HHS Public Access
Author manuscript
Soc Sci Med. Author manuscript; available in PMC 2019 October 01.

Published in final edited form as:
Soc Sci Med. 2018 October ; 214: 70–82. doi:10.1016/j.socscimed.2018.07.051.

The effect of unstable housing on HIV treatment biomarkers: an instrumental variables approach

Omar Galárraga[a], **Aadia Rana**[b], **Momotazur Rahman**[a], **Mardge Cohen**[c], **Adaora A. Adimora**[d], **Oluwakemi Sosanya**[e], **Susan Holman**[f], **Seble Kassaye**[g], **Joel Milam**[h], **Jennifer Cohen**[i], **Elizabeth T. Golub**[j], **Lisa R. Metsch**[k], and **Mirjam-Colette Kempf**[l]

[a]Brown University, School of Public Health, 121 S. Main St., Providence, RI 02912

[b]University of Alabama at Birmingham, School of Medicine, 1720 2nd Ave. South, Birmingham, AL 35294, USA

[c]Boston Health Care for the Homeless Program, 780 Albany St., Boston, MA 02118, USA

[d]University of North Carolina at Chapel Hill, Institute for Global Health and Infectious Diseases, 130 Mason Farm Rd., Chapel Hill, NC 27599, USA

[e]Montefiore Medical Center, 3311 Bainbridge Ave., Bronx, NY, 10467, USA

[f]SUNY Downstate Medical Center, 450 Clarkson Ave., Brooklyn, NY 11203, USA

[g]Georgetown University, Department of Medicine, 3800 Reservoir Rd., NW, Washington, DC 20007, USA

[h]University of Southern California, Institute for Health Promotion & Disease Prevention Research, 2001 N. Soto St., Los Angeles, CA 90032, USA

[i]University of California at San Francisco, School of Pharmacy, 1515 Scott St., San Francisco, CA 94115, USA

[j]Johns Hopkins Bloomberg School of Public Health, 615 N. Wolfe St., Baltimore, MD 21205, USA

[k]Columbia University, Mailman School of Public Health, 722 W. 168th St., New York, NY 10032, USA

[l]University of Alabama at Birmingham, School of Nursing, 1720 2nd Ave. South, Birmingham, AL 35294, USA

Abstract

Unstable housing, including homelessness, is a public policy concern for all populations, and more critically for people with a serious health condition such as HIV. We measure the effect of unstable housing on HIV treatment biomarkers: viral suppression (viral load < 200 HIV RNA copies per

Corresponding author Brown University, School of Public Health, 121 S. Main St., Providence, RI 02912; omar_galarraga@brown.edu.

ml) and adequate CD4+ T-cell count (CD4>350 cells per µl). We use panel data (1995–2015) from 3,082 participants of the Women's Interagency HIV Study (WIHS) sites in Bronx and Brooklyn (NY), Chicago (IL), Los Angeles and San Francisco (CA), and Washington (DC). The instrumental variable (IV) measures allocations for the Housing Opportunities for People with AIDS (HOPWA) per person newly infected with HIV, and it represents actual availability of housing assistance for HIV-positive persons at the metropolitan area level. Using an extended probit model with the IV, we find that unstable housing reduces the likelihood of viral suppression by 51 percentage points, and decreases the probability of having adequate CD4 cell count by 53 percentage points. The endogeneity-corrected results are larger than naïve probits, which show decreases of 8.1 and 7.8 percentage points, respectively. The hypothesized pathways for the effect are: decreased use of mental healthcare/counseling, any healthcare, and less continuity of care. Increasing efforts to improve housing assistance, including HOPWA, and other interventions to make housing more affordable for low-income populations, and HIV-positive populations in particular, may be warranted not only for the benefits of stable housing, but also to improve HIV-related biomarkers.

Keywords

unstable housing; HIV/AIDS; viral suppression; CD4 cell count; housing assistance; instrumental variables

1. Introduction

Understanding the impact of socioeconomic determinants of health, including unstable housing and homelessness, is a public policy priority. Stable housing has been shown to be associated with some health benefits, though these findings are inconsistent (Fortson and Sanbonmatsu, 2010; Gennetian et al., 2012; Jacob et al., 2015; Katz et al., 2001; Kling et al., 2005). The impact of housing status on persons living with HIV (PLHIV) has both individual and public health implications (Aidala et al., 2016). PLHIV are more likely to experience homelessness and decreased access to care than the general population (Blair et al., 2014).

Since the mid-1990s, antiretroviral treatment (ART) has extended the lives of PLHIV, and viral suppression has become the ultimate goal of HIV care and treatment. Sufficiently high adherence to a daily regimen of ART is necessary to obtain viral suppression. Unstable housing may be a barrier to adherence and a risk factor for unsuppressed viral load, which increases morbidity and mortality as well as likelihood of transmitting HIV to sexual partners, needle sharing partners, and infants (Muthulingam et al., 2013; Riley et al., 2007).

Stable housing may be associated with better HIV treatment outcomes, including viral suppression (Aidala et al., 2016; Leaver et al., 2007), though the issue is far from settled. A randomized controlled trial (RCT) testing the effects of housing assistance on the health and risk behaviors of homeless and unstably-housed PLHIV did not detect differences in viral suppression (Kidder et al., 2007; Wolitski et al., 2010). An earlier pilot project found some positive results in viral suppression and CD4 cell count but the sample size was small (n<100) and biomarkers were not balanced at baseline (Buchanan et al., 2009). Moreover, the Housing Opportunities for People with AIDS (HOPWA) program was associated with better engagement in the HIV care continuum, but not with virologic suppression (Terzian et al., 2015).

2. Conceptual Framework

Concerns about poor housing and health in the U.S. may be traced back to at least the work of Jacob Riis documenting the conditions of the New York tenements in *How the Other Half Lives* (Riis, 1890). More recently, the literature on the gradient has been important in distilling specific differences in socio-economic status and their effects on health (Adler et al., 1994); and how specific events can affect housing and health (Downing, 2016; Fussell and Lowe, 2014). Within that broad context, the economics literature characterizes unstable housing –and homelessness in particular–as currently living in a space with quality below a specified threshold (O'Flaherty, 1995); and in the Grossman model (Grossman, 1972), individuals produce health through investments in preventive and curative medical services, including adherence to current medication. Thus, we can think of three theoretical routes through which unstable housing would deplete health: time utilization, health depreciation, and income effect.

First, to motivate the analysis of the effect of unstable housing on health through time use, we modify a model of the demand for healthcare among the urban poor with special emphasis on the role of time (Acton, 1976, 1975). The intuition is that own-time devoted to housing concerns detracts from time needed for medical care. The partial derivative of medical care with respect to own-time devoted to housing concerns is strictly negative (Appendix A). Thus, this simple model implies that as the own-time input per unit of housing increases, medical services consumption decreases. Lack of stable housing implies increasing own-time for housing concerns for several potential reasons. Individuals experiencing an unstable housing situation, particularly those with chronic health conditions, may be more likely to miss physician's appointments, miss current medicine doses, need to switch clinic or healthcare provider, need to switch pharmacist, and/or suffer from mental health conditions (depression, anxiety) (Thomson and Thomas, 2015).

Second, unstable housing would have a deleterious effect on health through a higher depreciation rate. In the Grossman model (Grossman, 1972), housing is explicitly mentioned as a likely factor affecting health (see his footnote #3, p.226); and the rate of depreciation of health, in the normal process of living and aging, can also be affected by negative shocks such as unstable housing. In particular, unstable housing would increase the depreciation rate because of higher allostatic load (cumulative stress) (Fussell and Lowe, 2014).

Third, we posit that unstable housing adversely affects health through an income effect. Higher income is associated with improved health outcomes thorough the life cycle in the U.S. and elsewhere (Case et al., 2002). Under this conceptualization, unstable housing can lead to an income shock through reduced earnings and/or unemployment (Desmond and Gershenson, 2016), which in turn can affect use of healthcare and result in less efficient production of health.

Author Manuscript

Author Manuscript

Author Manuscript

Current Study

We use instrumental variables to analyze the causal effect of unstable housing on HIV treatment biomarkers (viral suppression and CD4 cell count). We quantify the effect of unstable housing on the HIV treatment outcomes using data from the Women's Interagency HIV Study (WIHS), the largest and longest-running cohort of HIV-infected women in the U.S.

We hypothesize first that unstable housing is associated with decreased viral suppression and CD4 cell counts. The use of instrumental variables helps to correct potential biases arising from unobserved variables that may be correlated with outcomes and unstable housing, as well as possible reverse causality. Second, in the empirical analysis, we test for specific effect pathways including mental health/counseling support; use of any healthcare provider; and continuity of care (with same provider). These channels are consistent with, and complementary to other empiricallysupported theories of change of housing investment and health (Thomson and Thomas, 2015).

3. Methods

3A. Clinical Sites and Inclusion Criteria

From 1994, the WIHS was conducted at six clinical consortia (with over 23 clinical sub-sites) in: New York City (Bronx and Brooklyn); Washington, DC; Los Angeles; San Francisco; and Chicago. The WIHS protocol includes a baseline assessment and follow-up study visits *every six months* (Barkan et al., 1998), and it has maintained very high retention rates (https://statepi.jhsph.edu/wihs/wordpress). Inclusion criteria for our current study require that: (1) Participants be HIV-positive and (2) have data available on living situation (i.e., responded to question: "*Where are you living now?"* at least twice; one of the times could be at the baseline interview). We have data on living situation for HIV-positive participants for 98% of the eligible visits. We limit the sample to data from 1995 to 2015.

3B. Variables

HIV treatment outcomes—We evaluate two dichotomous HIV treatment biomarkers. The primary outcome of interest is viral suppression (=1 if the patient has less than 200 copies of HIV RNA per mL of blood). This is an important biomarker because suppressed viral load (<200 copies/mL) correlates with low risk of transmitting HIV (Cohen et al., 2013; Eshleman et al., 2017; Hall et al., 2011). Our secondary outcome is CD4+ T-cell count (=1 if above 350 cells/µl blood). CD4 cells are blood cells that the HIV virus targets for infection, and eventually kills. As infection advances, the number of CD4 cells declines. When the CD4 cell count drops below 200 cells/µl due to advanced HIV disease, a person is diagnosed with AIDS. The normal range of CD4+ T cells is 500 to 1,500 cells/µl of blood. Our threshold is based on the D.H.H.S. treatment guidelines prevalent until 2010 (Panel on Antiretroviral Guidelines for Adults and Adolescents, 2009).

Unstable Housing—Unstable housing (H) is the main explanatory variable. It is a dichotomous variable (=1 if participant responded "yes" that she currently resides on the street/beach, shelter/welfare hotel, jail/correctional facility, or halfway house) (Appendix C).

Covariates—Based on the literature and previous research (Aidala et al., 2016), we use a covariate vector $\boldsymbol{X}$ which controls for age, age squared, WIHS site, educational level, race/ethnicity categories, marital status, number of children participant takes care of, injection drug use (IDU), total number of male sexual partners.

Potential pathways—Based on our conceptual framework (above), and previous empirical work (Thomson and Thomas, 2015), we hypothesize that the potential channels for the effect of unstable housing on HIV treatment outcomes include decreased use of any healthcare, mental healthcare/counseling, and less continuity of care. We operationalize these concepts with variables collected via WIHS questionnaires: use of any healthcare provider; mental health/counseling support; and continuity of care (with same provider) (Appendix C).

3C. Econometric Approach

We define y as a binary variable: the HIV treatment biomarker (either viral suppression or CD4 cell count>350, as defined earlier). Let $\boldsymbol{X}$ be a vector of observed (covariate) regressors, and $\boldsymbol{\beta}$ a corresponding coefficient vector, with ε an unobserved error. We include the endogenous binary indicator H for unstable housing. A maximum likelihood estimator is implemented as follows:

$$y_{it} = I\left(X_{it}\,\beta_1 + \beta_2\,H_{it} + \varepsilon_{it} \geq 0\right) \quad for\; i = 1\;,\ldots,n;\; t = 1,\ldots,42 \quad (1),$$

where $I(\cdot)$ is the indicator function, i indexes individual participants, and t is time (i.e., eligible biannual visits numbered 1 to 42, which correspond to calendar time 1995 to 2005). We first use a naïve probit model, with normally distributed error (ε). Our first estimation provides point and interval estimates of β_2, the coefficient of interest, and we estimate outcome probabilities and marginal effects as follows:

$$Pr[y = 1 | \boldsymbol{X},\ H] \text{ and}$$

$$\partial Pr[y = 1 | \boldsymbol{X},\ H] / \partial H$$

where the latter derivative expresses the change in the outcome probability from a discrete change of being in stable housing to becoming unstably housed (i.e., the change from H=0 to H=1).

There are at least two key endogeneity concerns when evaluating the relationship between unstable housing and HIV treatment outcomes: omitted variables bias and reverse causality. Unobserved variables omitted from the analysis could be, for example, time discounting and risk aversion, which are correlated with unstable housing (Eckel et al., 2009; James, 2009), and which could also be correlated with adherence and HIV treatment outcomes. Their omission could bias our results since we are not directly controlling for them (Wooldridge 2010, chapter 4). Moreover, there could be reverse causality because PLHIV with low adherence to ART are not likely to achieve adequate CD4 cell count and viral suppression, which in turn will have employment and earnings repercussions (Auld, 2002; Galárraga et al., 2010; Goldman, 2003), which could also affect housing.

To address the endogeneity concerns, we implement a probit model with instrumental variables augmenting equation (1) above with a second equation as follows:

$$H_{it} = \alpha_1 z_{it} + \boldsymbol{X}_{it}\boldsymbol{\alpha}_2 + v_{it} \qquad for\ i = 1, \ldots, n;\ t = 1, \ldots, 42 \quad (2),$$

where z_{it} is an instrumental variable (defined below); and ν a disturbance term. The main parameter of interest again is β_2, which we can now be estimated with equations (1) and (2) jointly using quasi-maximum likelihood methods to address endogeneity (Wooldridge, 2014, 2010). We use the extended probit command in Stata (eprobit with endogenous treatment), which make use of the conditional mix process (cmp) function to implement a triangular system of equations (Roodman, 2011) (Appendix B).

3D. Instrumental Variable

The main instrumental variable (IV) is a measure of the *actual* availability of the Housing Opportunity for Persons with AIDS (HOPWA) program at the metropolitan area level: HOPWA allocations (in current USD$) per 1,000 people *newly diagnosed* with HIV infection per year. This measure provides a more accurate picture of the actual availability of resources to address housing instability among PLHIV than just plain HOPWA allocations. This is because until July 2016 HOPWA allocations were made based on the number of *historical* AIDS cases (regardless of whether the people with AIDS were still alive), which in fact provided more resources to cities with older and more established epidemics (U.S. GAO, 2015). This arcane allocation formula creates a natural experiment: some cities receive more resources per PLHIV than others, and the additional resources are not allocated based on need. The IV exhibits time and geographic variation at the metropolitan area because of the differences between historical cases and the actual number of newly-diagnosed PLHIV.

We obtain the HOPWA data from publicly-available datasets maintained by the U.S. Department of Housing and Urban Development (http://data.hud.gov/data_sets.html), and combine them with data on incidence and prevalence of HIV from the Centers for Disease Control and Prevention (CDC) (https://www.cdc.gov/hiv/library/reports/hiv-surveillance.html). We then merge the IV with the WIHS dataset at the metropolitan area level to predict housing status (at the individual level) independently of the individual-level HIV treatment outcomes (Appendix D).

The model presented in equations (1)-(2) identifies the causal impact of unstable housing on HIV treatment outcomes under two key assumptions of relevance and validity. The IV is relevant because it is a strong predictor of the endogenous variable, unstable housing. We assess the relevance of the IV first using the Cragg-Donald *F*-statistic test, under the rule of thumb that it should be at least above ten (Staiger and Stock, 1997). The IV needs to be valid (i.e., uncorrelated with the error term in the outcome equation), in the sense that it should affect HIV treatment outcomes only through unstable housing. We hypothesize that our IV is valid first because it is generated at an aggregate metropolitan level area; and second because it varies substantially across time and geography due to the epidemic history and the governmental bureaucratic inertia, which left the arcane allocation rules unchanged (U.S. GAO, 2015) (until corrected in July 2016, i.e., after our period of observation).

3E. Effect Pathways

We test specific pathways through which unstable housing can affect HIV treatment outcomes, including: mental health/counseling support; use of (any) healthcare provider; and continuity of care (with same provider). For the effect channels estimation, we use the same econometric approach and IV as in the main analyses (equations 1–2) to correct for endogeneity. We substitute the effect pathway as the outcome in separate estimating equations.

4. Results

In Table 1, we present descriptive statistics. In terms of the main outcomes: 48.3 percent of 57323 observations exhibit viral suppression (<200 HIV RNA copies per ml), and 55.9 percent of observations have adequate CD4 cell counts (>350 per μl). Participants report unstable housing in 4.8 percent of the observations. Average age is 43.9 years. About a third of participants (32.4 percent) completed grades 7–11; 29.9 percent completed high school; and a fourth (25 percent) attended some college. Most participants are African American (57 percent) and Hispanic (including 7 percent who classify themselves as "*white Hispanic*", 2 percent as "*African-American Hispanic*", and 15.9 percent as "*other Hispanic*"). Participants are distributed across the six original WIHS sites: ranging from 14 percent from Washington, DC to 19.6 percent from the Bronx, NY. In terms of marital status, almost a third of participants have never been married (29.6 percent), 22 percent are married legally or by common law; and 11 percent are not married but live with a partner. Regarding drug use: Almost a third (30 percent) of participants have ever injected drugs, and almost three quarters (72 percent) have ever used non-injected recreational drugs. The mean number of lifetime male sex partners is 78 (median is 10; not shown). Finally, in terms of the main instrumental variable: the mean HOPWA allocations per newly HIV-diagnosed person at the metropolitan area was 8.6 (in current USD$ 000s).

Figure 1 summarizes the first stage results. It depicts a clearly downward-sloping relation of the probability of unstable housing (y-axis) and HOPWA funds allocations (in $000s) per newly-diagnosed PLHIV (in the x-axis). We find a negative relation with considerable variation by metropolitan area. This exogenous variation is the result of the particular HOPWA allocation formula that was in place until July 29, 2016, which provided funds based on historical cumulative AIDS cases, regardless of current need (i.e., without considering current persons living with HIV, and without considering unstable housing).

Furthermore, there is considerable variation across time in each metropolitan area. The funds per newly-diagnosed PLHIV increase more steeply in sites with older, more mature HIV/AIDS epidemics with fewer new cases (e.g., San Francisco); while they remain almost flat or declining in sites where PLHIV diagnoses continue to accrue at faster rates (Figure 2).

There is a consensus that the historical AIDS-cases-based HOPWA allocations did not keep up with the epidemiological trends (e.g., in Chicago): this is the main reason why the United States Government Accountability Office (GAO) recommended a revision of the HOPWA allocation formula (U.S. GAO, 2015), which was put into effect in July 2016. Thus, the unusually complex interaction of the allocation rules and the epidemiological trends, create temporal and spatial variation, which we can use as a natural experiment.

Table 2 confirms the initial graphical analysis by showing first stage regression results. The IV (HOPWA allocations per newly-diagnosed PLHIV) is negatively and strongly correlated with unstable housing. Column (1) shows the results controlling only for site: the relationship is statistically significant and negative. Column (2) adds more extensive controls including age, age squared, education dummies, race/ethnicity dummies, number of children participant takes care of, and marital status dummies. The coefficient remains negative and strongly significant. In column (3), we include controls for injected and non-injected (illegal) drug use as well as number of male sex partners. The coefficient is slightly attenuated, but remains negative and strongly significant. In the results of column (4), which constitute our main first-stage-regression results, in addition to all of the controls, we also use robust standard errors clustered at the individual level. For this last, preferred specification, which we use subsequently, the *F*-statistic for the excluded instrument is 25.98; well above the minimum recommended threshold of 10 (Staiger and Stock, 1997). Thus, these results suggest that the IV is highly relevant because of the strong negative correlation between HOPWA allocations per newly-diagnosed PLHIV and unstable housing.

While we cannot directly test the null hypothesis that HOPWA allocations are uncorrelated with the residual in the biomarker outcomes (viral suppression and adequate CD4 cell count), we can examine whether the instrument is correlated with observable factors that may be correlated with the unobservable factors that affect the second-stage residual. To that effect, we divide the observations into two groups: those with HOPWA allocations above the site-specific median (high value IV), and those whose with HOPWA allocations below the site-specific median (low value IV). In Table 3 we list the means of the variables for these two groups. The first explanatory variable is age which is greater in the high value IV group (47 years) versus the low IV group (41 years); this is consistent with the overall time trend in HOPWA allocations per newly-diagnosed PLHIV which increase over time (see also Figure 2). The rest of the explanatory variables have means that are generally similar across the two IV groups. The overall similarity in means of explanatory variables is consistent with the identifying assumption that the distribution of unobservable factors correlated with the residual in the biomarker's equation are uncorrelated with the instrumental variable. Furthermore, in Figure 3 we conduct an additional validity check by plotting the trends of the ratio of historical HIV cases to the new diagnoses. This ratio summarizes the macro-policy trends at the site level (Figure 3), and also shows considerable geographical and time variation. There is no a priori reason why this variation should be correlated with housing assistance need, or the residuals of HIV treatment biomarkers at the individual level.

Table 4 presents the main results. The first two columns of Table 4 contain probit estimates of the effect of unstable housing on the probability that viral suppression (viral load<200) is achieved (column 1) and the probability that adequate CD4 cell count (>350) is achieved (column 2). For each biomarker, the coefficient estimates are negative and statistically significant at the 1 percent level: women who experience unstable housing exhibit worse health outcomes.

Unstable housing produces clinically-meaningful negative impact on health: it decreases the probability of viral suppression by 8.1 percentage points (column 1); and it decreases the probability of having adequate levels of CD4 cell counts by 7.9 percentage points (column 2). Furthermore, we can see that unstable housing produces even more negative impacts on health when endogeneity is addressed. In column (3), using probit with IV, unstable housing reduces viral suppression by 51 percentage points, and it decreases the likelihood of having CD4 cell count above the threshold (>350 cells) by 53 percentage points.

In Table 5, we evaluate the potential pathways. In Pathways A, the corrected model using instrumental variables reveals that unstable housing reduces use of mental health/counseling by 25 percentage points. In Pathways B, we can see that unstable housing reduces use of (any) healthcare provider by 37 percentage points. Similarly, in Pathways C, we can see that unstable housing resulted in a reduction of 76.3 percentage points in the likelihood of seeing the same provider (continuity of care).

5. Discussion

This paper implements an econometric model of the effect of unstable housing on HIV treatment biomarkers (viral suppression and CD4 cell count). An extended probit model with an instrumental variable serves to correct for the endogeneity in unstable housing. We use panel data collected from participants in the Women's Interagency HIV Study (WIHS) between 1995 and 2015. The endogeneity concerns stem from potential omitted variables bias as well as potential reverse causality. Using a naïve probit model results in weaker associations of unstable housing with worse health outcomes, while in the corrected models unstable housing has larger negative effects on viral suppression and adequate CD4 cell count.

We make several contributions to the literature. First, we add to the emerging body of knowledge on the impacts of socio-economic disparities not just on self-reported health outcomes but on objectively measured health biomarkers (Chatterji et al., 2012; Jürges et al., 2013; Michaud et al., 2016). We find that unstable housing drastically reduces both HIV viral suppression and CD4+ T-cell counts for PLHIV; thus worsening clinical outcomes, and further exacerbating health disparities. Second, we show specific pathways for the effects, including use of any mental health/counseling, any healthcare, and continuity of care, which extends the empirically-observed conceptual framework (Thomson and Thomas, 2015). Third, we add to the growing literature on the econometric applications with binary outcomes and binary endogenous regressors that do not rely solely on parametric specifications for identification, but that use instrumental variables and more generalizable models (Angrist, 2001; Chiburis et al., 2012; Wooldridge, 2014). Fourth, we add to the emerging body of knowledge on the impacts of public policies to address housing instability among the poor (Fortson and Sanbonmatsu, 2010; Jacob et al., 2015; Jacob and Ludwig,

2012) by showing that actual HOPWA allocations per new HIV diagnosis (our IV) reduce housing instability among PLHIV.

Finally, this paper contributes to the literature by providing rigorous non-experimental evidence of the deleterious effects of unstable housing on HIV treatment outcomes– an area where conducting randomized trials is no longer feasible nor ethical (Frieden, 2017; Wolitski et al., 2010). The IV, as hypothesized, helps us to predict the likelihood of unstable housing. HOPWA allocations per newly-diagnosed PLHIV are strongly and negatively correlated with unstable housing. The IV is relevant as it shows high F statistics; and it is valid because of its quasi-experimental nature: it results from a naturally-occurring random combination of arcane allocation rules and the historical evolution of the HIV epidemic in the U.S. over the past 40 years. Using this natural experiment for identification gives us some confidence in the results. The endogeneity-corrected probit models help uncover potential pathways through which unstable housing affects HIV treatment outcomes, including use of mental health/counseling, any healthcare, and continuity of healthcare (with the same provider). The latter pathway is particularly strong: unstable housing dramatically disrupts continuity of care.

Limitations

This paper has some limitations. First, our definition of unstable housing is not fully consistent with the definition for chronically homeless population (as published for the Department of Housing and Urban Development, HUD, in the Federal Register of December 4, 2015: https://www.gpo.gov/fdsys/pkg/FR-2015-12-04/pdf/2015-30473.pdf). To be considered chronically homeless, a person must have been living in a place not meant for human habitation, in an emergency shelter, or a safe haven for the last 12 months continuously or on at least four occasions in the last three years where those occasions cumulatively total at least 12 months. Nevertheless, the question in the WIHS questionnaire only asked about the ***current*** living situation (Appendix C). It did not ask about the episodes of unstable housing in the previous months. Thus, future research should incorporate a more granular measurement of housing instability. Second, the period of study includes the period of the Great Recession of 2008–09 and its aftermath, and it may be a particularly difficult period in the housing market, which may have exacerbated some of the problems (Bitler and Hoynes, 2015).

Conclusion

This paper shows a strong negative effect on viral suppression and adequate CD4 cell count; and it elucidates specific channels by which unstable housing can affect these HIV treatment outcomes, including reduced use of any healthcare, mental health/counseling, and less continuity of care. The findings suggest that increasing efforts to improve housing assistance, including HOPWA, and other interventions to make housing more affordable for low-income populations, and HIV-positive populations in particular, may be warranted not only for the benefits of stable housing, but also to improve HIV-related biomarkers.

ACKNOWLEDGEMENTS

Kemi Sosanya [g]; Susan Holman [h]; Seble Kassaye [i]; Joel Milam [j]; Jennifer Cohen [k]; Elizabeth T. Golub [l]; and Lisa Metsch [m] participated in data collection and provided comments. Data were collected by the Women's Interagency HIV Study (WIHS). WIHS Principal Investigators are: UAB-MS WIHS (Mirjam-Colette Kempf and Deborah Konkle-Parker), U01-AI-103401; Atlanta WIHS (Ighovwerha Ofotokun and Gina Wingood), U01-AI-103408; Bronx WIHS (Kathryn Anastos and Anjali Sharma), U01-AI-035004; Brooklyn WIHS (Howard Minkoff and Deborah Gustafson), U01-AI-031834; Chicago WIHS (Mardge Cohen and Audrey French), U01-AI-034993; Metropolitan Washington WIHS (Seble Kassaye), U01-AI-034994; Miami WIHS (Margaret Fischl and Lisa Metsch), U01-AI-103397; UNC WIHS (Adaora Adimora), U01-AI-103390; Connie Wofsy Women's HIV Study, Northern California (Ruth Greenblatt, Bradley Aouizerat, and Phyllis Tien), U01-AI-034989; WIHS Data Management and Analysis Center (Stephen Gange and Elizabeth Golub), U01-AI-042590; Southern California WIHS (Joel Milam), U01-HD-032632 (WIHS I – WIHS IV). The WIHS is funded primarily by the National Institute of Allergy and Infectious Diseases (NIAID), with additional co-funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD), the National Cancer Institute (NCI), the National Institute on Drug Abuse (NIDA), and the National Institute on Mental Health (NIMH). Targeted supplemental funding for specific projects is also provided by the National Institute of Dental and Craniofacial Research (NIDCR), the National Institute on Alcohol Abuse and Alcoholism (NIAAA), the National Institute on Deafness and other Communication Disorders (NIDCD), and the NIH Office of Research on Women's Health. WIHS data collection is also supported by UL1-TR000004 (UCSF CTSA), UL1-TR000454 (Atlanta CTSA), and P30-AI-050410 (UNC CFAR). Earlier versions of this research were presented at the International Health Economics (iHEA) meetings at Boston University, MA in July 2017 and at Brown University's Population Studies and Training Center (PSTC) in November 2017. The contents of this publication are solely the responsibility of the authors and do not represent the official views of the National Institutes of Health (NIH). The sponsor(s) had no role in the study design; in the analysis and interpretation of data; in the writing of the article; or in the decision to submit it for publication.

APPENDICES

A.: THEORETICAL MODEL

Following a model to emphasize the role of time in medical care (Acton, 1976), we assume that individuals derive utility from medical care (*m*) and housing (*H*) as follows:

$$U = U(m, H) \quad \text{(A1a)}$$

subject to

$$(p + wt)m + (q + ws)H \leq F = a + wT \quad \text{(A1b)}$$

where

U = utility

m = medical services (clinical appointments, pharmacy, etc.)

H = housing

p = out-of-pocket money price per unit of medical services

t = own-time input per unit of medical services consumed

q = money price per unit of H consumed (i.e., rent or mortgage)

s = own-time input per unit of H (i.e., time dealing with housing concerns)

w = earnings per hour

F = total (full) income

a = non-earned (additional) income

T = total amount of time available

Healthcare may include medical appointments, adhering to current treatments, engaging on preventative care, etc. Housing is a "home good" for which rent or mortgage may be paid in the form of q, but for which also time is required in the form of looking for housing to rent, or furnishing/decorating a new place, or dealing with eviction, including its avoidance or its consequences (Desmond, 2016).

We assume that the utility function is twice differentiable for each good, and that the first and cross derivatives are positive, while the second derivatives are negative. We first construct the Lagrangian as follows:

$$\mathscr{L} = U(m, H) + \lambda[(p + wt)m + (q + ws)H - a - wt] \quad \text{(A2)}$$

with first-order conditions:

$$\frac{\partial \mathscr{L}}{\partial m} = U_m + \lambda(p + wt) = 0 \quad \text{(A3a)}$$

$$\frac{\partial \mathscr{L}}{\partial H} = U_H + \lambda(q + ws) = 0 \quad \text{(A3b)}$$

$$\frac{\partial \mathscr{L}}{\partial \lambda} = m(p + wt) + H(q + ws) - a - wT = 0 \quad \text{(A3c).}$$

We are interested in how medical services change with a change in own-time devoted to housing concerns *(∂m/∂s).* Thus, we differentiate the system of equations (A3) with respect to s to obtain:

$$U_{mm}\frac{\partial m}{\partial s} + U_{mH}\frac{\partial H}{\partial s} + (p + wt)\frac{\partial \lambda}{\partial s} = 0 \quad \text{(A4a)}$$

$$U_{Hm}\frac{\partial m}{\partial s} + U_{mH}\frac{\partial H}{\partial s} + (p + wt)\frac{\partial \lambda}{\partial s} = -w\lambda \quad \text{(A4b)}$$

$$(p + wt)\frac{\partial m}{\partial s} + (q + ws)\frac{\partial H}{\partial s} = -Hw \quad \text{(A4c).}$$

The determinant |D| is positive, and we can solve using Cramer's rule as follows:

$$\frac{\partial m}{\partial s} = \frac{\begin{vmatrix} 0 & U_{mH} & (p + wt) \\ -w\lambda & U_{MH} & (q + ws) \\ -Hw & (q + ws) & 0 \end{vmatrix}}{|D|} \quad \text{(A4d);}$$

to find the expression:

$$\frac{\partial m}{\partial s} = \frac{-U_{m\mu}(Hw)(q + ws) - (p + wt)w\lambda(q + ws)HwU_{HH}}{|D|} \quad \text{(A4e).}$$

Given the assumptions of a negative second derivative U_{HH} and a positive cross derivative, and given that the first order conditions (A3) imply that λ is we can conclude with certainty that $\frac{\partial m}{\partial s} < 0$. Since the expression of interest is strictly negative, the model implies that as the own-time input per unit of housing increases

B.: CONSTRUCTION AND ESTIMATION OF LOG LIKELIHOOD FUNCTIONS

a) Naïve probit model

In the naïve probit model:

$$y_i = I\left(\boldsymbol{X_i\beta_1} + \beta_2 H_i \quad + \varepsilon_i \geq 0\right) \quad \text{(D1)}$$

where I is the indicator function, y is the biomarker outcome, H represents unstable housing, and the i indexes individual observations. The assumption is that ε has a standard normal distribution. The log likelihood is given by:

$$lnL = \sum_{i=1}^{N}\left\{y_i ln\Phi\left(\boldsymbol{X_i\beta_1} + \beta_2 H_i\right) + \left(1 - y_i\right)ln\Phi\left(-\boldsymbol{X_i\beta_1} - \beta_2 H_i\right)\right\} \quad \text{(D2)}$$

where $\Phi(\cdot)$ is the standard normal cumulative distribution function; and the conditional probability of a successful outcome is given by:

$$E\left(y_i \middle| \boldsymbol{X_i}, H_i\right) = \Pr\left(y_i = 1 \middle| \boldsymbol{X_i}, H_i\right) = \Phi\left(\boldsymbol{X_i}\boldsymbol{\beta_1} + \beta_2 H_i\right) \quad \text{(D3).}$$

b) Probit with binary endogenous regressor and instrumental variable

Our preferred method provides an estimate of the effect of unstable housing (*H*) on HIV treatment outcomes (*y*) addressing endogeneity (Wooldridge, 2014, 2010) with the addition of an instrumental variable (z), which is correlated with *H*, as follows:

$$y = I\left(\boldsymbol{X}\boldsymbol{\beta_1} + \beta_2\, H \qquad + \varepsilon \geq 0\right) \quad \text{(D4)}$$

$$H = I\left(\boldsymbol{X}\boldsymbol{\alpha}_1 + \qquad + \alpha_2 z \quad + v \geq 0\right) \quad \text{(D5)}$$

where we omit the indexing at the individual level, for clarity, and as before, *y* represents the main biomarker outcome, ***X*** is the (same) covariate vector (in both equations), and ε and ν disturbance terms. The main parameter of interest is β_2, which we estimate using quasi-log likelihood with a linear reduced from of the system (D4-D5) given by:

$$E(y \mid H, \boldsymbol{X}, z) = E(y \mid H, z) = \Phi\left(\boldsymbol{X_3}\boldsymbol{\beta_3} + z\right) \quad \text{(D6)}$$

where is $\boldsymbol{X_3}$ a function of (*H,* ***X****, z*) The average effect of ***X*** and z. The average effect of exposure to unstable housing is given by:

$$\hat{\tau}_{ATE} = N^{-1} \sum_{l=1}^{N} [\Phi(\boldsymbol{X_{31}}\widehat{\boldsymbol{\beta_{31}} + z_1}) - \Phi(\boldsymbol{X_{30}}\widehat{\boldsymbol{\beta_{30}}} + z_0)] \quad \text{(D7)}$$

where we obtain the (scaled) estimated coefficients (β_{31} *and* β_{30}) by applying a selection-correction probit for *H=1* and *H=0* respectively.

C.: SELECTED QUESTIONNAIRE ITEMS

A.1 Unstable Housing

The endogenous variable was operationalized from responses to

“Where are you living now?” (question B3 in the WIHS F21 questionnaire) as follows:

Unstable housing (=1) was defined as two consecutive positive responses to either:

Rooming, boarding, or halfway house.......... 4

In a shelter/welfare hotel.............................. 5

On the street(s) (beach)................................ 6

Jail/Other correctional facility...................... 7

Residential drug/alcohol treatment facility….8

Other place..9

Unstable housing (=0) implies positive responses to either:

In your own house/apartment................... 1

At your parent's house.............................. 2

Someone else's house/apartment.............. 3

We reproduce the relevant portion of the questionnaire below, along with the highlighted directive, which may produce an “indication” bias:


B.3. HAND PARTICIPANT RESPONSE CARD 1.
Where are you living now?

In your own house/apartment.................. 1
At your parent's house........................ 2
Someone else's house/apartment............... 3
Rooming, boarding, or halfway house.......... 4 (B.13)
In a shelter/welfare hotel................... 5 (B.13)
On the street(s) (beach)..................... 6 (B.13)
Jail/Other correctional facility............ 7 (B.20b)
Residential drug/alcohol treatment facility.. 8 (B.13)
Other place.................................. 9 (B.13)

RES_SD

A.2 Potential pathways

The potential pathways were operationalized from responses to the Engagement in Care (WIHS F25) and other questionnaire items as follows:

Pathways A: Mental health / counselling provider

“Since your (MONTH) study visit, have you received care or services from a psychiatrist, counselor or other mental health professional?” Yes=1 No=0 [F25, B5]

Pathways B: Healthcare provider access

“Since your study visit on __ __ / __ __ / __ __, have you seen a healthcare provider? Yes=1, No=0 [F25, B1]

Pathways C: Same provider / continuity of care

“Since your (MONTH) study visit, when you went for medical care, did you usually (more than half of the time) see the same healthcare provider or group of providers for your medical appointments?” Yes=1, No=0 [F25, B2]

D.: INSTRUMENTAL VARIABLE CONSTRUCTION AND DOCUMENTATION

HOPWA Allocations per newly-diagnosed person living with HIV:

We construct the instrumental variable using data on Housing Opportunities for Persons with AIDS (HOPWA) allocations from various sources including the Department of Housing and Urban Development (HUD):

U.S. Department of Housing and Urban Development [last accessed 5 October 2016]: https://www.hudexchange.info/grantees/allocations-awards/ [for years 2003-2015]

https://archives.hud.gov/offices/cpd/communitydevelopment/congress/1994.pdf

https://www.gpo.gov/fdsys/pkg/FR-1995-01-25/pdf/95-1792.pdf

https://www.gpo.gov/fdsys/pkg/FR-1996-10-23/html/96-27116.htm

https://archives.hud.gov/budget/fy98/budg19.cfm

https://archives.hud.gov/budget/fy00/summary/cpd/hopwa.cfm

https://archives.hud.gov/budget/fy01/justif/cpd/hopwa.cfm

https://archives.hud.gov/budget/fy01/ny/new_york_city.cfm

https://archives.hud.gov/budget/fy03/cjs/part_1/cpd/hopwa.pdf

https://archives.hud.gov/budget/fy03/cjs/part_1/cpd/hopwa.pdf

Data on prevalence and incidence of HIV at the metropolitan area level:

We also use data on the prevalent and newlydiagnosed HIV cases from the Centers for Disease Control and Prevention (CDC) as follows:

Centers for Disease Control and Prevention. HIV Surveillance Report, 2015; vol. 27. http://www.cdc.gov/hiv/library/reports/hiv-surveillance.html. Published November 2016. Accessed 5 June 2017.

Centers for Disease Control and Prevention. HIV Surveillance Report, 2014; vol. 26. http://www.cdc.gov/hiv/library/reports/surveillance/. Published November 2015. Accessed 5 June 2017.

Centers for Disease Control and Prevention. HIV Surveillance Report, 2013; vol. 25. http://www.cdc.gov/hiv/library/reports/surveillance/. Published February 2015. Accessed 5 June 2017.

Centers for Disease Control and Prevention. HIV Surveillance Report, 2012; vol. 24. http://www.cdc.gov/hiv/library/reports/surveillance/. Published November 2014. Accessed 5 June 2017.

Centers for Disease Control and Prevention. HIV Surveillance Report, 2011; vol. 23. http://www.cdc.gov/hiv/topics/surveillance/resources/reports/. Published February 2013. Accessed 5 June 2017.

Centers for Disease Control and Prevention. HIV Surveillance Report, 2010; vol. 22. http://www.cdc.gov/hiv/topics/surveillance/resources/reports/. Published March 2012. Accessed 5 June 2017.

Centers for Disease Control and Prevention. HIV Surveillance Report, 2009; vol. 21. http://www.cdc.gov/hiv/topics/surveillance/resources/reports/. Published February 2011. Accessed 5 June 2017.

Centers for Disease Control and Prevention. HIV Surveillance Report, 2008; vol. 20. http://www.cdc.gov/hiv/topics/surveillance/resources/reports/. Published June 2010. Accessed 5 June 2017.

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 2007. Vol. 19. Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2009. http://www.cdc.gov/hiv/topics/surveillance/resources/reports/.

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 2006. Vol. 18. Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2008. http://www.cdc.gov/hiv/topics/surveillance/resources/reports/.

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 2005. Vol. 17. Rev ed. Atlanta: U.S.

Department of Health and Human Services, Centers for Disease Control and Prevention; 2007. http://www.cdc.gov/hiv/topics/surveillance/resources/reports/.

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 2004. Vol. 16. Atlanta: US Department of Health and Human Services, Centers for Disease Control and Prevention; 2005. http://www.cdc.gov/hiv/topics/surveillance/resources/reports/.

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 2003 (Vol. 15). Atlanta: US Department of Health and Human Services, Centers for Disease Control and Prevention; 2004

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report 2002; 14

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 2001; 13(No. 2)

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 2000; 12 (No. 2)

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 1999; 11 (No. 2)

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 1998; 10 (No. 2)

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 1997; 9 (No. 2)

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 1996; 8 (no. 2)

Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report, 1995; 7(no.2)

References

Acton JP, 1976 Demand for Health Care among the Urban Poor, with Special Emphasis on the Role of Time, in: Rosett RN (Ed.), The Role of Health Insurance in the Health Services Sector. National Bureau of Economic Research, New York, pp. 163–214.

Acton JP, 1975 Nonmonetary Factors in the Demand for Medical Services: Some Empirical Evidence. J. Polit. Econ. 83, 595–614.

Adler N, Boyce T, Chesney M, Cohen S, Folkman S, Kahn R, Syme S, 1994 Socioeconomic status and health. The challenge of the gradient. Am. Psychol 10.1037/0003-066X.49.1.15

Aidala AA, Wilson MG, Shubert V, Gogolishvili D, Globerman J, Rueda S, Bozack AK, Caban M, Rourke SB, 2016 Housing Status, Medical Care, and Health Outcomes Among People Living With HIV/AIDS: A Systematic Review. Am. J. Public Health 106, e1–e23. 10.2105/AJPH.2015.302905

Auld MC, 2002 Disentangling the effects of morbidity and life expectancy on labor market outcomes. Health Econ. 11, 471–483. 10.1002/hec.753 [PubMed: 12203751]

Barkan SE, Melnick SL, Preston-Martin S, Weber K, Kalish LA, Miotti P, Young M, Greenblatt R, Sacks H, Feldman J, 1998 The Women's Interagency HIV Study. WIHS Collaborative Study Group. Epidemiology 9, 117–25.

Bitler M, Hoynes H, 2015 Living Arrangements, Doubling Up, and the Great Recession: Was This Time Different? Am. Econ. Rev. Pap. Proc 105, 166–170.

Blair JM, Fagan JL, Frazier EL, Do A, Bradley H, Valverde EE, McNaghten A, Beer L, Zhang S, Huang P, Mattson CL, Freedman MS, Johnson CH, Sanders CC, Spruit McGoff KE, Heffelfinger JD, Skarbinski J, National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention, CDC, 2014 Behavioral and clinical characteristics of persons receiving medical care for HIV infection - Medical Monitoring Project, United States, 2009. MMWR Suppl. 63, 1–22.

Buchanan D, Kee R, Sadowski LS, Garcia D, 2009 The health impact of supportive housing for HIV-positive homeless patients: A randomized controlled trial. Am. J. Public Health 99, S675–S680. [PubMed: 19372524]

Case A, Lubotsky D, Paxson C, 2002 Economic Status and Health in Childhood: The Origins of the Gradient. Am. Econ. Rev 95, 1308–1334.

Cohen MS, Smith MK, Muessig KE, Hallett TB, Powers KA, Kashuba AD, 2013 Antiretroviral treatment of HIV-1 prevents transmission of HIV-1: where do we go from here? Lancet 382, 1515–24. 10.1016/S0140-6736(13)61998-4 [PubMed: 24152938]

Desmond M, 2016 Evicted: poverty and profit in the American city. Crown Publishers, New York. Desmond, M., Gershenson, C., 2016. Housing and Employment Insecurity among the Working Poor. Soc. Probl 63, 46–67. 10.1093/socpro/spv025

Downing J, 2016 The health effects of the foreclosure crisis and unaffordable housing: A systematic review and explanation of evidence. Soc. Sci. Med 162, 88–96. 10.1016/j.socscimed.2016.06.014 [PubMed: 27343818]

Eckel CC, El-Gamal MA, Wilson RK, 2009 Risk loving after the storm: A Bayesian-Network study of Hurricane Katrina evacuees. J. Econ. Behav. Organ 69, 110–124. 10.1016/j.jebo.2007.08.012

Eshleman SH, Hudelson SE, Redd AD, Swanstrom R, Ou S-S, Zhang XC, Ping L-H, Piwowar-Manning E, Porcella SF, Sievers MF, Martens CA, Bruno D, Dukhovlinova E, McCauley M, Gamble T, Fogel JM, Sabin D, Quinn TC, Gunde L, Maliwichi M, Nhando N, Akelo V, Moyo S, Panchia R, Kumarasamy N, Chotirosniramit N, Melo M.G. de, Pilotto J, Grinsztejn B, Mayer K, Chen YQ, Hughes JP, Cohen MS, 2017 Treatment as Prevention. JAIDS J. Acquir. Immune Defic. Syndr 74, 112–116. 10.1097/QAI.0000000000001158 [PubMed: 27532476]

Fortson JG, Sanbonmatsu L, 2010 Child health and neighborhood conditions: results from a randomized housing voucher experiment. J. Hum. Resour 45, 840–864. 10.1353/jhr.2010.0025

Frieden T, 2017 Evidence for Health Decision Making — Beyond Randomized, Controlled Trials. N Engl J Med 377, 465–475. [PubMed: 28767357]

Fussell E, Lowe SR, 2014 The impact of housing displacement on the mental health of lowincome parents after Hurricane Katrina. Soc. Sci. Med 113, 137–44. 10.1016/j.socscimed.2014.05.025 [PubMed: 24866205]

Galárraga O, Salkever DS, Cook JA, Gange SJ, 2010 An instrumental variables evaluation of the effect of antidepressant use on employment among HIV-infected women using antiretroviral therapy in the United States: 1996–2004. Health Econ. 19, 173–88. 10.1002/hec.1458 [PubMed: 19253267]

Gennetian LA, Sanbonmatsu L, Katz LF, Kling JR, Sciandra M, Ludwig J, Duncan GJ, Kessler RC, 2012 The Long-Term Effects of Moving to Opportunity on Youth Outcomes. Cityscape A J. Policy Dev. Res 14, 137–168. 10.2307/41581100

Goldman DP, 2003 Insurance Status of HIV-Infected Adults in the Post-Haart Era: Evidence from the United States. Appl. Health Econ. Health Policy 2, 85–90. [PubMed: 14619279]

Grossman M, 1972 On the Concept of Health Capital and the Demand for Health. J. Polit. Econ 80, 223–255.

Hall JC, Hall BJ (Brian J, Cockerell CJ, McKeon M, 2011 HIV/AIDS in the post-HAART era: manifestations, treatment, and epidemiology. People's Medical Publishing House (PMPH)-USA, Shelton, CT.

Jacob BA, Kapustin M, Ludwig J, 2015 The Impact of Housing Assistance on Child Outcomes: Evidence from a Randomized Housing Lottery. Q. J. Econ 130, 465–506. 10.1093/qje/qju030

James RN, 2009 Tenant time preference as a barrier to homeownership. Appl. Econ. Lett 16, 1073–1077. 10.1080/13504850701335327

Katz LF, Kling JR, Liebman JB, 2001 Moving to Opportunity in Boston: Early Results of a Randomized Mobility Experiment. Q. J. Econ 116.

Kidder DP, Wolitski RJ, Royal S, Aidala A, Courtenay-Quirk C, Holtgrave DR, Harre D, Sumartojo E, Stall R, 2007 Access to housing as a structural intervention for homeless and unstably housed people living with HIV: rationale, methods, and implementation of the housing and health study. AIDS Behav. 11, 149–61. 10.1007/s10461-007-9249-0 [PubMed: 17546496]

Kling JR, Ludwig J, Katz LF, 2005 Neighborhood Effects on Crime for Female and Male Youth: Evidence from a Randomized Housing Voucher Experiment. Q. J. Econ 120, 87–130. 10.2307/25098732

Leaver CA, Bargh G, Dunn JR, Hwang SW, 2007 The effects of housing status on healthrelated outcomes in people living with HIV: a systematic review of the literature. AIDS Behav. 11, 85–100. 10.1007/s10461-007-9246-3 [PubMed: 17682940]

Muthulingam D, Chin J, Hsu L, Scheer S, Schwarcz S, 2013 Disparities in engagement in care and viral suppression among persons with HIV. J. Acquir. Immune Defic. Syndr 63, 112–9. 10.1097/QAI.0b013e3182894555 [PubMed: 23392459]

O'Flaherty B, 1995 An Economic Theory of Homelessness and Housing. J. Hous. Econ 4, 13–49. 10.1006/jhec.1995.1002

Panel on Antiretroviral Guidelines for Adults and Adolescents, 2009 Guidelines for the use of antiretroviral agents in HIV-1-Infected Adults and Adolescents. Washington D.C.

Riis JA, 1890 How the other half lives: studies among the tenements of New York. Bedford Books of St. Martin's Press, Boston.

Riley ED, Gandhi M, Hare C, Cohen J, Hwang S, 2007 Poverty, unstable housing, and HIV infection among women living in the United States. Curr. HIV/AIDS Rep. 4, 181–6. [PubMed: 18366949]

Roodman D, 2011 Fitting fully observed recursive mixed-process models with cmp. Stata J. 11, 159–206. https://doi.org/TheStataJournal

Staiger D, Stock JH, 1997 Instrumental Variables Regression with Weak Instruments. Econometrica 65, 557–586.

Terzian AS, Irvine MK, Hollod LM, Lim S, Rojas J, Shepard CW, 2015 Effect of HIV Housing Services on Engagement in Care and Treatment, New York City, 2011. AIDS Behav. 19, 2087–96. 10.1007/s10461-015-1003-4 [PubMed: 25631320]

Thomson H, Thomas S, 2015 Developing empirically supported theories of change for housing investment and health. Soc. Sci. Med 124, 205–14. 10.1016/j.socscimed.2014.11.043 [PubMed: 25461878]

U.S. GAO, 2015 Persons with HIV Funding Formula for Housing Assistance Could Be Better Targeted, and Performance Data Could Be Improved Funding Formula for Housing Assistance Could Be. Washington D.C.

Wolitski RJ, Kidder DP, Pals SL, Royal S, Aidala A, Stall R, Holtgrave DR, Harre D, Courtenay-Quirk C, 2010 Randomized trial of the effects of housing assistance on the health and risk behaviors of homeless and unstably housed people living with HIV. AIDS Behav. 14, 493–503. 10.1007/s10461-009-9643-x [PubMed: 19949848]

Wooldridge JM, 2014 Quasi-maximum likelihood estimation and testing for nonlinear models with endogenous explanatory variables. J. Econom 182, 226–234. 10.1016/j.jeconom.2014.04.020

Wooldridge JM, 2010 Econometric Analysis of Cross Section and Panel Data (Second Edition). MIT Press, Cambridge, Mass.

Contribution to knowledge

- We measure the negative effect of unstable housing on objective health biomarkers
- We test specific pathways: mental health/healthcare use, and continuity of care
- We use instrumental variables allowing a causal interpretation of the effects
- We use panel data (1995–2015) for largest- & longest-running HIV+ cohort in U.S.

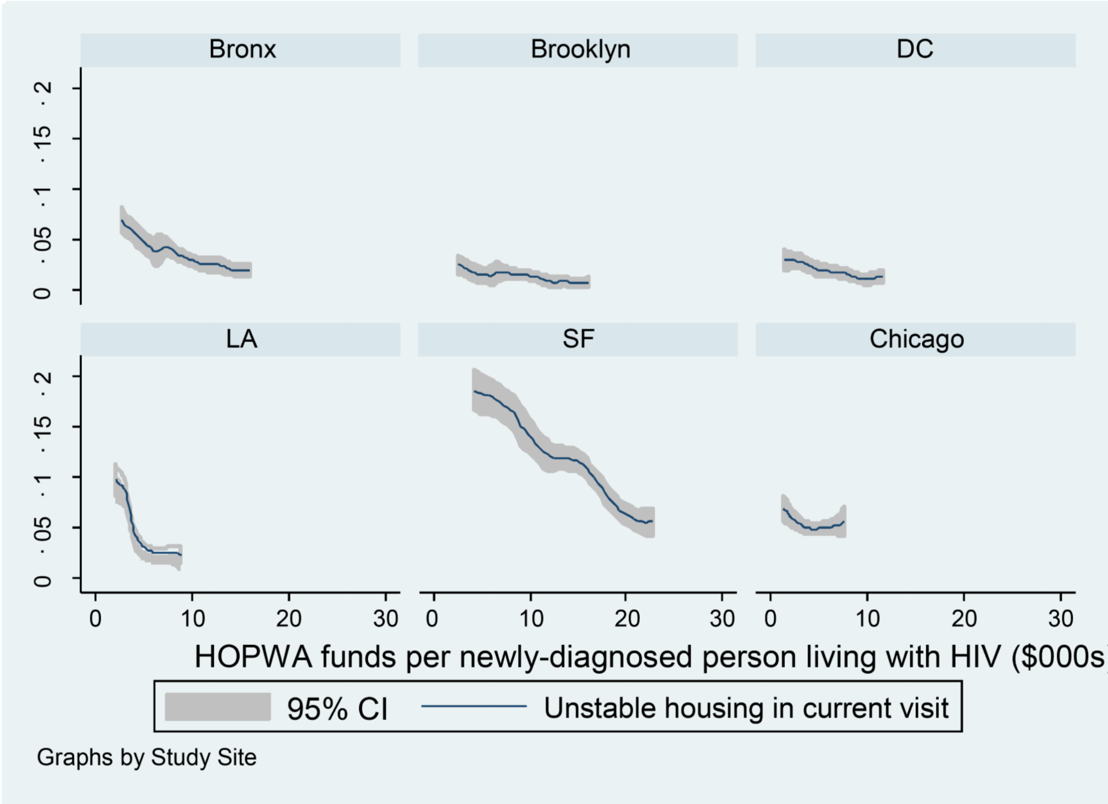

Figure 1.

First Stage: HOPWA funds per person newly-diagnosed with HIV and unstable housing

Notes: The figure shows kernel-weighted local polynomial regressions of unstable housing on HOPWA funds per newlydiagnosed PLHIV and displays a graph of the smoothed values with 95% confidence interval bands. HOPWA is the Housing Opportunities for Persons with AIDS, the only Federal program dedicated to the housing needs of people living with HIV/ AIDS. Under HOPWA, the U.S. Department of Housing and Urban Development (HUD) makes grants to local communities, States, and nonprofit organizations for projects that benefit low-income persons living with HIV. Until July 29, 2016, HOPWA funds were provided based on an allocation formula based on historical AIDS cases (not on the number of persons currently living with HIV).

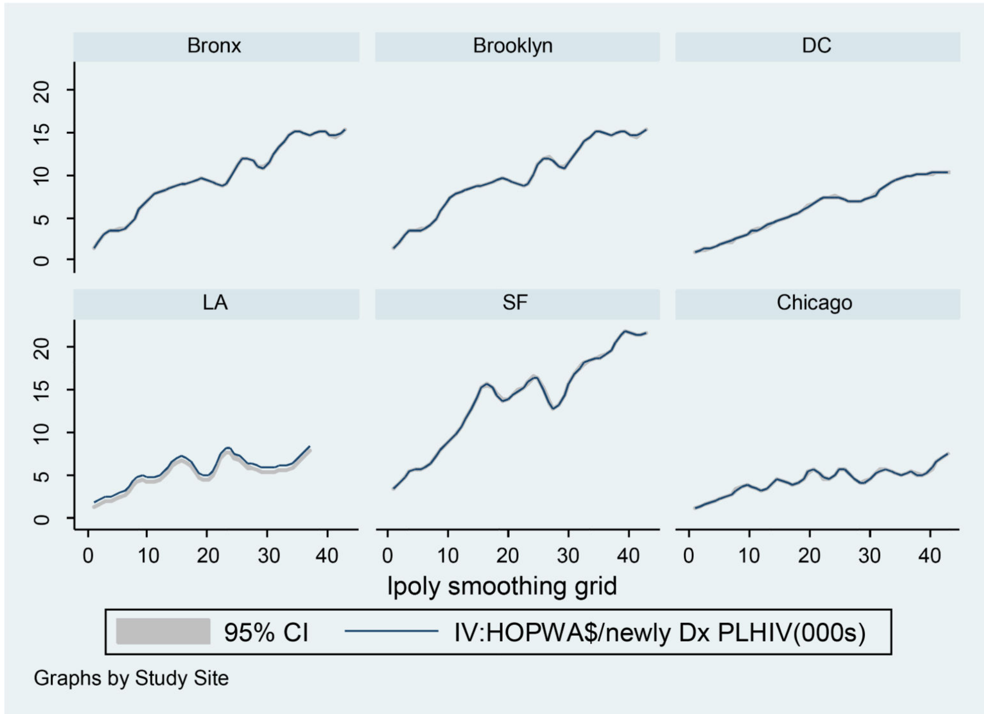

Figure 2.

Housing opportunity for persons with AIDS (HOPWA) allocations (in current USD$000s) per newly-diagnosed HIV-positive person, by site and eligible visits, 1995–2015

Notes: The figure shows kernel-weighted local polynomial regressions of HOPWA funds per newly-diagnosed PLHIV and eligible visits (which occur every six months and are numbered 1–42, and which correspond to the years 1995–2005). The graph displays smoothed values with 95% confidence interval bands. HOPWA is the Housing Opportunities for Persons with AIDS; the only Federal program dedicated to the housing needs of people living with HIV/AIDS. Under HOPWA, the U.S. Department of Housing and Urban Development (HUD) makes grants to local communities, States, and nonprofit organizations for projects that benefit low-income persons living with HIV. Until July 29, 2016, HOPWA funds were provided based on an allocation formula based on historical AIDS cases (not on the number of persons currently living with HIV).

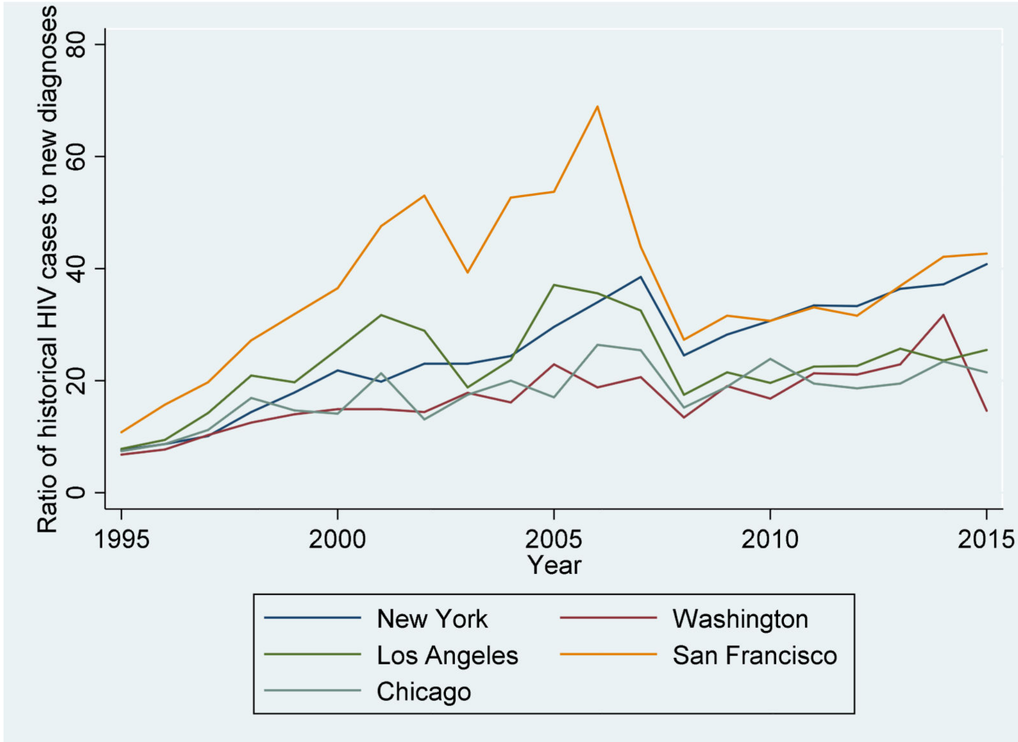

Figure 3.

Ratio of historical HIV cases to new diagnoses, by site and eligible visits, 1995–2015

Notes: The figure shows the trends in the ratio of historical HIV cases to new diagnoses by site and eligible visits. This ratio helps in assessing the validity of the instrumental variable: under HOPWA, the U.S. Department of Housing and Urban Development (HUD) made allocations based on historical AIDS cases (not on the number of persons newly diagnosed with HIV).

Table 1

Descriptive Statistics for the Women's Interagency HIV Study (WIHS) Cohort, 1995–2015

Variable	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Viral load<200 HIV RNA copies per ml (yes/no)	57323	0.4830	0.4997	0	1
CD4>350 cells per mm3(yes/no)	57560	0.5589	0.4965	0	1
Unstable housing in current visit	56307	0.0483	0.2144	0	1
Age in years at visit	60988	43.9	9.4	17.1	89.7
Age squared	60988	2017.3	857.1	293.8	8043.2
Number of children participant takes care of	61668	0.2087	0.7046	0	15
No schooling	58367	0.0063	0.0793	0	1
Grades 1–6	58367	0.0462	0.2099	0	1
Grades 7–11	58367	0.3241	0.4681	0	1
Completed high school	58367	0.2995	0.4580	0	1
Some college	58367	0.2511	0.4337	0	1
Completed 4 years of college	58367	0.0514	0.2209	0	1
Attended/Completed graduate school	58367	0.0213	0.1444	0	1
White(Non-Hispanic)	60988	0.1452	0.3523	0	1
White(Hispanic)	60988	0.0714	0.2575	0	1
African-American (Non-Hispanic)	60988	0.5709	0.4950	0	1
African-American (Hispanic)	60988	0.0216	0.1454	0	1
Other (Hispanic)	60988	0.1587	0.3654	0	1
Asian/Pacific Islander	60988	0.0098	0.0985	0	1
Native American/Alaskan	60988	0.0043	0.0654	0	1
Other race/ethnicity	60988	0.0182	0.1336	0	1
Bronx, NY	61668	0.1960	0.3969	0	1
Brooklyn, NY	61668	0.1843	0.3877	0	1
Washington DC	61668	0.1445	0.3516	0	1
Los Angeles, CA	61668	0.1702	0.3758	0	1
San Francisco, CA	61668	0.1592	0.3659	0	1
Chicago, IL	61668	0.1459	0.3530	0	1
Legally/common-law married	61668	0.2193	0.4138	0	1
Not married but living w/partner	61668	0.1080	0.3104	0	1
Widowed	61668	0.1032	0.3043	0	1
Divorced/Annulled	61668	0.1183	0.3229	0	1
Separated	61668	0.0870	0.2819	0	1
Never married	61668	0.2962	0.4566	0	1
Other marital status	61668	0.0679	0.2517	0	1
Participant ever injected drugs	58398	0.3000	0.4583	0	1
Non-injected recreational drugs ever used	58346	0.7233	0.4474	0	1
Number lifetime male sex partners at baseline	59879	78.2	303.7	0	8000
IV:HOPWA$/newly Dx PLHIV(000s)	60988	8.6226	4.8435	0.827	22.736

Notes: WIHS is the Women's Interagency HIV Study (https://statepi.jhsph.edu/wihs/wordpress/) Visits occur every six months; analysis restricted to WIHS original sites. Instrumental variable (IV) is: Funds allocation for HOPWA, Housing Opportunity for Persons with AIDS (www.hudexchange.info) per person newly-diagnosed (Dx) with HIV (https://www.cdc.gov/hiv/library/reports/hiv-surveillance.html) (Appendix D).

Table 2

First Stage: Unstable housing and HOPWA allocations per newly-diagnosed person with HIV

Dependent variable: Unstable housing=1	**(1)**		**(2)**		**(3)**		**(4)**	
IV:HOPWA$/newly Dx PLHIV(000s)	−0.005**	(0.000)	−0.005**	(0.000)	−0.003**	(0.000)	−0.003**	(0.001)
Brooklyn, NY	−0.018**	(0.003)	−0.022**	(0.003)	−0.013**	(0.003)	−0.013*	(0.006)
Washington DC	−0.031**	(0.003)	−0.027**	(0.003)	−0.018**	(0.003)	−0.018**	(0.006)
Los Angeles, CA	−0.024**	(0.003)	−0.007+	(0.003)	0.008*	(0.003)	0.008	(0.008)
San Francisco, CA	0.094**	(0.003)	0.098**	(0.003)	0.080**	(0.003)	0.080**	(0.011)
Chicago, IL	−0.016**	(0.003)	−0.011**	(0.004)	−0.002	(0.004)	−0.002	(0.008)
Age in years at visit			0.003**	(0.001)	0.001	(0.001)	0.001	(0.001)
Age squared			−0.000**	(0.000)	−0.000*	(0.000)	−0.000	(0.000)
Grades 1–6			−0.107**	(0.012)	−0.099**	(0.012)	−0.099*	(0.044)
Grades 7–11			−0.087**	(0.011)	−0.091**	(0.011)	−0.091*	(0.044)
Completed high school			−0.111**	(0.011)	−0.110**	(0.011)	−0.110*	(0.044)
Some college			−0.127**	(0.011)	−0.125**	(0.011)	−0.125**	(0.043)
Completed 4 years of college			−0.146**	(0.012)	−0.135**	(0.012)	−0.135**	(0.044)
Attended/Completed graduate school			−0.134**	(0.013)	−0.115**	(0.013)	−0.115**	(0.044)
Avg# children participant takes care of			−0.006**	(0.001)	−0.004**	(0.001)	−0.004*	(0.002)
White(Hispanic)			−0.016**	(0.004)	−0.000	(0.004)	−0.000	(0.010)
African-American (Non-Hispanic)			0.012**	(0.003)	0.023**	(0.003)	0.023**	(0.007)
African-American (Hispanic)			0.023**	(0.007)	0.036**	(0.006)	0.036+	(0.021)
Other (Hispanic)			−0.013**	(0.004)	0.003	(0.004)	0.003	(0.009)
Asian/Pacific Islander			−0.031**	(0.010)	−0.012	(0.010)	−0.012	(0.014)
Native American/Alaskan			0.147**	(0.014)	0.152**	(0.014)	0.152	(0.106)
Other race			0.004	(0.007)	0.017*	(0.007)	0.017	(0.020)
Not married but living w/partner			−0.009**	(0.003)	−0.010**	(0.003)	−0.010**	(0.004)
Widowed			0.026**	(0.003)	0.020**	(0.003)	0.020**	(0.007)
Divorced/Annulled			0.006+	(0.003)	0.006+	(0.003)	0.006	(0.006)
Separated			0.037**	(0.004)	0.037**	(0.004)	0.037**	(0.007)
Never married			0.030**	(0.003)	0.024**	(0.003)	0.024**	(0.005)
Other marital status			0.027**	(0.004)	0.023**	(0.004)	0.023**	(0.007)
Participant ever injected drugs					0.028**	(0.002)	0.028**	(0.006)
Non-injected recreational drugs ever used					0.021**	(0.002)	0.021**	(0.004)
No. lifetime male sex partners at baseline					0.000**	(0.000)	0.000	(0.000)
Constant	0.090**	(0.003)	0.106**	(0.019)	0.119**	(0.019)	0.119*	(0.053)
Number of Observations	56307		56256		55250		55250	

Author Manuscript

Author Manuscript

Author Manuscript

Dependent variable: Unstable housing=1	**(1)**	**(2)**	**(3)**	**(4)**
F-statistic of excluded instrument	361.17	233.14	108.92	25.98
Clustering at individual level	No	No	No	Yes
Robust standard errors	No	No	No	Yes

Notes: This table shows our first stage regressions. The dependent variable is unstable housing (=1) if participant currently resides on the street/beach, shelter/welfare hotel, jail/correctional facility, halfway house; and (=0) otherwise. The instrumental variable (IV) is fund allocations for the Housing Opportunities for Persons with AIDS (HOPWA) program per newly-diagnosed person living with HIV (PLHIV). Regressions in columns (1) to (4) include dummies for WIHS site (with Bronx, NY as reference); while columns (2) to (4) also include dummies for: educational level (with no formal education as reference), race (with White, non-Hispanic as reference), marital status (with married/common law as reference). The regression in column (4) represents the primary first stage regression. Standard errors in parentheses.

+Significant at 10%

*Significant at 5%

**Significant at 1%

Table 3

Women's Interagency HIV Study (WIHS) Cohort, 1995–2015: Mean Regressors by IV group

	Low value IV (HOPWA allocations below the site-specific median)					High value IV (HOPWA allocations above the site-specific median)				
Variable	**Number of Observations**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Number of Observations**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Age in years at visit	31245	40.95	8.56	17.14	87.68	29743	47.05	9.18	18.7	89.7
Age squared	31245	1750.2	734.6	293.8	7688.5	29743	2298.0	886.3	350.8	8043.2
Number of children participant takes care of	31245	0.0187	0.2172	0	7	29743	0.4130	0.9482	0	15
No schooling	30520	0.0066	0.0809	0	1	27847	0.0060	0.0774	0	1
Grades 1–6	30520	0.0415	0.1994	0	1	27847	0.0514	0.2208	0	1
Grades 7–11	30520	0.3219	0.4672	0	1	27847	0.3266	0.4690	0	1
Completed high school	30520	0.3068	0.4612	0	1	27847	0.2915	0.4544	0	1
Some college	30520	0.2516	0.4339	0	1	27847	0.2507	0.4334	0	1
Completed 4 years of college	30520	0.0501	0.2182	0	1	27847	0.0529	0.2238	0	1
Attended/Completed graduate school	30520	0.0216	0.1455	0	1	27847	0.0210	0.1433	0	1
White(Non-Hispanic)	31245	0.1585	0.3652	0	1	29743	0.1312	0.3376	0	1
White(Hispanic)	31245	0.0467	0.2109	0	1	29743	0.0973	0.2964	0	1
African-American (Non-Hispanic)	31245	0.5711	0.4949	0	1	29743	0.5707	0.4950	0	1
African-American (Hispanic)	31245	0.0199	0.1396	0	1	29743	0.0234	0.1512	0	1
Other (Hispanic)	31245	0.1752	0.3801	0	1	29743	0.1414	0.3484	0	1
Asian/Pacific Islander	31245	0.0081	0.0894	0	1	29743	0.0116	0.1071	0	1
Native American/Alaskan	31245	0.0039	0.0624	0	1	29743	0.0047	0.0684	0	1
Other race/ethnicity	31245	0.0167	0.1281	0	1	29743	0.0197	0.1391	0	1
Bronx, NY	31245	0.1912	0.3933	0	1	29743	0.2014	0.4010	0	1
Brooklyn, NY	31245	0.1871	0.3900	0	1	29743	0.1817	0.3856	0	1
Washington DC	31245	0.1406	0.3476	0	1	29743	0.1482	0.3553	0	1
Los Angeles, CA	31245	0.1693	0.3751	0	1	29743	0.1702	0.3758	0	1
San Francisco, CA	31245	0.1622	0.3686	0	1	29743	0.1570	0.3638	0	1
Chicago, IL	31245	0.1496	0.3567	0	1	29743	0.1415	0.3486	0	1
Legally/common-law married	31245	0.2193	0.4138	0	1	29743	0.2244	0.4172	0	1
Not married but living w/partner	31245	0.1193	0.3241	0	1	29743	0.0986	0.2982	0	1
Widowed	31245	0.1083	0.3108	0	1	29743	0.1003	0.3004	0	1
Divorced/Annulled	31245	0.1236	0.3292	0	1	29743	0.1154	0.3195	0	1
Separated	31245	0.0954	0.2937	0	1	29743	0.0803	0.2717	0	1

Variable	Low value IV (HOPWA allocations below the site-specific median)					High value IV (HOPWA allocations above the site-specific median)				
	Number of Observations	Mean	Standard Deviation	Minimum	Maximum	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Never married	31245	0.3138	0.4640	0	1	29743	0.2844	0.4511	0	1
Other marital status	31245	0.0203	0.1410	0	1	29743	0.0967	0.2955	0	1
Participant ever injected drugs	30529	0.3538	0.4781	0	1	27869	0.2411	0.4277	0	1
Non-injected recreational drugs ever used	30487	0.7451	0.4358	0	1	27859	0.6996	0.4585	0	1
Number lifetime male sex partners at baseline	30586	86.6	334.1	0	8000	29293	69.5	268.0	0	8000
IV:HOPWA$/newly Dx PLHIV(000s)	31245	5.94	3.34	0.83	14.79	29743	11.44	4.58	4.69	22.74

Notes: The table shows the mean value of the regressors by instrumental variable (IV) group (high and low-value HOPWA funds per newly-diagnosed person with HIV). Low value IV is defined as HOPWA allocations below the site-specific median. High value IV is defined as HOPWA allocations above the site-specific median. WIHS is the Women's Interagency HIV Study (https://statepi.jhsph.edu/wihs/wordpress/). Visits occur every six months; analysis restricted to WIHS original sites. The IV is: Funds allocation for HOPWA, Housing Opportunity for Persons with AIDS (www.hudexchange.info) per person newly-diagnosed with HIV (https://www.cdc.gov/hiv/library/reports/hiv-surveillance.html) (Appendix D).

Table 4

Probits and Probits with Instrumental Variables Effect of unstable housing on viral suppression and CD4 cell count

Dependent variable =1 if:	**Viral load<200 HIV RNA copies/mL**		**CD4 cell count>350 cells/μl**		**Viral load<200 HIV RNA copies/mL**		**CD4 cell count>350 cells/μl**	
	(1)		(2)		(3)		(4)	
Specification:	Probit		Probit		Probit IV		Probit IV	
Unstable housing	−0.081 **	(0.019)	−0.079 **	(0.021)	−0.5101 **	(0.0067)	−0.5306 **	(0.0244)
Mean outcome of dependent variable (control group)	0.509		0.5721		0.533		0.5914	
Observations	53452		53663		53452		53663	

Notes: This table presents our results of the effect of unstable housing on HIV treatment outcomes. Columns (1) and (2) present naïve probit models; columns (3) and (4) show extended instrumental variable (IV) probit models. Controls in all columns include all variables in presented earlier in Table 3: site, educational levels, race, marital status, baseline use of injectable drugs, baseline use of noninjectable drugs, baseline number of male sex partners (lifetime), as well as interactions of each covariate with endogenous variable (unstable housing).

Robust standard errors clustered at the individual level are shown in parentheses:

+ Significant at 10%

* Significant at 5%

** Significant at 1%

The endogenous variable, unstable housing (=1) if participant resides on the street/beach, shelter/welfare hotel, jail/correctional facility, halfway house; and (=0) otherwise. Main instrumental variable (IV) is: Funds (current $USD) allocations for HOPWA per newly-diagnosed PLHIV. IV constructed from Housing Opportunity for Persons with AIDS (www.hudexchange.info), and Centers for Disease Control and Prevention HIV Surveillance Reports (https://www.cdc.gov/hiv/library/reports/hiv-surveillance.html).

Regressions were estimated using Stata MP (College Station, TX) with probit and extended probit (eprobit with endogenous treatment).

Table 5

Evaluating pathways

	Probit IV
A. Mental health/counseling provider use	−0.2559 ** (0.0227)
Observations	33693
Mean outcome among stably housed	0.2964
B. Healthcare provider use	−0.3709 * (0.1637)
Observations	42052
Mean outcome among stably housed	0.9173
C. Same provider / continuity of care	−0.7630 ** (0.08995)
Observations	38390
Mean outcome among stably housed	0.9455

Notes: This table presents probit IV models of the effect of unstable housing on potential pathways. Controls in all columns include all variables presented earlier in Table 3: site, educational levels, race, marital status, baseline use of injectable drugs, baseline use of noninjectable drugs, baseline number of male sex partners (lifetime), as well as interactions of each covariate with endogenous variable (unstable housing).

Robust standard errors clustered at the individual level are shown in parentheses:

+ Significant at 10%

* Significant at 5%

** Significant at 1%

The endogenous variable, unstable housing (=1) if participant resides on the street/beach, shelter/welfare hotel, jail/correctional facility, halfway house; and (=0) otherwise.

Main instrumental variable (IV) is: Funds (current $USD) allocations for HOPWA per newly-diagnosed PLHIV. IV constructed from Housing Opportunity for Persons with AIDS (www.hudexchange.info), and Centers for Disease Control and Prevention HIV Surveillance Reports (https://www.cdc.gov/hiv/library/reports/hiv-surveillance.html).

Regressions were estimated using Stata MP (College Station, TX) with probit and extended probit (eprobit with endogenous treatment).