

## **Total Survey Error in the American Time Use Survey**

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### **Abstract**

The American Time Use Survey (ATUS) is the first continuous, Federally-funded survey designed to measure how people spend their time. The ATUS sample is drawn from households completing their final month of interviews for the Current Population Survey (CPS). Because the CPS records contain a wealth of demographic information about respondents, this design enables us to look directly at nonresponse without having to rely on techniques such as data matching or the use of reluctant respondents to model nonrespondents. The Contact History Instrument (CHI) from the CPS describes concerns about responding to the CPS, which may relate to responding in the ATUS. Our paper focuses on nonresponse bias and measurement error. First, we describe nonresponse rates by demographic characteristics, and then we use logistic analysis to examine correlates of nonresponse, including demographic and contact history characteristics. A propensity score model is utilized to examine differences in time-use patterns and to assess the extent of nonresponse bias. Measurement error is assessed with indicators based on item nonresponse and interviewer judgement.

### **Introduction**

The American Time Use Survey (ATUS) is the first continuous, Federally-funded survey designed to measure people's daily activities, including where they spend their time, what they spend their time doing, and with whom they spend their time. The ATUS is a one-time telephone interview with three main components: (1) questions updating the designated person's (DP)<sup>1</sup> employment status, industry and occupation, and earnings information from the CPS, (2) a 24-hour time diary, and (3) additional information on secondary childcare, paid work, volunteering, and travel away from home. The ATUS sample is drawn from households that have completed the entire CPS interview rotation of eight interviews over a 16-month period. Once a CPS household is selected, one household member is randomly selected to participate in the ATUS interview. Substitution or proxy response is not allowed. The selected DP must be 15 years old or older and may or may not have been the CPS reference person. Each DP is also required to report on a pre-assigned reporting day of the week—such as Tuesday, reporting about Monday. The specific day of the week assigned to each DP does not change, and there is no substitution of this day. The interviewing period for a case is up to eight weeks on the assigned day to secure an ATUS interview.

### **Design**

The ATUS is a computer assisted telephone survey conducted by the U.S. Census Bureau for the U.S. Bureau of Labor Statistics. Production began in January 2003. In 2010, approximately 2,000 participants were selected each month, and the average ATUS response rate was 57 percent.<sup>2</sup>

Key estimates of interest are the time-use patterns of the general population. All activities are classified into a three-tiered, hierarchical system, with 17 major, or first-tier, categories, each having two additional sub-levels of detail. The 17 first-tier categories include: personal care; household activities; caring for and helping household members; caring for and helping non-household members; work and work-related activities; education; consumer purchases; professional and personal care services; household services; government services and civic obligations; eating and drinking; socializing, relaxing, and leisure; sports, exercise, and recreation; religious activities; volunteering; telephone calls; and travel.

### **Analysis**

The difference between respondents and nonrespondents on key estimates of interest is usually unknown. Therefore, nonresponse bias typically must be examined using indirect measures that assume certain types of respondents can serve as accurate proxies for nonrespondents. However, since the ATUS draws its sample from respondents who have completed their final CPS interview, a direct comparison between respondents and nonrespondents on the ATUS is possible.<sup>3</sup> This paper focuses on nonresponse bias and measurement error. First, we investigate nonresponse bias from CPS nonresponse, then nonresponse bias due to ATUS nonresponse.

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<sup>1</sup> A designated person is the household member selected for ATUS.

<sup>2</sup> The response rate was calculated using the AAPOR Response Rate #2.

<sup>3</sup> In 2010, the CPS response rate was 92 percent.

We use logistic analysis (SAS PROC SURVEYLOGISTIC) to examine correlates of nonresponse, including both refusals and noncontacts. The ATUS nonresponse model was based on the characteristics of both refusals and noncontacts in the CPS and contains nine predictor variables and five interaction variables based on models developed by Dixon and Tucker (2000) as well as summary variables from the CHI. In the Dixon and Tucker study, variables were selected based on a theory of nonresponse (Groves and Couper, 1998) and effects found in previous studies. The independent predictors include: age, race, ethnicity, presence of children under 6 years old in the household, marital status, household size, number of relatives in the household other than spouse, school enrollment, and number of attempted interview contacts. The interactions include age by relative present in the household, ethnicity by household size, presence of child under 6 by household size, household size by school enrollment, and presence of relatives by race.

Using the predicted values from the model described above and in Table 2, a propensity score model is then used to examine differences in time-use patterns and to assess the extent of nonresponse bias. A propensity score model allows us to predict the probability of group membership. In this case, we use CPS variables to predict the probability of respondents versus nonrespondents for the CPS and the ATUS separately. The propensity scores were categorized as refusals and noncontacts in the same proportions as the real refusals and noncontacts in the surveys. While we cannot know the nonrespondents' true time-use estimates, we can estimate the bias due to nonresponse by contrasting the time-use estimates for those responders who were most similar to the nonrespondents based on propensity scores (Dixon 2004). A similar analysis was repeated for noncontacts. Measurement error may have an impact on data quality as well. Bose and Sharp (2005) and Meekins, Downey, and Fricker (2010) studied a number of sources of error in reporting for the ATUS. For this study, we will use non-reporting of income in the CPS as an indicator of privacy concerns, and the quality concerns reported by the interviewer for likely response error due to memory failure or willingness to provide quality data.

## **Results**

### **Refusal**

Table 1 shows the results of a logistic regression; the refusal model of the ATUS includes ten independent variables as predictors and five interaction terms and has a rescaled R-square of 0.3077. The statistically significant predictors are; Hispanic origin, children, marital status, household size, relatives present, in school, and the interaction of age by relatives present, children by family size, family size by "in school", and race(White) by relatives present in the household. Specifically, White respondents are less likely to refuse, while married and older respondents are more likely to refuse. The significant interaction shows that White respondents with relatives present are more likely to refuse. The concerns expressed in the CPS CHI and the number of attempted contacts were also significant.

Each DP, (respondents only), is assigned a "refusal propensity score," which is then used to create the same proportion of "refusers" that existed in the sample. Then, those respondents most like the refusers are compared to those who are most unlike the refusers. This was done with the logistic model (Table 1) by using the predicted values to classify those who responded to the ATUS into two groups, those most like refusers and those least like refusers. This provided an indication of the direction and magnitude of bias in the time-use estimates. Similar models were used to predict ATUS noncontact (Table 2) as well as CPS refusal and CPS noncontact. Groups proportionate to their respective sizes from the CPS and ATUS were created from those propensity scores.

### **Noncontact**

The noncontact model uses the same variables as the refusal model to permit easier comparison between models (Table 2.) If different variables are used, the relative importance of the different variables would not be seen. This is because the variables left out of the model would get a nonsignificant weight in the model and would not affect the propensity scores. The noncontact model has a rescaled R-square of 0.1858. The best predictors of noncontact propensity are marital status, age and the interaction of age and relatives present, and number of attempted contacts. Specifically, white respondents and older respondents were less likely to be noncontacts (since their logistic model estimates are negative), and households with more attempted contacts are more likely to be noncontacts (which is obvious, but helps estimate the likelihood of contact for those who were eventually contacted). The relative bias for each ATUS measure was calculated as the difference between the estimate for the total sample and those who were most like those who responded, divided by the total sample (Groves and Peytcheva,2008).

### Nonresponse bias and Measurement error

Table 3 shows the standardized estimates of nonresponse bias and measurement error, using different indicators. This is the difference between the survey estimates and what the estimates would be with those like the nonresponders (or measurement errors) removed, divided by the estimates standard error (from SAS PROC SURVEYMEANS). This gives the estimate of bias relative to its' precision of estimation. The table is sorted by the average length of the activity. For the total activities measure, the CPS refusal is low (-0.00634) standard errors relative to the other sources. The CPS nonresponse sources are negative, while the ATUS sources are positive, which may counterbalance the effect. The measurement error indicators are also in opposite directions, although those missing income had a stronger effect.

Table 4 shows the relative error for nonresponse bias and measurement error. The difference between survey estimates and the estimates without those like the nonresponders (or measurement errors) removed, divided by the estimates. This gives the bias relative to the scale of the estimate. For example, the bias for sleep could be compared to the bias for food preparation. Table 5 shows the relationship between nonresponse and measurement error. There was only weak correlation, with the strongest from "no income" with the nonresponse indicators, but in opposite directions for CPS and ATUS.

### Discussion

The estimates of bias were very small from all sources. For overall error, ATUS noncontact had the largest effect; 0.34706 of a standard error, or .01 percent relative error (about 1 and a half minutes out of 1434). Of the top three categories, only work showed much bias (approximately 10 minutes out to 205). The direction of bias was opposite for the CPS indicators and the ATUS indicators, with CPS underestimating work time and ATUS overestimating it. The ATUS indicators were three times as large as the CPS indicators. The measurement error indicators were in the same direction as the ATUS nonresponse, so the overall effect would be to overestimate work time. Socializing had overall overestimation for all sources of nonresponse, and underestimation from measurement error sources. Sleep was in the opposite direction from "work" for nonresponse bias. Abraham et.al. discussed "volunteering" in terms of overestimating, since those who spend more time volunteering may be more likely to participate in the survey. This study found the same effect from all the nonresponse sources. The largest effect was due to "education", underestimating the time by as 8 or 9 minutes based on ATUS nonresponse. This may be due to those in school less likely to refuse, and so reducing the total education time (relative to those who had already completed school). The largest effects for CPS refusal are "traveling" and "personal" underestimation. Those who are like those who refuse the CPS spend more time on those activities. They spent slightly more time on "sports". Some of the smallest time use categories had large estimates of bias, but they were so small they are likely to be unreliable. The category "household health care- other" was consistent in underestimating for refusal and overestimating for non-contact, so there might be some concern there. Child care showed small effects for CPS nonresponse, but larger effects for ATUS nonresponse with overestimation. This may be due to child care providers being more available and willing to participate, as seen in the propensity models. ATUS nonresponse had higher estimates of bias, particularly non-contact. The biases were usually overestimation for most categories, but underestimation for "sleep", "education", "sports", and "telephone calls". For measurement error, many of the estimates were as large as for nonresponse, but the effect on the estimates is much harder to justify. In this study we assume the effects are proportionate for privacy concerns and quality concerns from the interviewer, but there haven't been any studies to calibrate the effect the way there has been with nonresponse.

### Limitations and Future Work

There are several limitations to the current research. First, the assumption that the propensity model represents nonresponse needs to be examined with other models. Second, many of the time-use categories had non-normal distributions and would have been better analyzed using a model that did not assume a normal distribution. Next, due to the wide confidence intervals associated with small proportions, the bias model for time categories with small time amounts, like volunteering, did not provide as good a fit as in categories with large time values. Future studies should focus on better evaluations for categories with smaller time amounts. The current study adjusted for the fit of the nonresponse propensity models to provide some measure of the bias adjusting for nonresponse. If the models fit more poorly, the intervals would have been wider. Other estimates adjusting for the variability of each of the time use categories would also give wider confidence intervals.

While the differences due to nonresponse in mean times for activities are of interest, the trade-offs between activities is also of interest. To better understand bias, subgroups of interest, such as those living in households with young children, should also be modeled separately. More indicators of measurement error should be used, particularly comparisons with CPS estimates. More link functions need to be explored to better match the

distributions, particularly the zeros. Multivariate methods (seemingly unrelated regressions or structural equation models) may help describe the patterns of bias more clearly.

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Table 1: ATUS Refusal model

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	33730.232	26817.033
SC	33738.526	26949.734
-2 Log L	33728.232	26785.033
R-Square	0.2094	Max-rescaled R-Square 0.3077

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	6943.1989	15	<.0001
Score	6275.1312	15	<.0001
Wald	4995.0898	15	<.0001

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-1.1060	0.1258	77.3448	<.0001
nrfact	1	1.9181	0.2323	68.1942	<.0001
modage	1	-0.00223	0.00192	1.3498	0.2453
modhsp	1	-0.2417	0.0931	6.7358	0.0094
modkid	1	-1.6281	0.0947	295.7850	<.0001
modmar	1	1.2431	0.0410	917.4167	<.0001
modnum	1	-0.0548	0.0178	9.4163	0.0022
modrel	1	3.3415	0.1364	600.3804	<.0001
modsch	1	-0.8294	0.1467	31.9656	<.0001
modwht	1	-0.0652	0.0773	0.7114	0.3990
agerel	1	-0.0914	0.00234	1529.0785	<.0001
hspnum	1	0.0220	0.0277	0.6314	0.4268
kidnum	1	0.1510	0.0252	35.9776	<.0001
numsch	1	0.2550	0.0448	32.4241	<.0001
relwht	1	0.0184	0.0886	0.0432	0.8354
cnt	1	0.1491	0.0243	37.7901	<.0001

Table 2: ATUS Noncontact model

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	20842.095	17874.903
SC	20850.491	18009.236
-2 Log L	20840.095	17842.903

R-Square 0.0875 Max-rescaled R-Square 0.1858

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	2997.1923	15	<.0001
Score	2867.3138	15	<.0001
Wald	2412.6254	15	<.0001

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-0.7601	0.1711	19.7312	<.0001
nnfact	1	1.0481	0.3092	11.4896	0.0007
modage	1	-0.0327	0.00303	115.8767	<.0001
modhsp	1	0.1940	0.1129	2.9502	0.0859
modkid	1	-0.7189	0.1094	43.2072	<.0001
modmar	1	1.0250	0.0590	302.2942	<.0001
modnum	1	-0.00926	0.0223	0.1722	0.6781
modrel	1	0.8804	0.1775	24.6070	<.0001
modsch	1	-0.1773	0.1653	1.1505	0.2834
modwht	1	-0.3745	0.1117	11.2394	0.0008
agerel	1	-0.0408	0.00346	139.2758	<.0001
hspnum	1	-0.0279	0.0334	0.6983	0.4033
kidnum	1	0.0550	0.0297	3.4381	0.0637
numsch	1	0.0663	0.0496	1.7886	0.1811
relwht	1	-0.0650	0.1221	0.2835	0.5944
cnt	1	0.2401	0.0268	80.5744	<.0001

Table 3. Standardized error based on propensity models and measurement error indicators.

VarName	mean(se)	CPS ref	CPS nc	ATUS ref	ATUS nc	Income	quality
Total	1434.349373(0.429733)	-0.00634	-0.31017	0.20610	0.34706	-0.27024	0.06808
Sleep	513.261979(1.749497)	-0.28334	-0.10668	1.27051	1.20539	-0.11525	0.09101
Socializing	269.590682(2.866224)	-0.62015	-0.38357	-0.13482	-0.14722	0.97496	0.18441
Work	205.073491(3.590434)	0.36012	0.41445	-1.24162	-1.36072	-0.28730	-0.25724
Traveling	72.379727(1.027571)	0.73809	0.11839	0.17373	0.29382	-0.46285	-0.16278
Eating	67.587840(0.730269)	-0.39656	-0.20350	-1.00318	-1.29477	0.80975	-0.08807
Personal	46.331073(1.333924)	0.40965	0.02093	-0.00373	0.12341	0.01762	0.08313
Activities	42.529503(1.055025)	-0.39201	-0.18261	0.96375	1.28989	0.23030	0.02180
Hhtasks	41.829792(1.257063)	-0.07690	-0.21840	-0.90910	-1.46067	1.21300	0.03169
Groom	39.835070(0.474536)	0.40836	0.24648	1.01235	1.56389	-0.50777	-0.05444
Housework	36.068538(1.029151)	0.14042	0.08188	-1.39424	-1.29502	-0.40938	-0.05101
Food	35.496786(0.764786)	-0.05992	-0.04040	-1.88065	-2.13662	0.00803	-0.03047
Hhchild	32.782657(0.910129)	0.16845	0.09169	-1.45998	-1.44397	-2.33673	-0.17759
hhcare_child	29.288916(0.834368)	0.21721	-0.00582	-1.46947	-1.37716	-2.08323	-0.14853
buyservice	28.800984(0.738385)	0.15148	0.05526	-0.99988	-1.10156	1.15518	-0.15511
purchase	22.528956(0.620087)	0.11538	-0.05581	-0.82688	-0.91969	1.01960	-0.12798
education	18.776018(1.314530)	0.08536	0.20614	6.44868	7.09043	-1.38272	0.23704
uncoded	18.737085(0.813104)	-0.04300	-0.28104	-0.08324	0.14770	-0.62886	0.45087
sports	18.242611(0.651214)	-0.57810	-0.09716	2.06266	2.09597	-0.64388	-0.06333
lawn	12.996173(0.763881)	-0.03792	-0.25048	-0.73285	-0.95579	1.17388	0.19315
hh_management	12.074965(0.503313)	-0.02086	-0.07129	-1.15933	-1.05185	0.54568	-0.04071
religious	9.701637(0.542893)	0.23845	-0.15174	-0.46905	-0.19056	0.66749	0.26640
volunteer	8.639446(0.524938)	-0.10874	-0.09742	-0.67198	-0.76503	0.41417	-0.09287
telcall	5.945809(0.311095)	-0.35194	0.01327	0.90307	1.61040	0.26516	-0.10167
health	5.815100(1.297034)	0.19855	-0.04893	-0.34023	-0.42024	0.20247	0.03448
pets	5.539110(0.412736)	-0.21236	-0.08813	-0.57986	-0.24342	0.45665	-0.11621
professional	4.990976(0.339517)	0.06809	0.09020	-0.51396	-0.65206	0.50365	-0.12911
tnhhadult	4.572612(0.404680)	0.00720	0.31212	-0.09287	-0.22371	0.56313	-0.06238
tnhhchild	4.292052(0.512466)	0.12035	-0.22113	-0.00994	0.06654	0.70496	-0.03114
nhhcare_child	4.075828(0.504031)	0.12060	-0.21433	0.00811	0.10124	0.75016	-0.02700
int_repair	4.049268(0.410666)	-0.14610	0.05980	-0.23791	-0.77576	0.47087	0.04252
ext_repair	3.354132(0.313338)	-0.18478	-0.12719	-0.73464	-0.86202	0.40359	-0.05876
hheduc_child	2.904238(0.202429)	-0.12935	0.42121	-0.53405	-0.81623	-1.28292	-0.15569
vehicle	2.498088(0.504304)	-0.05273	0.00413	1.30844	0.44854	-0.40013	-0.04760
thhadult	1.839136(0.257434)	-0.12611	0.12682	-0.45071	-0.51383	-0.20560	0.03557
appliance	1.303314(0.234260)	0.74413	0.00227	-0.38689	-0.47776	0.21455	-0.06038
hhcare_adult	0.963780(0.221390)	-0.10056	-0.04049	-0.32277	-0.39540	0.17394	0.04955
hh_services	0.757084(0.111084)	-0.10429	-0.05574	-0.06382	-0.12739	0.27610	0.12918
personal	0.680903(0.147162)	0.64646	-0.17388	-0.29957	-0.22035	0.01254	0.62515
hhhlth_child	0.589504(0.110366)	-0.01575	0.02758	0.04909	0.00077	-1.16741	-0.05603
gymnt	0.523967(0.116575)	0.24681	0.43732	-0.37719	-0.06476	0.16345	-0.04878
hhcare_other	0.063610(0.058618)	-0.12253	0.47493	-0.10911	-0.13015	0.28718	-0.01178
hh_other	0.014740(0.010877)	0.05695	0.15915	-0.13625	-0.16253	-0.30454	-0.01471

Table 4. Relative error based on propensity models and measurement error indicators.

VarName	total(se)	CPS_ref	CPS_nc	ATUS_ref	ATUS_nc	No income	Quality
Total	1434.349(0.430)	-0.000	-0.009	00.006	00.010	-0.008	00.002
Sleep	513.262(1.749)	-0.097	-0.036	00.433	00.411	-0.039	00.031
Socializing	269.591(2.866)	-0.659	-0.408	-0.143	-0.157	01.037	00.196
Work	205.073(3.590)	00.631	00.726	-2.174	-2.382	-0.503	-0.450
Traveling	72.380(1.028)	01.048	00.168	00.247	00.417	-0.657	-0.231
Eating	67.588(0.730)	-0.428	-0.220	-1.084	-1.399	00.875	-0.095
Personal	46.331(1.334)	01.179	00.060	-0.011	00.355	00.051	00.239
Activities	42.530(1.055)	-0.972	-0.453	02.391	03.200	00.571	00.054
Hhtasks	41.830(1.257)	-0.231	-0.656	-2.732	-4.390	03.645	00.095
Groom	39.835(0.475)	00.486	00.294	01.206	01.863	-0.605	-0.065
Housework	36.069(1.029)	00.401	00.234	-3.978	-3.695	-1.168	-0.146
Food	35.497(0.765)	-0.129	-0.087	-4.052	-4.603	00.017	-0.066
Hhchild	32.783(0.910)	00.468	00.255	-4.053	-4.009	-6.487	-0.493
Hhcare_child	29.289(0.834)	00.619	-0.017	-4.186	-3.923	-5.935	-0.423
Buysservice	28.801(0.738)	00.388	00.142	-2.563	-2.824	02.962	-0.398
purchase	22.529(0.620)	00.318	-0.154	-2.276	-2.531	02.806	-0.352
education	18.776(1.315)	00.598	01.443	45.148	49.641	-9.681	01.660
uncoded	18.737(0.813)	-0.187	-1.220	-0.361	00.641	-2.729	01.957
sports	18.243(0.651)	-2.064	-0.347	07.363	07.482	-2.298	-0.226
lawn	12.996(0.764)	-0.223	-1.472	-4.308	-5.618	06.900	01.135
hh_management	12.075(0.503)	-0.087	-0.297	-4.832	-4.384	02.275	-0.170
religious	9.702(0.543)	01.334	-0.849	-2.625	-1.066	03.735	01.491
volunteer	8.639(0.525)	-0.661	-0.592	-4.083	-4.648	02.517	-0.564
telcall	5.946(0.311)	-1.841	00.069	04.725	08.426	01.387	-0.532
health	5.815(1.297)	04.429	-1.091	-7.589	-9.373	04.516	00.769
pets	5.539(0.413)	-1.582	-0.657	-4.321	-1.814	03.403	-0.866
professional	4.991(0.340)	00.463	00.614	-3.496	-4.436	03.426	-0.878
nhhadult	4.573(0.405)	00.064	02.762	-0.822	-1.980	04.984	-0.552
nhhchild	4.292(0.512)	01.437	-2.640	-0.119	00.794	08.417	-0.372
nhhcare_child	4.076(0.504)	01.491	-2.650	00.100	01.252	09.277	-0.334
int_repair	4.049(0.411)	-1.482	00.606	-2.413	-7.868	04.775	00.431
ext_repair	3.354(0.313)	-1.726	-1.188	-6.863	-8.053	03.770	-0.549
hheduc_child	2.904(0.202)	-0.902	02.936	-3.722	-5.689	-8.942	-1.085
vehicle	2.498(0.504)	-1.064	00.083	26.414	09.055	-8.078	-0.961
hhadult	1.839(0.257)	-1.765	01.775	-6.309	-7.192	-2.878	00.498
appliance	1.303(0.234)	13.375	00.041	-6.954	-8.587	03.856	-1.085
hhcare_adult	0.964(0.221)	-2.310	-0.930	-7.414	-9.083	03.996	01.138
hh_services	0.757(0.111)	-1.530	-0.818	-0.936	-1.869	04.051	01.895
personal	0.681(0.147)	13.972	-3.758	-6.475	-4.762	00.271	13.511
hhhlth_child	0.590(0.110)	-0.295	00.516	00.919	00.014	-21.86	-1.049
gvment	0.524(0.117)	05.491	09.730	-8.392	-1.441	03.637	-1.085
hhcare_other	0.064(0.059)	-11.29	43.766	-10.05	-11.99	26.464	-1.085
hh_other	0.015(0.011)	04.202	11.744	-10.05	-11.99	-22.47	-1.085

Table 5. Nonresponse Propensity and Measurement Error.

Variable	No Income	Interviewer
CPS refusal	0.041	-0.0077
CPS noncontact	0.067	0.0038
ATUS refusal	-0.0936	-0.0100
ATUS noncontact	-0.0750	-0.0138