved factors that might affect state-level trends in STD rates) we modified equation (2) to include state-specific trends.\(^{28}\) Adding the state-specific time trends improves the good-


\(^{28}\) Our incorporation of state-specific trends follows Leora Friedberg, Did Unilateral Divorce Raise Divorce Rates? 88 Am. Econ. Rev. 608 (1998); and Louis S. Jacobson, Robert J. LaLande, & Daniel G. Sullivan, Earnings Losses of Displaced Workers, 83 Am. Econ. Rev. 685 (1993). We create a variable TREND that is one in year 1, two in year 2, and so on. The trend variable is interacted with the state dummy variables so that each state has its own coefficient for TREND. The squared values of TREND are not jointly significant and are not included in the model or results presented in Table 5.
### TABLE 3
**Fixed-Effects Estimates of Equation (2) (Lagged Tax Levels Included as Covariates)**

<table>
<thead>
<tr>
<th></th>
<th>Beer Tax</th>
<th>Liquor Tax</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a)</td>
<td>(b)</td>
</tr>
<tr>
<td></td>
<td>(c)</td>
<td>(d)</td>
</tr>
<tr>
<td></td>
<td>(a)</td>
<td>(b)</td>
</tr>
<tr>
<td></td>
<td>(c)</td>
<td>(d)</td>
</tr>
<tr>
<td><strong>Tax</strong></td>
<td>$-0.254^*$</td>
<td>$-0.36$</td>
</tr>
<tr>
<td></td>
<td>(.102)</td>
<td>(.228)</td>
</tr>
<tr>
<td><strong>Tax, 1-year lag</strong></td>
<td>$-0.274^{**}$</td>
<td>$-0.177$</td>
</tr>
<tr>
<td></td>
<td>(.101)</td>
<td>(.259)</td>
</tr>
<tr>
<td><strong>Tax, 2-year lag</strong></td>
<td>$-0.407^{**}$</td>
<td>$-0.238$</td>
</tr>
<tr>
<td></td>
<td>(.111)</td>
<td>(.201)</td>
</tr>
<tr>
<td><strong>Lagged gonorrhea rate (log)</strong></td>
<td>$.829^{**}$</td>
<td>$.817^{**}$</td>
</tr>
<tr>
<td></td>
<td>(.029)</td>
<td>(.034)</td>
</tr>
<tr>
<td><strong>Degrees of freedom</strong></td>
<td>615</td>
<td>563</td>
</tr>
<tr>
<td><strong>Sum of errors</strong></td>
<td>17.69</td>
<td>16.22</td>
</tr>
<tr>
<td><strong>Residual test</strong></td>
<td>.302</td>
<td>.352</td>
</tr>
<tr>
<td><strong>Summary of combined tax coefficients</strong></td>
<td>$-0.451^{**}$</td>
<td>$-0.027^*$</td>
</tr>
<tr>
<td></td>
<td>(.119)</td>
<td>(.016)</td>
</tr>
</tbody>
</table>

**Note.**—The dependent variable is gonorrhea rate (log). Covariates include the alcohol tax measure (with a lag of 0, 1, or 2 years), state and year dummy variables, and the lagged gonorrhea rate. Gonorrhea rates include all age groups. The residual test is the Breusch-Godfrey chi-square test for residual autocorrelation; the 5% critical value for rejecting no autocorrelation is 3.84.

* Statistically significant, .10 level, two-tailed test.
* Statistically significant, .05 level, two-tailed test.
** Statistically significant, .01 level, two-tailed test.
TABLE 4
Reverse Causality Equation Estimates

<table>
<thead>
<tr>
<th></th>
<th>Beer Tax</th>
<th>Liquor Tax</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gonorrhea</td>
<td>Syphilis</td>
</tr>
<tr>
<td>Lagged gonorrhea rate (log)</td>
<td>.002 (.002)</td>
<td>.084 (.067)</td>
</tr>
<tr>
<td>Lagged syphilis rate (log)</td>
<td>.001 (.001)</td>
<td>.025 (.029)</td>
</tr>
<tr>
<td>Lagged tax</td>
<td>.837** (.041)</td>
<td>.856** (.042)</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>623</td>
<td>609</td>
</tr>
</tbody>
</table>

Note.—The model estimated is a modified version of equation (2) in which the alcohol tax (not the STD rate) is the dependent variable. Covariates include the lagged alcohol tax, the lagged STD rate, and state and year dummy variables. Gonorrhea rates include all age groups; syphilis rates include ages 25 and higher.

** Statistically significant, .01 level, two-tailed test.

TABLE 5
Estimates of Equation (2) with State Trend Variables Included as Covariates for Three Alternative Alcohol Tax Measures

<table>
<thead>
<tr>
<th></th>
<th>Liquor Tax</th>
<th>Beer Tax</th>
<th>Beer Tax, Lagged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol tax</td>
<td>-.035* (.014)</td>
<td>-.302* (.172)</td>
<td>-.410* (.197)</td>
</tr>
<tr>
<td>Lagged STD rate (log)</td>
<td>.497*** (.065)</td>
<td>.512** (.054)</td>
<td>.504*** (.056)</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>351</td>
<td>565</td>
<td>564</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>.972</td>
<td>.979</td>
<td>.979</td>
</tr>
<tr>
<td>Sum of errors²</td>
<td>7.69</td>
<td>14.27</td>
<td>14.19</td>
</tr>
<tr>
<td>Residual test</td>
<td>.698</td>
<td>2.160</td>
<td>2.26</td>
</tr>
</tbody>
</table>

Note.—The dependent variable is gonorrhea rate (log). Covariates include the alcohol tax measure, state and year dummy variables, the lagged STD rate, and a time trend variable for each state.

* Statistically significant, .10 level, two-tailed test.

** Statistically significant, .01 level, two-tailed test.

ness of fit, and the trends are jointly significant. With these state trend variables included, we again find an association between higher alcohol taxes and reduced gonorrhea rates, as shown by the negative estimated alcohol tax coefficients (Table 5). The magnitude of the estimated effect of alcohol taxation is greater (perhaps because including the state-specific trends might control for the positive feedback described above), although the statistical significance of the tax coefficients is reduced. In some specifications (such
as one examining the effect of beer taxes on STD rates by gender), the inclusion of the state trend variables eliminates the statistical significance of the tax coefficients, perhaps because the additional covariates reduce the estimation precision.

E. Cross-Sectional Heterogeneity

The assumption that the alcohol tax coefficient is the same for each state is likely unrealistic. It is interesting to consider how the responsiveness of STD rates to alcohol taxation may vary across states. We hypothesize that the cross-sectional sensitivity could potentially be a function of the state’s STD prevalence and/or the prevalence of alcohol consumption in the state and therefore split our sample in half along the median of each measure. Dividing the data in this manner and estimating equation (2) for each subsample does not change the qualitative response of gonorrhea rates to beer taxes. However, we find that the magnitude of the response to alcohol tax is significantly greater in states with higher incidence rates, which is reasonable given that STDs are communicable diseases, and in higher incidence states there is greater potential for an observable impact of alcohol policy on STD rates. The alcohol tax coefficient does not differ significantly between states with high and low per capita beer consumption.

F. Robustness to Estimation and Specification

Because estimation of dynamic fixed-effects models is potentially biased, we check the robustness of our results using a number of alternative approaches. For example, we compute random-effects estimation, and the findings are very similar to those already reported and again support a statistically significant negative alcohol tax coefficient. Although the random-effects estimates are qualitatively similar to the fixed-effects estimates, it seems clear that we should prefer a fixed-effects model because the constant differences between states are likely nonrandom. As an additional test of

29 We use per capita alcohol consumption in 1995 to divide the sample. We note that the correlation between a state’s per capita alcohol consumption and STD incidence is not statistically significant for 1995.

30 See Stephen Nickell, Biases in Dynamic Models with Fixed Effects, 49 Econometrica 1417 (1981); Cheng Hsiao, Analysis of Panel Data, ch. 4 (1986); and Badi H. Baltagi, Econometric Analysis of Panel Data, ch. 8 (1995). The asymptotic bias depends on if T (the number of years in the panel data) approaches infinity, while the finite-sample bias likely depends on the size of N (the number of states in the panel data) and T. In our setting it makes sense to consider N fixed and T approaching infinity, as we can add time periods but not states, so asymptotically the bias will tend to zero.

31 This is a good check against the impact of the size of the dimension N relative to T since the random effects are drawn from a distribution with a single estimated parameter.
sensitivity, we reduce the number of state dummy variables by combining states by region, and this combination leaves the results intact. Allowing the state fixed effects to vary over time by including two dummy variables per state (one for the first half of the sample time period and another for the latter half) preserves the qualitative findings, as does deleting the first 4 years of data. This analysis indicates that the potential bias in the dynamic fixed-effects estimation may not be a major concern.

We also considered other independent variables that we thought might influence the STD rate. For instance, including per capita income in the regression did not change the results, and its coefficient was not significant. Additional demographic variables, which tend to be fairly constant or changing slowly over time, should also be picked up by the state-specific dummies. As discussed below, including a measure of changes in the minimum legal drinking age did not alter the results and was not significant, except for certain subsamples of the data.

G. Examination of Drinking-Age Increases

If alcohol taxes affect STD rates, it would also be expected that the minimum legal drinking age (MLDA) might affect STD rates, at least among youth. When equation (2) included a dummy variable to represent the instance of an increase in the MLDA, this MLDA dummy was not significant in the analysis. It is not surprising that drinking-age changes (which affect only a small subset of the population) do not appear to influence overall STD rates. To focus on the effect of increasing the MLDA we examine the gonorrhea rate among youth 15–19 years of age. The results of equation (2) augmented by the MLDA dummy variable are presented in Table 6.

32 This suggests that the estimation is not overly sensitive to the size of $T$.
33 We also note that Nickell’s (supra note 30) analytical results (his equation (26)) suggest that any bias will likely be small in this instance, and Hsiao (supra note 30, at 78) suggests that our tax coefficient would be biased downward. Furthermore, Badi H. Baltagi & James Griffin, Pooled Estimators versus Their Heterogenous Counterparts in the Context of Dynamic Demand for Gasoline, 77 J. Econometrics 303 (1997), finds that standard least-squares fixed-effects models with lagged dependent variables perform well in Monte Carlo exercises when compared to alternative instrumental variable methods.
34 Other more severe specification changes can dramatically alter the results, but most of these specifications tend to preserve the finding of a significant role of alcohol taxes on STD rates, at least for male STD rates. For example, we found similar results when including the square of the tax rate in the model to allow for a diminishing marginal effect, when allowing the tax coefficient to vary by state, and when using the log of the tax rate as well as when not using the log of STD rate. In differencing the data to eliminate state fixed effects, some first-difference specifications support a significant relation between the tax and STD rate, although some do not.
35 We note that the estimated beer tax coefficients are stronger for young adults than for the general population, which is reasonable given that young adults have higher rates of STDs than the overall population.
The MLDA changes are significant and negative, which suggests that increases in the drinking age were followed by reductions in the gonorrhea rate. However, repeating the analysis for the 20- to 24-year-old group provides an important null finding: that MLDA changes do not influence STD rates for older age groups. Since most of the 20- to 24-year-old group is age 21 or older and not affected by the drinking age, it is not surprising that the drinking-age increases showed no association with the gonorrhea rates among this age group. If there were confounding effects on STD rates in the states that had increases in the drinking age, such effects would be expected to have an effect on both age groups. The results, however, suggest that drinking-age increases influenced only the age group subject to the drinking-age regulations.

VII. Quasi-Experimental Analysis of Alcohol Tax and Drinking-Age Increases

As a supplemental approach to validate the fixed-effects model, we conduct quasi-experimental analysis of beer tax increases, liquor tax increases,

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**Note:** The dependent variable is gonorrhea rate (log). Covariates include the beer tax measure, state and year dummy variables, the lagged gonorrhea rate (log), and a drinking-age dummy variable (which is set to one for a state in a given year if there was any increase in the state’s drinking age in that year, zero otherwise).

* Statistically significant, .10 level, two-tailed test.
** Statistically significant, .05 level, two-tailed test.
*** Statistically significant, .01 level, two-tailed test.

---

<table>
<thead>
<tr>
<th>Ages 15–19</th>
<th>Ages 20–24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beer tax</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-.376†</td>
</tr>
<tr>
<td>Male</td>
<td>-.729**</td>
</tr>
<tr>
<td>Female</td>
<td>-.181</td>
</tr>
<tr>
<td>(Beer tax)</td>
<td>(.194)</td>
</tr>
<tr>
<td></td>
<td>(.230)</td>
</tr>
<tr>
<td>Drinking age (dummy variable)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-.069**</td>
</tr>
<tr>
<td>Male</td>
<td>-.075*</td>
</tr>
<tr>
<td>Female</td>
<td>-.079*</td>
</tr>
<tr>
<td>(Drinking age)</td>
<td>(.027)</td>
</tr>
<tr>
<td></td>
<td>(.033)</td>
</tr>
</tbody>
</table>

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36 Ideally, we would like to examine the effect of drinking-age increases on those in the 15- to 21-year-old group, but we are limited by the age groupings designated in the national STD surveillance records.
and increases in the legal minimum drinking age. These alcohol policy changes provide natural experiments concerning the effect of alcohol policy on STD rates. We will describe the methodology of the beer tax increase experiments, as our analysis of liquor tax increases and drinking-age changes follows the same approach.

State beer tax increases are assumed to be exogenous, as it is unlikely that STD rates are a factor in the decision to raise taxes. The experiment associated with each tax increase is a comparison between the proportional change in the gonorrhea rate (from the year before to the year after the tax increase) for the experiment state and the median value of the proportional changes in the gonorrhea rates for the control states.

We calculate the proportional change in the gonorrhea rate for state $i$ in year $t$ according to the equation

$$
\Delta_i^t = \frac{R_{i,t+1} - R_{i,t-1}}{R_{i,t-1}},
$$

where $R_{i,t}$ is the gonorrhea rate for state $i$ in year $t$.

A state is considered an experiment state in year $t$ if it increased its beer tax in year $t$ and did not decrease the tax in the following year. A state is considered a control state in year $t$ if its nominal beer tax is constant over the 3-year period from year $t - 1$ to year $t + 1$. As the data run from 1981 to 1995, proportional changes in the gonorrhea rate could be calculated for tax changes in the years 1982–94. There were 39 increases in state excise beer taxes over this period, and the average beer tax increase (in 1998 dollars) was $.09 per gallon, with a median increase of $.07. Two of these beer tax increases were followed by a decrease in the tax in the following year, and one of these increases took place in states for which STD incidence data were missing, leaving 36 tax increases in the analysis. For each instance of a beer tax increase in year $t$, the proportional change in gonorrhea rates is calculated for the experiment state (or states) and then compared against the median value of the proportional changes in year $t$ for the control states. If beer tax increases have no effect on STD rates, then the proportional change in gonorrhea rates in an experiment state is assumed to have a 50/50 chance of being below the median proportional change among

the control states. In a majority of the instances of a tax increase, however, the proportional change in the gonorrhea rate for the experiment state was lower than the median proportional change among the control states (Table 7). In the 15- to 19-year-old group, 24 of the 36 (66.7 percent) experiment states had a proportional decrease in gonorrhea rates relative to the median proportional change among the control states ($p = .065$). In the 20- to 24-year-old group, 26 (72 percent) of the experiments resulted in a relative proportional decrease in gonorrhea rates ($p = .011$).

For males in both age groups the results are even more striking. For males aged 15–19, 28 of the 36 (78 percent) tax increases resulted in a relative proportional decrease in gonorrhea rates ($p = .001$), with similar results for the 20- to 24-year-old group. For females in both age groups there was a similar trend, but these results were not statistically significant.

A. Drinking-Age Experiments

A significant percentage of the drinking-age increases were accompanied by a relative proportional decrease in the total gonorrhea rates (and in particular gonorrhea rates in males) in the 15- to 19-year-old group, as reported in Table 7. The rates for females in this age group followed the same trend, although the results were not significant. For the 20- to 24-year-old group, however, the drinking-age increases appeared to have no effect on gonorrhea rates. The quasi-experimental analysis of drinking-age increases offers results consistent with the regression analysis reported in Table 6: that drinking-age increases appear to reduce STD rates in the 15- to 19-year-old group but have no effect on older age groups.

B. Liquor Tax Experiments

There were 25 increases in state liquor taxes (one of which was not included in the analysis owing to missing STD incidence data) over the period of analysis for the 32 states and the District of Columbia without monopoly control over liquor commerce. The average and median per-gallon tax increases were $1.36 and $1.42, respectively. As with the beer tax increases, a significant majority of liquor tax increases were followed by a relative proportional decrease in the gonorrhea rate (Table 7). Among the 15- to 24-year-old group as a whole, 19 of the 24 experiments had a proportional decrease in STD rates relative to the median proportional change among the control states. Among the 25 and older group, 18 of the 24 liquor tax increases resulted in a relative proportional decrease in gonorrhea rates.
<table>
<thead>
<tr>
<th></th>
<th>Ages 15–19</th>
<th>Ages 20–24</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>STD rate decreases</td>
<td>24 of 36</td>
<td>28 of 36</td>
<td>22 of 36</td>
</tr>
<tr>
<td>(29 of 44)</td>
<td>(29 of 44)</td>
<td>(27 of 44)</td>
<td></td>
</tr>
<tr>
<td>Sign test: (p)-value</td>
<td>.065</td>
<td>.001</td>
<td>.243</td>
</tr>
<tr>
<td>(.049)</td>
<td>(.049)</td>
<td>(.174)</td>
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</table>

B. Liquor Tax Increase Experiments (Syphilis Results)

<table>
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<th>Ages 15–24</th>
<th>Ages 25 and Up</th>
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<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>STD rate decreases</td>
<td>19 of 24</td>
<td>20 of 24</td>
<td>13 of 24</td>
</tr>
<tr>
<td>(17 of 23)</td>
<td>(14 of 23)</td>
<td>(17 of 22)</td>
<td></td>
</tr>
<tr>
<td>Sign test: (p)-value</td>
<td>.007</td>
<td>.002</td>
<td>.839</td>
</tr>
<tr>
<td>(.035)</td>
<td>(.405)</td>
<td>(.017)</td>
<td></td>
</tr>
</tbody>
</table>

Note.—Four drinking-age experiments were omitted owing to missing gonorrhea data. Missing observations for syphilis rates account for the difference in the number of gonorrhea and syphilis experiments. There are more drinking-age experiments for the 15- to 19-year-old group, as drinking-age changes not affecting those aged 20 or over were not included in the analysis for the 20–24 age group. Including all drinking-age increases does not affect the results (the \(p\)-values are not significant) for the 20–24 age group.

\(a\) Denotes a decrease relative to the control states. This summary of the experiments shows the number of times the proportional change in the STD rate in the state with the alcohol policy change was below the median proportional change among the states without the alcohol policy change.

\(b\) The \(p\)-values represent a two-tailed test under the null hypothesis that states with an alcohol policy change have a 50-50 chance of having a proportional change in the STD rate below the median proportional change in the control states.
C. Robustness Checks of Quasi-Experiments

These results are consistent over a range of manipulations of the quasi-experimental procedure. Further, we repeated the quasi-experiment using syphilis as an outcome measure. The results were similar to those using gonorrhea as the outcome measure. However, these results should be considered in light of the geographic distribution of syphilis across states. Since many states have little or no incidence of syphilis, a small absolute change in the syphilis rate could result in a large proportional change. Further, the proportional change in the syphilis rate cannot be calculated for instances in which a state reports no syphilis in the year before the tax increase, which explains why the number of experiments using syphilis rates is not always the same as when using gonorrhea as an outcome measure. Unlike the findings for the gonorrhea rates, the results of the experiments using syphilis as the outcome measure varied under each of the alternative specifications described above. However, for most manipulations of the experiment (as described above), a majority of the states with a liquor tax increase showed a proportional decrease in syphilis rates compared to the control states, although this majority was not always statistically significant.

VIII. Conclusions

We offer strong evidence that alcohol policy can affect STD rates. Our analysis links a $1 increase in the per-gallon state liquor tax with a reduction in gonorrhea rates of 2.1 percent, with slightly higher estimated reductions in syphilis rates. Similarly, a $.20 increase in the tax on a six-pack of beer is associated with an 8.9 percent reduction in gonorrhea rates and a 32.7 percent reduction in syphilis rates. Since our analysis cannot distinguish between the effects of beer taxes and liquor taxes (which are highly correlated), the estimated effect of an increase in the excise tax on beer (or liquor) should be interpreted as the effect of increasing the excise tax on beer (or liquor) when this tax increase is accompanied by a proportional tax increase on all other forms of alcoholic beverages (wine, beer, and liquor). Our findings are robust under a number of specifications and are supported by a quasi-experimental analysis of alcohol policy changes. We interpret our findings as empirical support for the idea that alcohol is a causal factor in risky sexual behavior, at least for a fraction of the population at risk of acquiring an STD.

38 The three main variations in the experiments include using a different control measure (the mean proportional change in gonorrhea rates for the United States as a whole rather than the median value of the proportional changes among the control states), using Cook’s (supra note 6) formula (which used $R_i^t$ rather than $R_i^{t-1}$ in the denominator of equation (3)), and excluding Alaska, Hawaii, and the District of Columbia. Combining these three manipulations allows for eight different specifications of the experiment to be conducted.
The estimated direct cost of STDs in the United States exceeds $12.5 billion annually. Since a substantial portion of the cost of STDs is borne by federal and state governments and other third parties such as private insurers, much of the cost of STDs can be considered external costs of risky sexual behavior. We assume conservatively that half of the $12.5 billion cost of STDs can be considered external costs. Taking our model estimates at face value, if a $.20 increase in the tax per six-pack of beer reduces gonorrhea rates (and STD rates in general) by 8.9 percent, it follows that at least 8.9 percent of the $6.25 billion external cost of STDs is attributable to alcohol consumption. Thus, the estimated external cost of alcohol-related STDs is at least 8.9 percent of $6.25 billion, or $556 million annually. The tax revenue (federal, state, and local) from wine, beer, and liquor in the 1990s typically amounts to $17 billion annually, so this $556 million externality represents roughly 3.3 percent of total annual alcohol tax revenue. Thus, the estimated external cost of risky sex attributable to alcohol is not trivial and could be an important factor in the determination of optimal tax policy.

We note that the estimated external cost of risky sex attributable to alcohol would be even more substantial if secondary cases of STDs were considered. For example, an alcohol-attributable HIV transmission in a given year might lead to subsequent HIV transmissions to new partners in future years. Since these secondary HIV transmissions can also lead to subsequent HIV transmissions (and so on), it is likely that our estimate of the external cost of alcohol-related risky sex is quite conservative.

Finally, the issue of the external costs of alcohol is not the only argument for taxing alcohol, as alcohol taxation is often suggested as a public health measure. Our study suggests that an increase in the alcohol tax could bring about substantial public health benefits by reducing STD rates. For example, an 8.9 percent reduction across all STDs (the estimated decrease in gonorrhea rates in response to a $.20 increase in the tax on a six-pack of beer accompanied by similar increases in wine and liquor taxes) would avert approximately 3,400 new cases of HIV, 8,900 cases of infertility due to STD-attributable pelvic infections, and 700 new cases of cervical cancer annually.

39 Institute of Medicine, supra note 3.
40 DISCUS, History of Beverage Alcohol Tax Changes, supra note 13.
41 For example, see Philip J. Cook, Alcohol Taxes as a Public Health Measure, 77 Brit. J. Addiction 245 (1982); and Cook & Moore, supra note 2.
42 These calculations assume 60,000 new HIV cases annually (based on Philip S. Rosenberg, Scope of the AIDS Epidemic in the United States, 270 Science 1372 (1995)), of which 64 percent are not transmitted through drug use (National Center for HIV, STD, and TB Prevention, CDC Fact Sheet: Dangerous Intersection of Drug Use and Sexual HIV Transmission Points to Critical Need for Comprehensive HIV Prevention among Drug Users (1998)), 100,000 cases of STD-attributable infertility (Division of STD Prevention, Division of STD Prevention Annual Report 1994 (1995)), and 16,000 new cases of cervical cancer, of which at least half are STD related (Institute of Medicine, supra note 3).
Bibliography


Newey, Whitney K., and West, Kenneth D. “‘A Simple Positive Semi-definite, Het-


