Supporting Information for "Estimating Uncertainty in Respondent-Driven Samples Using a Tree Bootstrap Method"

Aaron J. Baraff [*], **Tyler H. McCormick** [*] **and Adrian E. Raftery** [*]

[*]University of Washington, Seattle, WA

Submitted to Proceedings of the National Academy of Sciences of the United States of America

Project 90 Results

We include here additional results from our simulations based on the Colorado Springs Project 90 study, a network of sex workers, paying and nonpaying partners of sex workers, injecting drug users, and sexual partners of drug users collected from 1988 to 1992 [1, 2, 3]. From each of 1,000 simulated respondent-driven samples from the Project 90 data, various methods were used to infer the population proportions for each of the 13 attributes using confidence intervals. Since these true population proportions are known from the data, we can use these inferences to compare the coverage probabilities of the confidence intervals derived from the different methods. Figure S1(a) shows the resulting coverage probabilities of the 80% confidence intervals as estimated by the following methods: (*i*) the naive proportion variance estimator; (*ii*) the Volz-Heckathorn variance estimator; (*iii*) the Salganik bootstrap; (*iv*) the Yamanis bootstrap; (*v*) the Gile successive sampling bootstrap; and (*vi*) the tree bootstrap. Figure S1(b) shows the coverage probabilities of these 80% confidence intervals as estimated by the same methods but with sampling performed without replacement. Figure S1(c) shows the mean widths of these 80% confidence intervals for each attribute along with the expected widths of the intervals calculated using the 10th and 90th percentiles flanking the central 80% of the point estimates from 10,000 simulated samples.

Add Health Results

We include here additional results from our simulations based on the National Longitudinal Study of Adolescent Health (Add Health), a nationally representative longitudinal study of adolescents in grades 7-12 collected during the 1994-95 school year from 84 pairs of middle and high schools [4, 5]. Population proportions for each of the school pairs and 43 attributes in the Add Health data were inferred using confidence intervals from 1,000 simulated respondent-driven samples. Figure S2 shows the resulting mean coverage probabilities across the school pairs of 80% confidence intervals as estimated by the following methods: (*i*) the naive proportion variance estimator; (*ii*) the Volz-Heckathorn variance estimator; (*iii*) the Salganik bootstrap; (*iv*) the Gile successive sampling bootstrap; and (*v*) the tree bootstrap. The other bootstrap methods used above were excluded from this simulation study because their computation times would have been prohibitive due to the presence of 46 attributes. Figures S3 and S4 show the mean coverage probabilities of 95% and 80% confidence intervals, respectively, as estimated by the same methods but with sampling performed without replacement.

We observe that the tree bootstrap method gave 80% confidence intervals that are better calibrated than the other method when sampling is with replacement. When sampling is without replacement, however, the coverage of the tree bootstrap intervals was above the nominal level.

This suggests that the tree bootstrap gives intervals that are too wide when RDS is performed without replacement from a small population in which the sample size is a substantial proportion of the population size. The median network size from the Add Health schools was 753, so for a majority of these networks, our samples of size 500 accounted for more than half of the total population. In these cases, we see that the intervals estimated by the tree bootstrap method were wider than necessary, with coverage approaching 100%. However, as noted by Rohe, although the concept of "with replacement sampling" approximating "without replacement sampling" does extend to RDS, it falls apart when the sample size is not small with respect to the population size [6]. One could also argue that this problem of overcoverage is less serious in many contexts than the problem of undercoverage documented by Goel and Salganik, although of course one would wish to avoid both [7].

Ukraine IDU Results

We include here the complete results from the data collected in 2011 from injecting drug users (IDUs) in major Ukrainian cities. In each of 26 targeted cities, between 2 and 6 seed respondents were selected non-randomly based on prespecified criteria, and each respondent recruited up to three additional respondent until between 200 and 500 total IDUs were surveyed, with the target sample size being higher in cities with higher HIV prevalence [8, 9]. We analyzed four attributes measured by the behaviorial survey in each city: (*i*) hospitalization to state drug treatment in-patient clinics during 2010; (*ii*) participation in the state substitution maintenance therapy (SMT) program; (*iii*) registration at non-governmental organizations (NGO) that provide HIV prevention services; and (*iv*) use of HIV rapid tests distributed by NGOs that provide HIV prevention services. Tables S1-S4 show the resulting 80% and 95% confidence intervals obtained from the following methods: (*i*) the naive proportion variance estimator; (*ii*) the Volz-Heckathorn variance estimator; (*iii*) the Salganik bootstrap; (*iv*) the Yamanis bootstrap; (*v*) the Gile successive sampling bootstrap; and (*vi*) the tree bootstrap.

Reserved for Publication Footnotes

1. Woodhouse DE et al. (1994) Mapping a social network of heterosexuals at high risk for hiv infection. AIDS 8(9):1331–1336.
2. Klovdahl AS et al. (1994) Social networks and infectious disease: The Colorado Springs study. Social Science and Medicine 38(1):79–88.
3. Rothenberg RB et al. (1995) Social networks in disease transmission: the Colorado Springs study. NIDA Research Monograph 151:3–19.
4. Harris KM et al. (2009) The national longitudinal study of adolescent to adult health: Research design. See http://www.cpc.unc.edu/projects/addhealth/design (accessed 27 May 2016).
5. Morris M et al. (2006) Prevalence of HIV infection among young adults in the United States: Results from the Add Health study. American Journal of Public Health 96(6):1091–1097.
6. Rohe K (2015) Network driven sampling; a critical threshold for design effects. arXiv preprint arXiv:1505.05461.
7. Goel S, Salganik MJ (2010) Assessing respondent-driven sampling. Proceedings of the National Academy of Sciences 107(15):6743–6747.
8. Berleva GO et al. (2010) Analytical Report Based on Sociological Study Results: Estimation of the Size of Populations Most-at-Risk for HIV Infection in Ukraine in 2009. (International HIV/AIDS Alliance in Ukraine, Kiev, Ukraine).
9. Balakiryeva OM, Bondar TV, V. SY, Sazonova YO (2012) Analytical report: Behavior monitoring and HIV prevalence among injecting drug users as a component of second generation sentinel surveillance (http://www.aidsalliance.org.ua/ru/library/our/2012/me/idu_en_2011.pdf). Accessed: 2015-10-10.

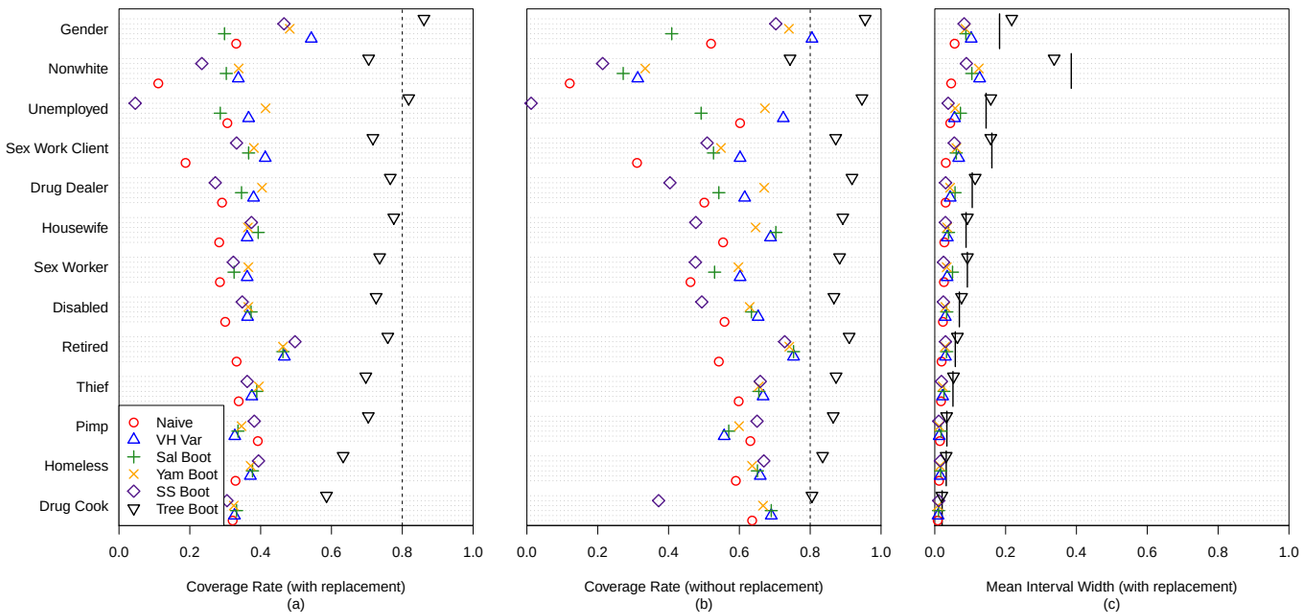

Fig. S1: *Estimating population proportions via RDS with the Project 90 data. Coverage probabilities and widths of 80% confidence intervals estimated by the following methods:* (i) *the naive proportion variance estimator;* (ii) *the Volz-Heckathorn variance estimator;* (iii) *the Salganik bootstrap;* (iv) *the Yamanis bootstrap;* (v) *the Gile successive sampling bootstrap; and* (vi) *the tree bootstrap. For the coverage probabilities and widths in panels (a) and (c), sampling was performed with replacement, and for the coverage probabilities in panel (b), sampling was performed without replacement. Attributes are in decreasing order of prevalence in the network. The dashed vertical black lines in panels (a) and (b) are at 0.80, so that for a perfectly calibrated method the symbol would lie on the line. The short black lines in panel (c) are the expected 80% interval widths based on 10,000 simulated sample estimates.*

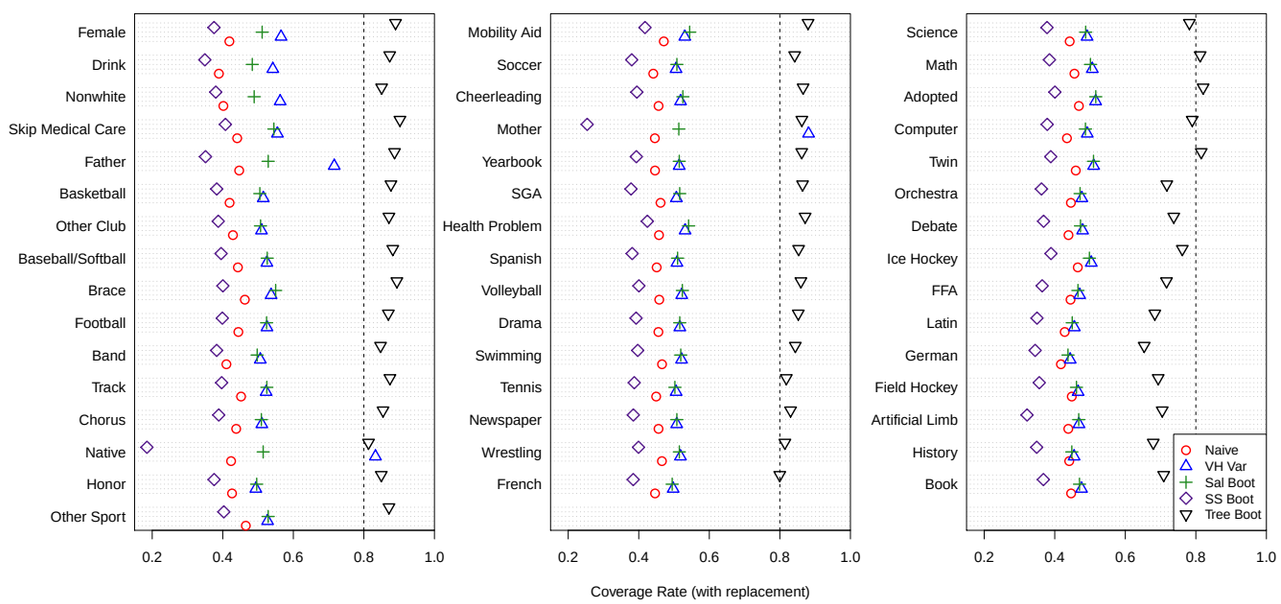

Fig. S2: *Estimating population proportions via RDS with the Add Health data. Mean coverage probabilities of 80% confidence intervals across the 84 school pairs estimated by the following methods:* (i) *the naive proportion variance estimator;* (ii) *the Volz-Heckathorn variance estimator;* (iii) *the Salganik bootstrap;* (iv) *the Gile successive sampling bootstrap; and* (v) *the tree bootstrap. Sampling was performed with replacement, and attributes are in decreasing order of mean prevalence over the 84 networks. The dashed vertical black lines are at 0.80, so that for a perfectly calibrated method the symbol would lie on the line.*

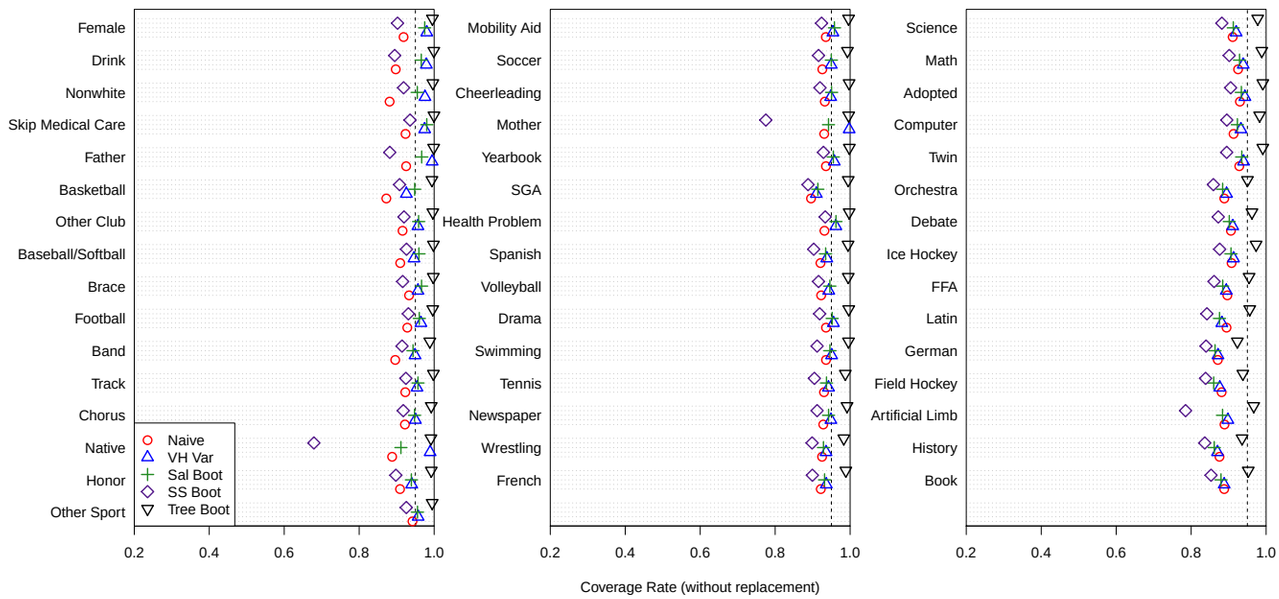

Fig. S3: *Estimating population proportions via RDS with the Add Health data. Mean coverage probabilities of 95% confidence intervals across the 84 school pairs estimated by the following methods:* (i) *the naive proportion variance estimator;* (ii) *the Volz-Heckathorn variance estimator;* (iii) *the Salganik bootstrap;* (iv) *the Gile successive sampling bootstrap; and* (v) *the tree bootstrap Sampling was performed without replacement, and attributes are in decreasing order of mean prevalence over the 84 networks. The dashed vertical black lines are at 0.95, so that for a perfectly calibrated method the symbol would lie on the line.*

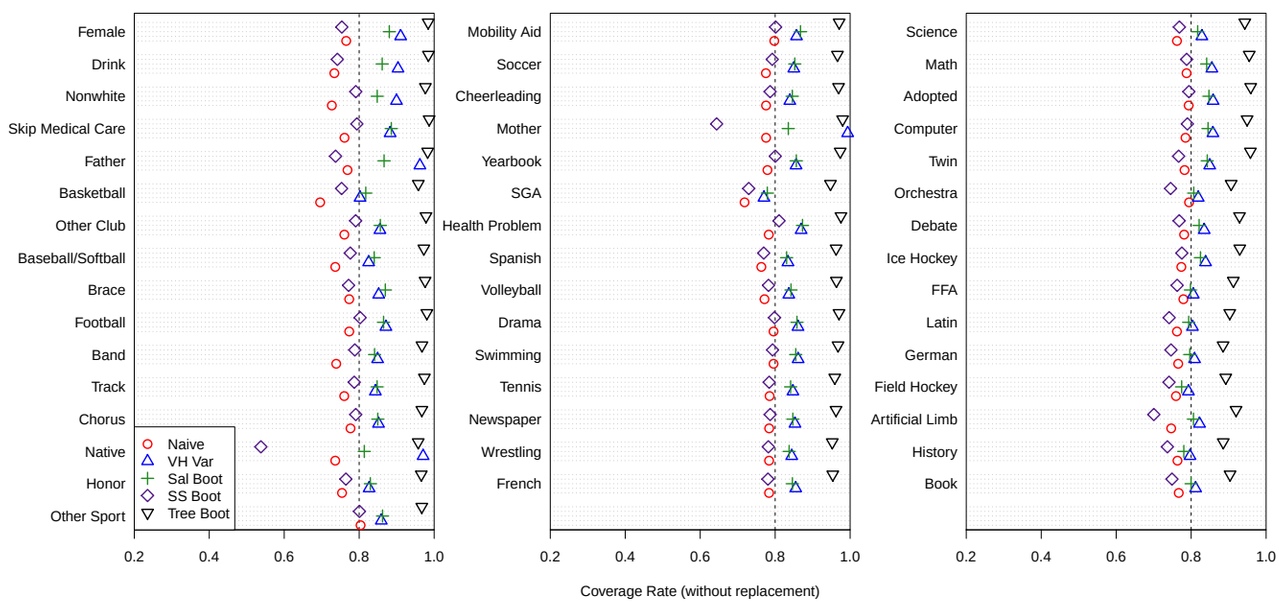

Fig. S4: *Estimating population proportions via RDS with the Add Health data. Mean coverage probabilities of 80% confidence intervals across the 84 school pairs estimated by the following methods:* (i) *the naive proportion variance estimator;* (ii) *the Volz-Heckathorn variance estimator;* (iii) *the Salganik bootstrap;* (iv) *the Gile successive sampling bootstrap; and* (v) *the tree bootstrap Sampling was performed without replacement, and attributes are in decreasing order of mean prevalence over the 84 networks. The dashed vertical black lines are at 0.80, so that for a perfectly calibrated method the symbol would lie on the line.*

Table S1: *80% and 95% confidence intervals obtained from the naive proportion variance estimator, the Volz-Heckathorn variance estimator, the Salganik bootstrap, the Yamanis bootstrap, the Gile successive sampling bootstrap, and the tree bootstrap for the proportion of IDUs hospitalized to state drug treatment in-patient clinics during 2010 in various Ukrainian cities.*

Hospitalization

City	CI	Naive	VH Var	Sal Boot	YAM Boot	SS Boot	Tree Boot
Simferopol	80%	(0.007, 0.020)	(0.005, 0.021)	(0.006, 0.021)	(0.005, 0.021)	(0.006, 0.021)	(0.001, 0.027)
	95%	(0.003, 0.023)	(0.001, 0.025)	(0.003, 0.026)	(0.003, 0.026)	(0.003, 0.026)	(0.000, 0.036)
Vinnytsia	80%	(0.003, 0.017)	(0.002, 0.019)	(0.002, 0.019)	(0.002, 0.019)	(0.002, 0.019)	(0.000, 0.024)
	95%	(0.000, 0.021)	(0.000, 0.024)	(0.001, 0.024)	(0.001, 0.027)	(0.001, 0.025)	(0.000, 0.034)
Lutsk	80%	(0.031, 0.059)	(0.026, 0.064)	(0.027, 0.066)	(0.027, 0.064)	(0.028, 0.065)	(0.017, 0.081)
	95%	(0.023, 0.067)	(0.015, 0.075)	(0.018, 0.076)	(0.018, 0.076)	(0.022, 0.076)	(0.008, 0.108)
Dnipropetrovsk	80%	(0.000, 0.006)	(0.000, 0.007)	(0.000, 0.006)	(0.000, 0.006)	(0.000, 0.006)	(0.000, 0.011)
	95%	(0.000, 0.008)	(0.000, 0.009)	(0.000, 0.009)	(0.000, 0.009)	(0.000, 0.009)	(0.000, 0.020)
Donetsk	80%	(0.009, 0.024)	(0.007, 0.026)	(0.007, 0.026)	(0.008, 0.027)	(0.008, 0.025)	(0.002, 0.035)
	95%	(0.006, 0.028)	(0.002, 0.031)	(0.004, 0.032)	(0.004, 0.033)	(0.004, 0.031)	(0.000, 0.047)
Zhytomyr	80%	(0.000, 0.003)	(0.000, 0.003)	(0.000, 0.002)	(0.000, 0.002)	(0.000, 0.002)	(0.000, 0.005)
	95%	(0.000, 0.005)	(0.000, 0.003)	(0.000, 0.004)	(0.000, 0.004)	(0.000, 0.003)	(0.000, 0.009)
Uzhgorod	80%	(0.000, 0.014)	(0.000, 0.015)	(0.000, 0.014)	(0.000, 0.014)	(0.000, 0.014)	(0.000, 0.023)
	95%	(0.000, 0.018)	(0.000, 0.020)	(0.000, 0.022)	(0.000, 0.021)	(0.000, 0.020)	(0.000, 0.046)
Zaporizhzhia	80%	(0.044, 0.090)	(0.043, 0.091)	(0.046, 0.098)	(0.045, 0.096)	(0.045, 0.093)	(0.035, 0.105)
	95%	(0.032, 0.102)	(0.030, 0.104)	(0.034, 0.112)	(0.035, 0.113)	(0.035, 0.111)	(0.021, 0.142)
Ivano-Frankivsk	80%	(0.000, 0.005)	(0.000, 0.004)	(0.000, 0.004)	(0.000, 0.004)	(0.000, 0.004)	(0.000, 0.005)
	95%	(0.000, 0.007)	(0.000, 0.005)	(0.000, 0.005)	(0.000, 0.006)	(0.000, 0.004)	(0.000, 0.007)
Bila Tserkva	80%	(0.008, 0.028)	(0.000, 0.040)	(0.000, 0.035)	(0.000, 0.026)	(0.001, 0.032)	(0.001, 0.044)
	95%	(0.003, 0.033)	(0.000, 0.052)	(0.000, 0.052)	(0.000, 0.049)	(0.001, 0.047)	(0.000, 0.097)
Kirovograd	80%	(0.005, 0.020)	(0.005, 0.019)	(0.006, 0.020)	(0.006, 0.019)	(0.007, 0.020)	(0.000, 0.020)
	95%	(0.001, 0.024)	(0.002, 0.022)	(0.003, 0.026)	(0.003, 0.024)	(0.005, 0.023)	(0.000, 0.026)
Lugansk	80%	(0.048, 0.088)	(0.016, 0.120)	(0.022, 0.120)	(0.023, 0.117)	(0.023, 0.129)	(0.012, 0.134)
	95%	(0.037, 0.099)	(0.000, 0.147)	(0.014, 0.148)	(0.014, 0.150)	(0.014, 0.164)	(0.000, 0.198)
Lviv	80%	(0.013, 0.038)	(0.011, 0.040)	(0.012, 0.039)	(0.011, 0.040)	(0.011, 0.040)	(0.003, 0.057)
	95%	(0.006, 0.045)	(0.003, 0.048)	(0.007, 0.049)	(0.006, 0.048)	(0.007, 0.049)	(0.000, 0.079)
Mykolaiv	80%	(0.021, 0.040)	(0.020, 0.041)	(0.020, 0.042)	(0.021, 0.042)	(0.021, 0.041)	(0.014, 0.050)
	95%	(0.015, 0.046)	(0.015, 0.047)	(0.017, 0.049)	(0.016, 0.048)	(0.016, 0.047)	(0.006, 0.070)
Odessa	80%	(0.000, 0.006)	(0.001, 0.005)	(0.001, 0.005)	(0.001, 0.005)	(0.000, 0.005)	(0.000, 0.007)
	95%	(0.000, 0.007)	(0.000, 0.006)	(0.000, 0.007)	(0.000, 0.007)	(0.000, 0.007)	(0.000, 0.011)
Poltava	80%	(0.006, 0.021)	(0.007, 0.020)	(0.007, 0.021)	(0.007, 0.022)	(0.008, 0.020)	(0.002, 0.023)
	95%	(0.001, 0.025)	(0.003, 0.024)	(0.005, 0.026)	(0.005, 0.027)	(0.005, 0.023)	(0.000, 0.031)
Rivne	80%	(0.016, 0.039)	(0.017, 0.038)	(0.017, 0.038)	(0.017, 0.039)	(0.018, 0.038)	(0.012, 0.039)
	95%	(0.010, 0.044)	(0.011, 0.043)	(0.013, 0.045)	(0.013, 0.047)	(0.013, 0.044)	(0.005, 0.054)
Sumy	80%	(0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)
	95%	(0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)
Ternopil	80%	(0.020, 0.054)	(0.011, 0.063)	(0.012, 0.066)	(0.012, 0.064)	(0.015, 0.065)	(0.001, 0.078)
	95%	(0.011, 0.063)	(0.000, 0.077)	(0.003, 0.085)	(0.004, 0.083)	(0.005, 0.081)	(0.000, 0.120)
Kharkiv	80%	(0.000, 0.007)	(0.000, 0.006)	(0.000, 0.006)	(0.000, 0.006)	(0.000, 0.006)	(0.000, 0.008)
	95%	(0.000, 0.009)	(0.000, 0.007)	(0.000, 0.008)	(0.000, 0.008)	(0.000, 0.008)	(0.000, 0.012)
Kherson	80%	(0.009, 0.027)	(0.008, 0.028)	(0.009, 0.029)	(0.009, 0.029)	(0.009, 0.028)	(0.003, 0.037)
	95%	(0.004, 0.032)	(0.003, 0.033)	(0.005, 0.036)	(0.005, 0.036)	(0.005, 0.034)	(0.000, 0.060)
Khmelnytskyi	80%	(0.031, 0.060)	(0.026, 0.066)	(0.025, 0.065)	(0.026, 0.066)	(0.029, 0.065)	(0.024, 0.071)
	95%	(0.024, 0.068)	(0.015, 0.076)	(0.019, 0.077)	(0.019, 0.078)	(0.022, 0.076)	(0.015, 0.093)
Cherkasy	80%	(0.046, 0.079)	(0.045, 0.081)	(0.046, 0.082)	(0.045, 0.081)	(0.047, 0.082)	(0.023, 0.106)
	95%	(0.038, 0.088)	(0.035, 0.090)	(0.036, 0.093)	(0.038, 0.092)	(0.039, 0.091)	(0.010, 0.138)
Chernivtsi	80%	(0.001, 0.019)	(0.002, 0.018)	(0.003, 0.019)	(0.003, 0.018)	(0.004, 0.018)	(0.000, 0.024)
	95%	(0.000, 0.024)	(0.000, 0.022)	(0.000, 0.024)	(0.000, 0.023)	(0.000, 0.023)	(0.000, 0.035)
Chernihiv	80%	(0.004, 0.018)	(0.000, 0.022)	(0.001, 0.022)	(0.001, 0.022)	(0.001, 0.021)	(0.000, 0.030)
	95%	(0.000, 0.021)	(0.000, 0.028)	(0.000, 0.030)	(0.000, 0.030)	(0.000, 0.029)	(0.000, 0.048)
Kiev	80%	(0.002, 0.011)	(0.000, 0.014)	(0.000, 0.014)	(0.000, 0.014)	(0.000, 0.007)	(0.000, 0.020)
	95%	(0.000, 0.013)	(0.000, 0.019)	(0.000, 0.020)	(0.000, 0.020)	(0.000, 0.013)	(0.000, 0.040)

Table S2: *80% and 95% confidence intervals obtained from the naive proportion variance estimator, the Volz-Heckathorn variance estimator, the Salganik bootstrap, the Yamanis bootstrap, the Gile successive sampling bootstrap, and the tree bootstrap for the proportion of IDUs who participated in the state SMT program in various Ukrainian cities.*

SMT Program

City	CI	Naive	VH Var	Sal Boot	YAM Boot	SS Boot	Tree Boot
Simferopol	80%	(0.019, 0.038)	(0.018, 0.040)	(0.019, 0.042)	(0.019, 0.042)	(0.019, 0.040)	(0.010, 0.047)
	95%	(0.014, 0.043)	(0.012, 0.045)	(0.015, 0.049)	(0.014, 0.049)	(0.015, 0.047)	(0.002, 0.059)
Vinnytsia	80%	(0.029, 0.057)	(0.027, 0.060)	(0.032, 0.069)	(0.025, 0.057)	(0.025, 0.056)	(0.013, 0.077)
	95%	(0.022, 0.065)	(0.018, 0.069)	(0.023, 0.081)	(0.019, 0.067)	(0.018, 0.066)	(0.004, 0.098)
Lutsk	80%	(0.171, 0.225)	(0.155, 0.242)	(0.107, 0.174)	(0.150, 0.229)	(0.143, 0.226)	(0.144, 0.259)
	95%	(0.156, 0.240)	(0.132, 0.265)	(0.093, 0.194)	(0.131, 0.251)	(0.127, 0.253)	(0.124, 0.296)
Dnipropetrovsk	80%	(0.017, 0.035)	(0.011, 0.041)	(0.013, 0.042)	(0.013, 0.042)	(0.013, 0.041)	(0.004, 0.047)
	95%	(0.012, 0.040)	(0.004, 0.048)	(0.007, 0.053)	(0.007, 0.051)	(0.007, 0.050)	(0.000, 0.058)
Donetsk	80%	(0.018, 0.036)	(0.017, 0.037)	(0.018, 0.038)	(0.017, 0.038)	(0.018, 0.037)	(0.012, 0.045)
	95%	(0.013, 0.041)	(0.012, 0.043)	(0.014, 0.045)	(0.013, 0.044)	(0.013, 0.044)	(0.007, 0.059)
Zhytomyr	80%	(0.083, 0.124)	(0.075, 0.132)	(0.076, 0.132)	(0.078, 0.133)	(0.080, 0.124)	(0.059, 0.148)
	95%	(0.072, 0.135)	(0.060, 0.147)	(0.064, 0.146)	(0.066, 0.147)	(0.070, 0.137)	(0.040, 0.172)
Uzhgorod	80%	(0.015, 0.047)	(0.015, 0.047)	(0.011, 0.039)	(0.012, 0.039)	(0.015, 0.044)	(0.009, 0.066)
	95%	(0.007, 0.055)	(0.007, 0.055)	(0.006, 0.048)	(0.007, 0.049)	(0.010, 0.055)	(0.005, 0.108)
Zaporizhzhia	80%	(0.024, 0.061)	(0.008, 0.077)	(0.010, 0.079)	(0.009, 0.077)	(0.010, 0.073)	(0.000, 0.088)
	95%	(0.014, 0.070)	(0.000, 0.095)	(0.001, 0.094)	(0.001, 0.098)	(0.001, 0.094)	(0.000, 0.138)
Ivano-Frankivsk	80%	(0.363, 0.443)	(0.345, 0.461)	(0.344, 0.448)	(0.343, 0.451)	(0.358, 0.444)	(0.267, 0.520)
	95%	(0.342, 0.464)	(0.314, 0.492)	(0.315, 0.474)	(0.318, 0.478)	(0.331, 0.469)	(0.221, 0.580)
Bila Tserkva	80%	(0.003, 0.018)	(0.000, 0.026)	(0.000, 0.031)	(0.000, 0.028)	(0.001, 0.026)	(0.000, 0.035)
	95%	(0.000, 0.022)	(0.000, 0.034)	(0.000, 0.047)	(0.000, 0.041)	(0.000, 0.035)	(0.000, 0.054)
Kirovograd	80%	(0.027, 0.054)	(0.022, 0.058)	(0.020, 0.051)	(0.017, 0.053)	(0.025, 0.057)	(0.000, 0.077)
	95%	(0.020, 0.061)	(0.013, 0.068)	(0.014, 0.061)	(0.012, 0.066)	(0.020, 0.067)	(0.000, 0.099)
Lugansk	80%	(0.040, 0.079)	(0.027, 0.091)	(0.026, 0.085)	(0.024, 0.089)	(0.028, 0.088)	(0.006, 0.115)
	95%	(0.030, 0.089)	(0.010, 0.108)	(0.017, 0.107)	(0.015, 0.108)	(0.018, 0.106)	(0.002, 0.192)
Lviv	80%	(0.006, 0.027)	(0.000, 0.037)	(0.000, 0.035)	(0.000, 0.034)	(0.000, 0.035)	(0.000, 0.044)
	95%	(0.001, 0.032)	(0.000, 0.048)	(0.000, 0.051)	(0.000, 0.051)	(0.000, 0.053)	(0.000, 0.067)
Mykolaiv	80%	(0.063, 0.094)	(0.056, 0.102)	(0.055, 0.100)	(0.055, 0.101)	(0.058, 0.101)	(0.049, 0.111)
	95%	(0.055, 0.102)	(0.043, 0.114)	(0.047, 0.113)	(0.046, 0.115)	(0.048, 0.114)	(0.039, 0.146)
Odessa	80%	(0.016, 0.034)	(0.017, 0.033)	(0.017, 0.033)	(0.016, 0.033)	(0.017, 0.034)	(0.011, 0.040)
	95%	(0.011, 0.039)	(0.012, 0.037)	(0.014, 0.038)	(0.013, 0.038)	(0.013, 0.038)	(0.005, 0.054)
Poltava	80%	(0.142, 0.193)	(0.130, 0.206)	(0.111, 0.182)	(0.111, 0.185)	(0.126, 0.195)	(0.086, 0.252)
	95%	(0.129, 0.207)	(0.109, 0.226)	(0.095, 0.202)	(0.093, 0.208)	(0.109, 0.215)	(0.043, 0.313)
Rivne	80%	(0.035, 0.065)	(0.032, 0.069)	(0.027, 0.062)	(0.027, 0.063)	(0.031, 0.064)	(0.022, 0.094)
	95%	(0.027, 0.073)	(0.022, 0.078)	(0.020, 0.073)	(0.020, 0.073)	(0.023, 0.075)	(0.015, 0.173)
Sumy	80%	(0.005, 0.021)	(0.005, 0.021)	(0.005, 0.019)	(0.006, 0.021)	(0.008, 0.021)	(0.001, 0.026)
	95%	(0.001, 0.025)	(0.001, 0.025)	(0.003, 0.025)	(0.003, 0.027)	(0.005, 0.024)	(0.000, 0.040)
Ternopil	80%	(0.220, 0.299)	(0.179, 0.340)	(0.181, 0.326)	(0.178, 0.325)	(0.187, 0.325)	(0.093, 0.466)
	95%	(0.199, 0.321)	(0.137, 0.383)	(0.145, 0.368)	(0.147, 0.363)	(0.160, 0.364)	(0.035, 0.552)
Kharkiv	80%	(0.021, 0.046)	(0.020, 0.047)	(0.019, 0.046)	(0.018, 0.043)	(0.021, 0.046)	(0.011, 0.062)
	95%	(0.015, 0.052)	(0.013, 0.054)	(0.014, 0.054)	(0.013, 0.052)	(0.016, 0.054)	(0.005, 0.090)
Kherson	80%	(0.062, 0.099)	(0.053, 0.108)	(0.055, 0.108)	(0.055, 0.109)	(0.056, 0.107)	(0.047, 0.112)
	95%	(0.052, 0.109)	(0.038, 0.123)	(0.045, 0.126)	(0.044, 0.124)	(0.046, 0.122)	(0.027, 0.144)
Khmelnytskyi	80%	(0.055, 0.091)	(0.042, 0.104)	(0.046, 0.106)	(0.047, 0.102)	(0.046, 0.102)	(0.039, 0.118)
	95%	(0.046, 0.100)	(0.025, 0.120)	(0.036, 0.128)	(0.037, 0.121)	(0.035, 0.119)	(0.024, 0.158)
Cherkasy	80%	(0.042, 0.073)	(0.038, 0.077)	(0.034, 0.070)	(0.029, 0.067)	(0.039, 0.075)	(0.030, 0.088)
	95%	(0.033, 0.082)	(0.028, 0.087)	(0.026, 0.081)	(0.021, 0.079)	(0.032, 0.086)	(0.021, 0.111)
Chernivtsi	80%	(0.069, 0.122)	(0.064, 0.127)	(0.061, 0.121)	(0.058, 0.120)	(0.066, 0.124)	(0.052, 0.142)
	95%	(0.055, 0.136)	(0.048, 0.143)	(0.045, 0.142)	(0.045, 0.141)	(0.052, 0.141)	(0.037, 0.169)
Chernihiv	80%	(0.064, 0.102)	(0.056, 0.109)	(0.056, 0.109)	(0.056, 0.108)	(0.058, 0.108)	(0.013, 0.198)
	95%	(0.054, 0.112)	(0.042, 0.124)	(0.046, 0.124)	(0.045, 0.125)	(0.047, 0.122)	(0.003, 0.280)
Kiev	80%	(0.032, 0.055)	(0.029, 0.058)	(0.030, 0.059)	(0.029, 0.061)	(0.029, 0.059)	(0.019, 0.068)
	95%	(0.026, 0.061)	(0.021, 0.066)	(0.025, 0.071)	(0.023, 0.072)	(0.024, 0.070)	(0.011, 0.088)

Table S3: *80% and 95% confidence intervals obtained from the naive proportion variance estimator, the Volz-Heckathorn variance estimator, the Salganik bootstrap, the Yamanis bootstrap, the Gile successive sampling bootstrap, and the tree bootstrap for the proportion of IDUs registered at NGOs that provide HIV prevention services in various Ukrainian cities.*

NGO Registration

City	CI	Naive	VH Var	Sal Boot	YAM Boot	SS Boot	Tree Boot
Simferopol	80%	(0.457, 0.515)	(0.416, 0.556)	(0.434, 0.542)	(0.424, 0.550)	(0.426, 0.541)	(0.320, 0.639)
	95%	(0.442, 0.530)	(0.379, 0.593)	(0.407, 0.560)	(0.392, 0.578)	(0.393, 0.570)	(0.219, 0.699)
Vinnytsia	80%	(0.046, 0.079)	(0.040, 0.085)	(0.030, 0.069)	(0.030, 0.069)	(0.032, 0.073)	(0.040, 0.087)
	95%	(0.037, 0.088)	(0.028, 0.097)	(0.022, 0.079)	(0.021, 0.079)	(0.025, 0.086)	(0.030, 0.104)
Lutsk	80%	(0.649, 0.713)	(0.627, 0.735)	(0.755, 0.819)	(0.643, 0.729)	(0.642, 0.720)	(0.601, 0.754)
	95%	(0.632, 0.730)	(0.599, 0.763)	(0.737, 0.835)	(0.622, 0.750)	(0.621, 0.741)	(0.549, 0.797)
Dnipropetrovsk	80%	(0.018, 0.036)	(0.013, 0.041)	(0.013, 0.042)	(0.015, 0.041)	(0.014, 0.041)	(0.006, 0.054)
	95%	(0.013, 0.041)	(0.005, 0.049)	(0.009, 0.052)	(0.010, 0.050)	(0.009, 0.051)	(0.002, 0.114)
Donetsk	80%	(0.257, 0.309)	(0.251, 0.315)	(0.395, 0.480)	(0.234, 0.303)	(0.244, 0.310)	(0.228, 0.337)
	95%	(0.243, 0.322)	(0.233, 0.332)	(0.372, 0.504)	(0.219, 0.322)	(0.228, 0.328)	(0.199, 0.375)
Zhytomyr	80%	(0.263, 0.325)	(0.245, 0.343)	(0.251, 0.337)	(0.251, 0.336)	(0.253, 0.323)	(0.181, 0.424)
	95%	(0.246, 0.342)	(0.219, 0.369)	(0.228, 0.362)	(0.228, 0.361)	(0.236, 0.342)	(0.142, 0.488)
Uzhgorod	80%	(0.057, 0.107)	(0.050, 0.114)	(0.047, 0.106)	(0.048, 0.106)	(0.053, 0.111)	(0.034, 0.139)
	95%	(0.044, 0.120)	(0.034, 0.131)	(0.034, 0.127)	(0.037, 0.127)	(0.040, 0.129)	(0.021, 0.192)
Zaporizhzhia	80%	(0.186, 0.262)	(0.162, 0.286)	(0.169, 0.285)	(0.165, 0.287)	(0.166, 0.278)	(0.146, 0.317)
	95%	(0.166, 0.282)	(0.129, 0.319)	(0.145, 0.318)	(0.142, 0.321)	(0.143, 0.307)	(0.107, 0.381)
Ivano-Frankivsk	80%	(0.287, 0.363)	(0.271, 0.379)	(0.306, 0.407)	(0.275, 0.372)	(0.283, 0.366)	(0.228, 0.429)
	95%	(0.267, 0.383)	(0.243, 0.408)	(0.273, 0.433)	(0.252, 0.400)	(0.260, 0.390)	(0.200, 0.495)
Bila Tserkva	80%	(0.231, 0.296)	(0.202, 0.326)	(0.350, 0.482)	(0.214, 0.328)	(0.218, 0.308)	(0.159, 0.383)
	95%	(0.214, 0.314)	(0.169, 0.358)	(0.313, 0.525)	(0.187, 0.354)	(0.199, 0.332)	(0.132, 0.615)
Kirovograd	80%	(0.070, 0.110)	(0.061, 0.119)	(0.059, 0.117)	(0.056, 0.116)	(0.066, 0.119)	(0.041, 0.146)
	95%	(0.060, 0.120)	(0.045, 0.135)	(0.049, 0.135)	(0.044, 0.135)	(0.056, 0.133)	(0.027, 0.181)
Lugansk	80%	(0.129, 0.188)	(0.103, 0.215)	(0.084, 0.191)	(0.064, 0.153)	(0.093, 0.194)	(0.072, 0.242)
	95%	(0.114, 0.204)	(0.073, 0.245)	(0.063, 0.219)	(0.048, 0.183)	(0.076, 0.230)	(0.056, 0.388)
Lviv	80%	(0.046, 0.086)	(0.029, 0.103)	(0.025, 0.073)	(0.023, 0.094)	(0.030, 0.096)	(0.012, 0.136)
	95%	(0.035, 0.097)	(0.009, 0.123)	(0.016, 0.091)	(0.012, 0.121)	(0.017, 0.121)	(0.006, 0.201)
Mykolaiv	80%	(0.143, 0.185)	(0.134, 0.194)	(0.131, 0.189)	(0.133, 0.188)	(0.134, 0.191)	(0.119, 0.214)
	95%	(0.131, 0.196)	(0.118, 0.210)	(0.116, 0.207)	(0.119, 0.203)	(0.122, 0.206)	(0.101, 0.268)
Odessa	80%	(0.233, 0.284)	(0.219, 0.298)	(0.181, 0.258)	(0.156, 0.232)	(0.198, 0.281)	(0.128, 0.406)
	95%	(0.220, 0.297)	(0.198, 0.319)	(0.164, 0.275)	(0.138, 0.255)	(0.178, 0.303)	(0.091, 0.470)
Poltava	80%	(0.249, 0.311)	(0.229, 0.332)	(0.238, 0.325)	(0.230, 0.316)	(0.241, 0.325)	(0.204, 0.353)
	95%	(0.233, 0.327)	(0.201, 0.359)	(0.216, 0.350)	(0.210, 0.341)	(0.219, 0.351)	(0.168, 0.405)
Rivne	80%	(0.027, 0.055)	(0.027, 0.055)	(0.026, 0.053)	(0.024, 0.051)	(0.027, 0.055)	(0.020, 0.073)
	95%	(0.020, 0.062)	(0.019, 0.063)	(0.020, 0.062)	(0.019, 0.060)	(0.022, 0.064)	(0.016, 0.136)
Sumy	80%	(0.714, 0.774)	(0.703, 0.785)	(0.809, 0.869)	(0.665, 0.761)	(0.700, 0.777)	(0.675, 0.820)
	95%	(0.698, 0.790)	(0.682, 0.806)	(0.793, 0.880)	(0.636, 0.785)	(0.678, 0.799)	(0.640, 0.861)
Ternopil	80%	(0.221, 0.300)	(0.197, 0.323)	(0.206, 0.329)	(0.203, 0.328)	(0.205, 0.316)	(0.128, 0.379)
	95%	(0.199, 0.321)	(0.164, 0.357)	(0.179, 0.364)	(0.179, 0.363)	(0.181, 0.350)	(0.050, 0.427)
Kharkiv	80%	(0.041, 0.073)	(0.030, 0.084)	(0.032, 0.084)	(0.033, 0.084)	(0.031, 0.083)	(0.018, 0.108)
	95%	(0.033, 0.081)	(0.016, 0.098)	(0.025, 0.101)	(0.025, 0.100)	(0.024, 0.098)	(0.008, 0.153)
Kherson	80%	(0.279, 0.342)	(0.265, 0.356)	(0.301, 0.386)	(0.270, 0.355)	(0.270, 0.350)	(0.238, 0.407)
	95%	(0.262, 0.359)	(0.240, 0.381)	(0.278, 0.410)	(0.247, 0.380)	(0.251, 0.373)	(0.196, 0.503)
Khmelnytskyi	80%	(0.138, 0.189)	(0.125, 0.202)	(0.143, 0.229)	(0.104, 0.174)	(0.123, 0.192)	(0.110, 0.218)
	95%	(0.125, 0.202)	(0.104, 0.222)	(0.124, 0.249)	(0.090, 0.197)	(0.106, 0.213)	(0.085, 0.280)
Cherkasy	80%	(0.612, 0.677)	(0.591, 0.697)	(0.667, 0.754)	(0.612, 0.702)	(0.615, 0.707)	(0.536, 0.736)
	95%	(0.595, 0.694)	(0.563, 0.725)	(0.644, 0.774)	(0.584, 0.728)	(0.589, 0.730)	(0.455, 0.773)
Chernivtsi	80%	(0.725, 0.802)	(0.667, 0.860)	(0.505, 0.699)	(0.470, 0.748)	(0.633, 0.829)	(0.507, 0.963)
	95%	(0.705, 0.823)	(0.616, 0.911)	(0.450, 0.749)	(0.391, 0.799)	(0.573, 0.862)	(0.432, 0.995)
Chernihiv	80%	(0.235, 0.296)	(0.225, 0.306)	(0.229, 0.309)	(0.229, 0.306)	(0.230, 0.306)	(0.150, 0.393)
	95%	(0.219, 0.312)	(0.203, 0.328)	(0.208, 0.331)	(0.210, 0.327)	(0.210, 0.327)	(0.103, 0.462)
Kiev	80%	(0.211, 0.260)	(0.188, 0.283)	(0.209, 0.293)	(0.178, 0.263)	(0.188, 0.276)	(0.154, 0.329)
	95%	(0.199, 0.272)	(0.163, 0.308)	(0.188, 0.320)	(0.162, 0.289)	(0.170, 0.303)	(0.119, 0.372)

Table S4: *80% and 95% confidence intervals obtained from the naive proportion variance estimator and the tree bootstrap for the average number of HIV rapid tests distributed by NGOs that are used by each registered IDU in various Ukrainian cities.*

HIV Rapid Tests

City	CI	Naive	VH Var	Sal Boot	YAM Boot	SS Boot	Tree Boot
Simferopol	80%	(0.302, 0.370)	-	-	-	-	(0.211, 0.454)
	95%	(0.284, 0.388)	-	-	-	-	(0.134, 0.514)
Vinnytsia	80%	(0.208, 0.300)	-	-	-	-	(0.198, 0.315)
	95%	(0.183, 0.324)	-	-	-	-	(0.173, 0.346)
Lutsk	80%	(0.110, 0.213)	-	-	-	-	(0.102, 0.233)
	95%	(0.082, 0.241)	-	-	-	-	(0.082, 0.269)
Dnipropetrovsk	80%	(0.059, 0.156)	-	-	-	-	(0.061, 0.166)
	95%	(0.033, 0.181)	-	-	-	-	(0.041, 0.203)
Donetsk	80%	(0.129, 0.195)	-	-	-	-	(0.099, 0.232)
	95%	(0.112, 0.212)	-	-	-	-	(0.071, 0.280)
Zhytomyr	80%	(0.247, 0.326)	-	-	-	-	(0.217, 0.360)
	95%	(0.226, 0.347)	-	-	-	-	(0.181, 0.405)
Uzhgorod	80%	(0.051, 0.109)	-	-	-	-	(0.043, 0.128)
	95%	(0.035, 0.124)	-	-	-	-	(0.030, 0.168)
Zaporizhzhia	80%	(0.120, 0.228)	-	-	-	-	(0.017, 0.315)
	95%	(0.091, 0.256)	-	-	-	-	(0.000, 0.370)
Ivano-Frankivsk	80%	(0.344, 0.451)	-	-	-	-	(0.284, 0.520)
	95%	(0.315, 0.479)	-	-	-	-	(0.243, 0.624)
Bila Tserkva	80%	(0.149, 0.229)	-	-	-	-	(0.104, 0.278)
	95%	(0.127, 0.251)	-	-	-	-	(0.068, 0.365)
Kirovograd	80%	(0.077, 0.184)	-	-	-	-	(0.065, 0.196)
	95%	(0.049, 0.212)	-	-	-	-	(0.029, 0.252)
Lugansk	80%	(0.367, 0.515)	-	-	-	-	(0.240, 0.683)
	95%	(0.328, 0.554)	-	-	-	-	(0.202, 0.857)
Lviv	80%	(0.009, 0.058)	-	-	-	-	(0.002, 0.069)
	95%	(0.000, 0.072)	-	-	-	-	(0.002, 0.092)
Mykolaiv	80%	(0.189, 0.277)	-	-	-	-	(0.151, 0.312)
	95%	(0.166, 0.300)	-	-	-	-	(0.104, 0.377)
Odessa	80%	(0.109, 0.185)	-	-	-	-	(0.060, 0.243)
	95%	(0.089, 0.205)	-	-	-	-	(0.044, 0.332)
Poltava	80%	(0.162, 0.257)	-	-	-	-	(0.129, 0.294)
	95%	(0.136, 0.283)	-	-	-	-	(0.056, 0.346)
Rivne	80%	(0.062, 0.142)	-	-	-	-	(0.056, 0.173)
	95%	(0.041, 0.163)	-	-	-	-	(0.050, 0.274)
Sumy	80%	(0.465, 0.558)	-	-	-	-	(0.427, 0.599)
	95%	(0.441, 0.582)	-	-	-	-	(0.394, 0.668)
Ternopil	80%	(0.137, 0.278)	-	-	-	-	(0.080, 0.356)
	95%	(0.100, 0.316)	-	-	-	-	(0.013, 0.446)
Kharkiv	80%	(0.093, 0.141)	-	-	-	-	(0.022, 0.245)
	95%	(0.080, 0.154)	-	-	-	-	(0.007, 0.336)
Kherson	80%	(0.185, 0.286)	-	-	-	-	(0.117, 0.446)
	95%	(0.159, 0.312)	-	-	-	-	(0.096, 0.577)
Khmelnytskyi	80%	(0.079, 0.184)	-	-	-	-	(0.086, 0.185)
	95%	(0.051, 0.212)	-	-	-	-	(0.072, 0.257)
Cherkasy	80%	(0.553, 0.641)	-	-	-	-	(0.410, 0.792)
	95%	(0.529, 0.665)	-	-	-	-	(0.304, 0.875)
Chernivtsi	80%	(1.106, 1.256)	-	-	-	-	(0.623, 1.681)
	95%	(1.066, 1.296)	-	-	-	-	(0.487, 1.771)
Chernihiv	80%	(0.072, 0.135)	-	-	-	-	(0.034, 0.202)
	95%	(0.055, 0.152)	-	-	-	-	(0.019, 0.265)
Kiev	80%	(0.148, 0.249)	-	-	-	-	(0.138, 0.275)
	95%	(0.121, 0.276)	-	-	-	-	(0.111, 0.337)