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INFRASTRUCTURE UPGRADING AND BUDGETING SPILLOVERS: MEXICO'S HÁBITAT EXPERIMENT*

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January 2014

Abstract

This paper reports on the results of a large infrastructure investment experiment in which \$68 million in spending was randomly allocated across a set of low-income urban neighborhoods in Mexico. We show that the program resulted in meaningful improvements in the access of the average household to numerous forms of infrastructure, such as electric lighting, street lights, sidewalks, medians, and road paving. We exploit the study's randomized saturation design to understand how spillovers at the municipal level might work to undermine causal inference when multiple levels of government provide forms of investments that are close substitutes. Our results suggest that the strategic response of municipal governments to federal spending is muted. The program increased the aggregate real estate value in program neighborhoods by two dollars for every dollar invested.

Keywords: Infrastructure impacts, flypaper effects, spillover effects

JEL Codes: O18, C93, H73

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1. INTRODUCTION

We present the results of a major federal infrastructural spending experiment implemented in low-income neighborhoods across Mexico during the years 2009-2011 by the Hábitat program of the Social Development Secretariat (SEDESOL). Hábitat primarily builds heavy infrastructure such as roads, water, sewerage, lighting, and sidewalks, but also invests in community centers, parks, and sports facilities. We exploit detailed household & block-level data to measure impacts on specific forms of infrastructure, and then use professional property price valuations to compare the overall amenity value of the improvements to the cost of the program (Greenstone and Gallagher 2008). Our work joins a rapidly-growing literature using experiments to examine the impact of improvements in infrastructure, such as road paving (Gonzales-Navarro and Quintana-Domeque 2011), new home construction (Galiani et al. 2013), and improvement of water resources (Kremer et al. 2011). The study is very large in absolute scale: \$68 million in infrastructure investment was randomly allocated, including most of the urban parts of the country (60 municipalities across 20 different Mexican states), and therefore helps to address the paucity of infrastructure evaluation studies that are performed ‘at scale’ (Field and Kramer 2006).

In considering the effect of such programs, however, a large public finance literature has suggested that federal spending will be crowded out by changes in local government spending (Hines and Thaler 1995, Dahlberg et al. 2008, Nesbit and Kreft 2009).¹ When multiple levels of government provide goods that are close substitutes, the true causal change in total spending induced by a one dollar change in federal spending is complex. Estimation of impacts will be bedeviled by flypaper effects in overall municipal spending as well as by spillovers across neighborhoods. The study features a two-level experimental design in which the intensity of treatment was first randomized at the municipal level and then the treatment was randomized at the neighborhood level (Crépon et al 2013). We exploit this two-level design to shed light on the magnitude of the relationship between federal and municipal spending, estimating flypaper effects at the municipal level and then interference within municipalities. We illustrate how experimental estimates of the spillovers experienced in the study can be used to correct the standard intention-to-treat effect.

¹ A recent literature on federal programs intended to promote long-term employment such as works programs or enterprise zones has discussed general-equilibrium effects when worker migration causes arbitrage; see Busso et al. (2013) or Suárez-Serrato and Wingender (2011). Hábitat makes a relatively short-term investment in durable infrastructure, and thus we expect effects driven by long-term relocation for work to be small. We are therefore primarily concerned with spillovers in expenditures rather than in labor markets.

To frame the strategic relationship between federal and municipal governments, we develop a simple electoral model motivating the tension between crowd-out incentives and the effects of municipal matching requirements that are typically included in such federal programs. This theory is then tied directly to the estimands uncovered by the randomized saturation experiment.² In the randomized saturation experiment, all HÁbitat-eligible neighborhoods in study municipalities were selected into the study and then the fraction of eligible neighborhoods to be treated per municipality was drawn from a uniform distribution between .1 and .9. Treatment is then assigned randomly at the neighborhood level so as to make the actual study fraction treated per municipality as close as possible to the assigned saturation given the integer problem.

The randomization of the intensity of treatment within a municipality proves useful in two dimensions. First, we look for flypaper effects in aggregate municipal spending on infrastructure, instrumenting for total federal spending in each municipality with the randomized saturation. We then use neighborhood-level data to examine within-municipality spillovers caused by the experiment. We investigate whether increasing the fraction of neighborhoods treated with federal infrastructure alters the quality of infrastructure in the remaining control neighborhoods. This form of displacement is particularly important because it represents a form of causal interference that would otherwise bias a study using within-municipality counterfactuals. We discuss the rich set of estimands uncovered by the randomized saturation design, and follow Baird et al (2013) in using the saturation experiment to estimate the average interference on controls in the study. This quantity is then used to correct the ITT so that it is estimated relative to an unperturbed counterfactual.

The results of the study show that HÁbitat investment resulted in very large improvements in the reported quality of road paving, sidewalks, medians, and public lighting, but less so in forms of infrastructure to which baseline access was very high; namely water and sewerage. An index of infrastructure quality, to which we committed as the core outcome indicator in a pre-analysis plan, is significantly improved by the intervention.³ Spillover effects are found to be muted overall, although generally consistent with a mild crowd-in or flypaper effect. Control neighborhood infrastructure becomes slightly worse as treatment intensity in a municipality increases, so the

² The use of a two-level randomized saturation experiment follows a relatively new literature that is seeking to understand spillover effects using experiments designed explicitly for this purpose, such as Sinclair et al. 2011, Gine and Mansuri 2011, Crepon et al. 2013, and Callen et al. 2013.

³ The companion paper to this, Zenteno et al. 2013, presents the impacts of the program on the other outcomes indicated in the pre-analysis plan, and shows that while the program did not improve public health outcomes or transportation times, it resulted in a meaningful improvement in trust between neighbors and large decrease in the household-reported rate of violent crime.

estimates of the IIT that correct for this indicate somewhat smaller impacts than uncorrected estimates. Private investment in the housing stock is broadly improved by the program, and the value of a square meter of land in treatment neighborhoods increases by more than \$2 for every \$1 invested by the program, a sign of under-investment in infrastructure in low income neighborhoods. Contrary to Gonzales-Navarro & Quintana-Domeque (2011) we find the program was very neutral politically, with no electoral advantage having been incurred by the incumbent political party in the 2012 elections.

The paper is organized as follows: Section 2 presents a simple theory for the multi-level budgeting game induced by the experiment and the ways in which the randomized saturation design helps to disentangle the causal inference problem. Section 3 introduces the program and the data collection strategy, Section 4 presents the estimates of the impact of the program, and Section 5 concludes.

2. THE MULTILEVEL BUDGETING PROBLEM

2.1. Multilevel Budgeting and Causal Inference.

The response of local governments when given block grants from the central government has been a major focus of inquiry in public economics for many decades. A basic model of rationality at the local level would suggest when the pattern of federal spending is well understood, such grants should be almost entirely crowded out by changes in local spending behavior. Nonetheless numerous studies have documented the ‘flypaper effect’ in which money “sticks where it hits” and the corresponding changes in total spending arising from block grants are close to 100% of the size of the grant (Hines and Thaler 1995, Nesbit and Kreft 2009). Indeed, some recent empirical studies have found evidence not of crowd-out but of crowd-in, whereby federal grants induce an absolute increase in local spending (Dahlberg et al, 2008). Recognizing that the variation in federal spending is endogenous, researchers have attempted to exploit discontinuities (Gordon 2004) or instrumental variables (Dahlberg et al., 2008) to identify casual effects on municipal spending. Our first empirical analysis in Section 4.1 uses the randomized component of the variation in federal spending per municipality to examine this relationship.

We then turn to the estimation of the impact of the program at the neighborhood level using untreated neighborhoods in study municipalities to form counterfactuals. Even holding overall municipal spending constant, the causal effect recovered by such an experiment is far from clear. While municipal governments likely have incentives to crowd out federal spending, Hábitat like

many similar programs foresees this problem and consequently requires that local governments match federal spending, thereby attempting to crowd in local expenditure. To formalize these competing incentives we now develop a simple theoretical environment, and show how the randomization of the intensity of treatment across municipalities allows us to recover estimates of the critical parameters.⁴

The basic evaluation problem is to measure the intention-to-treat (ITT) of an experiment that randomizes an additional injection of federal spending at the neighborhood level. Consider a municipal government that takes federal spending as given, and then maximizes a concave electoral return function where spending in each neighborhood i within municipality j yields a higher vote total at an ever-decreasing rate. We assume homogeneous neighborhoods within which voters have no ability to attribute spending to the correct entity, so that baseline federal expenditures S_{ij} and municipal expenditures s_{ij} are perfect substitutes. Municipal governments maximize this objective function subject to an overall budget constraint leading to an optimized pre-experimental per-neighborhood spending s_{ij}^* , with $s_{ij}' = s_{kj}' \forall i \neq k$. Because the two forms of spending are perfect substitutes and the objective function is concave, the municipal government will want to counteract any exogenous change in spending by the federal government one-for-one.

From this initial equilibrium, the federal government initiates a randomized experiment in which a fraction σ_j of the locations within each municipality are selected to be a part of the study, a fraction τ_j of study locations treated per municipality is randomized at the municipal level, and then conditional on this saturation and the locations within each municipality are randomly assigned a binary treatment indicator T_{ij} . Assume that the federal government spends a fixed amount K per treatment neighborhood.

Foreseeing the desire towards crowd-out, Hábitat like many similar federal programs requires matching of federal monies by state and municipal government, so that municipal governments are

⁴ Our study contains only 60 municipalities, and while every Hábitat-eligible neighborhood in the study municipalities was included in the study, these neighborhoods cover only an average of 3% of the population and 1% of the surface areas of study municipalities. Because the poligono is a definition of a neighborhood used only by Hábitat, municipal governments do not record spending at this level, and the most disaggregated data available to us is total annual spending by the municipality on 'Public works and social action', a category which includes public infrastructure, public safety, and economic development. This investment category maps relatively well to the activities in which Hábitat invests, but the randomized saturation experiment was conducted within a very small subset of the overall population of the municipalities. This implies that a 90% treatment saturation, while treating almost all of the Hábitat-eligible neighborhoods, may still generate a small budgeting spillover to the municipality as a whole. We nonetheless show that the saturation experiment delivers randomized variation of more than two million dollars across municipalities.

required to contribute spending of mK towards Hábitat investments in treatment neighborhoods. Municipalities thus face competing incentives to crowd out windfall federal spending, and yet if the matching requirements are high enough it may force them to crowd in municipal spending to the treatment.

We make a slight change to the standard counterfactual notation to consider the impacts recovered by an experiment in this context where spillovers occur, and hence the Stable Unit Treatment Value Assumption (SUTVA) is violated. Let s_{0ij}^* be the optimized spending per neighborhood in the absence of *the experiment*, and s_{1ij}^* be the optimized spending in the presence of the experiment. By the properties of randomization, $E(s_{0ij}^* | T=1) = E(s_{0ij}^* | T=0)$, but the possibility of strategic spillovers means that $E(s_{1ij}^* | T=0)$ is not necessarily equal to $E(s_{0ij}^* | T=0)$.

The experiment induces a ‘Net Budget Effect $NBE(\tau)$ ’ equal to $\sigma_j \tau_j K$; this is the amount by which spending would increase in every neighborhood if the additional federal resources were spread evenly within the municipality.⁵ After the experiment, municipal governments will *want* a total amount of $s_{0j}^* + \sigma_j \tau_j K$ to be spent in every location, meaning that absent constraints, $s_{1ij}^* = s_{0j}^* - K(1 - \sigma_j \tau_j)$ in treatment locations and $s_{1ij}^* = s_{0j}^* + \sigma_j \tau_j K$ in control locations. The ability of municipal governments to achieve this given the matching requirements will determine what is measured in the experiment.

If the matching constraint does not bind, meaning that $mK < s_{0j}^* - K(1 - \sigma_j \tau_j)$, then every neighborhood sees its spending rise by the NBE, the experiment is completely unwound, and the Average Spillover on the Control $ASC(\tau)$ will be the $NBE(\tau)$. Therefore, if matching constraints do not bind then we have $\frac{dNBE(\tau)}{d\tau} = \frac{dASC(\tau)}{d\tau} = \sigma_j K > 0$, and we will observe a Net Budget Differential (the difference between final optimized spending in the treatment and the control) $NBD(\tau) = ITT(\tau) = 0$ for every τ (even though the $NBE(\tau)$ increases with τ).

⁵ It is important to recognize that while τ_j is randomized σ_j is not, and it may have an endogenous relationship with the dependent variable. Thus in any context in which the product $\sigma_j \tau_j$ is used empirically it should be instrumented for with τ_j .

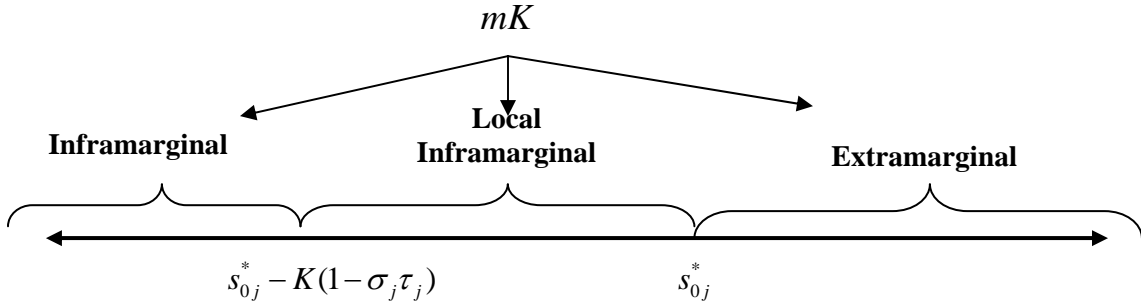
If on the other hand the matching constraint is binding meaning that $mK > s_{0j}^* - K(1 - \sigma_j \tau_j)$, then municipal spending will equal mK in all treatment locations and there is no longer equalization of marginal returns across neighborhoods.. Within this range if $mK > s_{0j}^*$ then the control locations must be taxed to pay for the matching money, while if $mK < s_{0j}^*$ then the additional resources from the experiment will be partially redistributed to the control. When the matching constraint is binding

then $ASC(\tau) = \frac{\sigma_j \tau_j}{1 - \sigma_j \tau_j} (s_{0j}^* - mK)$ and $\frac{dASC(\tau)}{d\tau} = \frac{s_{0j}^* - mK}{(1 - \sigma_j \tau_j)^2}$, both of which have the same sign

as $s_{0j}^* - mK$. Also, $NBD(\tau) = K - \frac{(\sigma_j \tau_j)^2}{1 - \sigma_j \tau_j} (s_{0j}^* - mK)$ and

$\frac{dNBD(\tau)}{d\tau} = -\frac{(1 - \sigma_j \tau_j) 2\sigma_j^2 \tau_j + \sigma_j^3 \tau_j^2}{(1 - \sigma_j \tau_j)^2} (s_{0j}^* - mK)$, both of which have the opposite sign to

$s_{0j}^* - mK$. The fact that the signs of these derivatives across the saturation distribution flip depending on whether $mK < s_{0j}^*$ allows us to divide the decision space into three empirically relevant regions:



If the matching requirement is higher than the pre-treatment spending per neighborhood, then the matching is strictly binding and the municipality will have to tax the control locations in order to be able to balance its budget. This is an ‘extramarginal’ transfer. If the matching amount is smaller than the re-optimized municipal spending, the experiment can be completely unwound and we are in the ‘inframarginal’ case. In between these two values (the ‘local inframarginal’ case) the matching

constraint will be binding but rather than taxing controls to pay for the matching, the experiment will generate a net transfer to controls (although not a complete unwinding of the experiment).⁶

We can now consider how randomizing the treatment saturation τ_j allows us to distinguish these cases from each other when we consider some outcome $Y_{ijt} = f(S_{ijt} + K_{ijt} + s_{ijt}^*)$, where $f(\cdot)$ is a strictly non-decreasing function of total expenditure. Our core outcome will be an index of infrastructural quality calculated at the neighborhood level (we do not observe municipal infrastructure spending at the neighborhood directly).

Consider the following regression equations using panel neighborhood-level data:

$$(1) \quad Y_{ijt} = \alpha_{ij} + \delta_t^A + \gamma(T_{ij} * \delta_t) + \varepsilon_{ijt}$$

Here, α_{ij} is a set of neighborhood-level fixed effects, δ_t^A measures the average change in outcomes for the control group, and γ gives:

$$I\hat{T}T(\tau) = E(Y(S_{ij} + \bar{K} + s_{ij}^*) | \tau_j, T_{ij} = 1) - E(Y(S_{ij} + s_{ij}^*) | \tau_j, T_{ij} = 0).$$
 We can also write the term recovered by the experiment as $I\hat{T}T(\tau) = E(\Delta Y(NBD(\tau)))$. To achieve a simple parameterization of the saturation effects, we can linearize the slope terms identified by the Randomized Saturation experiment:

$$(2) \quad Y_{ijt} = \alpha_{ij} + \delta_t^B + \beta(T_{ij} * \delta_t) + \mu_1(\tau_j * \delta_t) + \mu_2(\tau_j * T_{ij} * \delta_t) + \varepsilon_{ijt}$$

In this regression, μ_1 linearizes the slope of $E(\Delta Y(\cdot) | \tau)$ in the control, and μ_2 measures whether this saturation-driven change is different for treated neighborhoods than control neighborhoods. Experimental identification of spillover effects allows us to posit four observationally distinct possibilities for how treatment and control outcomes will respond to randomized variation in municipal-level saturations.

1. No strategic response.

Here, local governments do not re-optimize, and we recover the standard causal estimands under SUTVA:

- $\hat{\gamma} = \hat{\beta} = IIT(K)$
- $\hat{\mu}_1 = \hat{\mu}_2 = 0$

⁶ Note that there is a close analogy between this problem and the large literature on infra-marginal food aid (Moffit 1989, Gentili 2007).

2a. Inframarginal strategic response. No treatment effect, treatment and control outcomes improve equally with saturations by the Net Budget Effect.

- $\hat{\gamma} = 0$
- $\hat{\mu}_1 = \frac{dASC(\tau)}{d\tau} > 0, \quad \hat{\mu}_2 = \frac{dNBD(\tau)}{d\tau} = 0$

2b. Local Inframarginal strategic response. Partial treatment effect, positive net spillover effect to the control.

- $0 < \hat{\gamma} = ITT(NBD) < ITT(K)$
- $\hat{\mu}_1 = \frac{dASC(\tau)}{d\tau} > 0, \quad \hat{\mu}_2 = \frac{dNBD(\tau)}{d\tau} < 0$

2c. Extramarginal strategic response. Estimated treatment effect amplified by municipal spending, negative net spillover effect to the control.

- $\hat{\gamma} = ITT(NBD) > ITT(K)$
- $\hat{\mu}_1 = \frac{dASC(\tau)}{d\tau} < 0, \quad \hat{\mu}_2 = \frac{dNBD(\tau)}{d\tau} > 0$

In an RCT in which treatment had been blocked at the municipal level, there would be no way to investigate this bias in the ITT empirically because $\tau_i = \bar{\tau}$, and so controls within every municipality would receive identical spillover effects. This two-layer experiment with randomization of both τ_j and T_{ij} allows us to directly test the ways in which spillovers may be biasing causal inference.

2.2. Recovering Internally Valid Estimates in the Face of Interference.

If we find evidence of spillover effects, even an RCT will be subject to bias if it is using within-cluster observations as a counterfactual (we lack pure control clusters because the program was unwilling to recruit municipalities and then leave them completely untreated). The problem comes from the fact that the panel counterfactual outcome $\delta^A = E(\Delta Y(s_{ij}^*) | T_i = 0)$ includes the mean of the $ASC(\tau)$ across the empirical saturations used in the experiment, while the desired unperturbed control outcome $E(\Delta Y(s_{0ij}^*) | T_i = 0)$ would have no spillovers. As shown in Baird et al (2013), by imposing a continuity assumption on the distribution of outcomes as a function of τ we can estimate the control outcome that would have obtained in the absence of the experiment

(that is, at zero treatment saturation). With this, we can adjust the ITT by the difference between the desired and observed counterfactual outcome. A very simple means of establishing this is to linearize the system, in which case $\hat{\delta}^B$ from Equation (2) above gives the desired quantity. This intercept is the estimated control group outcome at a saturation of $\tau = 0$ given a linear (affine) relationship between the saturation and the outcome.

The actual counterfactual change in outcome used in the simple ITT regression, on the other hand, is estimated by $\hat{\delta}^A$ in Equation (1).. This implies that the bias in the simple \hat{ITT} is given by $\delta_t^B - \delta_t^A$, which is the average spillover to the control observed in the trial, and the ‘corrected’ ITT that is purged of this average estimated spillover effect is given by $\gamma + (\delta_t^A - \delta_t^B)$.

Graphical intuition for this correction is provided in Figure I. The figure shows a scatterplot of the average change in the infrastructure index for the treatment group (black) and the control group (gray), as well as the linear fit of the change in outcomes across saturations for each group. The point represented by a star illustrates the average empirical saturation in the experiment (.462) and the average weighted change in outcomes among control locations. This value ($\delta_t^A = .115$) serves as the actual counterfactual for the experiment. The point represented by a diamond is the projected change in outcomes for the control where the saturation equals zero; this quantity ($\delta_t^B = .230$) gives the estimated pure control change that would have obtained in the absence of the experiment, and represents the desired counterfactual outcome. The difference between these two terms is weighted average bias caused by spillovers into the control group, and suggests that the treatment effect is overestimated by the difference, .115. The standard ITT estimate is .220, and so the ‘corrected’ ITT, given by $\gamma + (\delta_t^A - \delta_t^B)$, is .105. The downward slope for both the treatment and control as saturations increase suggests that municipal spending is extramarginal: as the total amount of federal spending they are asked to match increases, improvements in infrastructure within each location become smaller due to binding budget constraints. Without the use of the randomized saturation design we would have been unable to investigate the average spillover to untreated locations, and hence unable to correct for this bias. We now present the context and data for the evaluation, and then move on to the analysis of impacts.

3. IMPLEMENTATION AND DATA

3.1. Program Description.

The Mexican federal government created the Hábitat program in 2003 in order to provide infrastructure investments to marginalized urban parts of the country, and to provide public resources to improve the quality of life in these communities. The program targets the urban poor and focuses on neighborhood upgrading, pouring money into urban infrastructure investment but also investing heavily in Community Development Centers (CDCs) and skills upgrading such as job training for the unemployed and health and nutrition training for young mothers.

When it intervenes, Hábitat defines a ‘polygon’ which is effectively a shapefile identifying a specific neighborhood. A Hábitat polygon is smaller than a locality and is a designation not used by other layers of government. In order to be eligible to benefit from Hábitat, a polygon must have a state and municipal government that is willing to cooperate with Hábitat’s cost-sharing rules (which involve local governments providing 50% of project costs; in our projects the municipalities provided 40%, the states 8%, and the beneficiaries 2%).⁷ The target population of the program is settled households in marginalized urban areas with concentrations of asset poverty greater than 50%, located in cities of 15,000 inhabitants or more, with a deficit of infrastructure and urban services, and with at least 80% of the lots having no active conflict over property rights (this will prove important in interpreting the welfare implications of our results).

The lion’s share of Hábitat investment goes into a set of activities it calls ‘Urban Environment Improvement’. These consist of the introduction or improvement of basic urban infrastructure networks (water, drainage and electrification) street lighting, paving, curbs, sidewalks and wheelchair ramps; the construction or improvement of roads, neighborhood gardens and community sports fields, installation or strengthening systems for trash collection, water sanitation and the improvement and equipping of community development. The second most important is ‘Social and Community Development’, which consists of job training and gender violence workshops, the development and updating of community development plans, and social service provision for students secondary and higher education. Table I provides the breakdown of how the money was spent in the 155 treatment polygons studied in this paper.

⁷ This is the reason that our study does not include a pure control consisting of municipalities with no treatment. SEDESOL felt that in return for going through the cost-sharing negotiations municipal governments should be guaranteed that they would receive at least one neighborhood assigned to treatment.

3.2. Sample Selection and Survey.

The polygons included in the study were required to satisfy two additional eligibility restrictions beyond the standard conditions for the program: we excluded municipalities that had only had one polygon, and cities that had fewer than four polygons. With these criteria the impact study consists of 370 polygons, of which 176 neighborhoods serve as the treatment group and 194 as the comparison. Table II presents the distribution of polygons by state and treatment group. The analysis is based on a household survey instrument with two versions, one short and one long. These instruments were conducted between the months of March to July 2009 (baseline observation) and January-March 2012 (follow-up observation) in the 370 polygons. The block-level survey and the household survey were conducted in all the blocks in those polygons with 100 or fewer blocks. For polygons with more than 100 blocks (only 4.3% of total polygons) 100 blocks were randomly sampled. Households were randomly assigned to answer the short versus the long version of the questionnaire (the questions on the short version are all included on the long), resulting in 6,419 long-form and 5,065 short-form questionnaires. Panel tracking was done at the *house* level (not the household level) to capture changes in the attributes of structures.⁸

The study had a pre-analysis plan submitted to the Mexican government at the time the analysis of the baseline survey was being completed. The outcomes included in that pre-analysis plan include those evaluated here (core infrastructure impacts, private investment, and real estate impacts) as well as impacts on social capital, crime, health, transport time, and access to and use of community centers. An overview of the project is given by Ordóñez et al. (2013), and the impacts on pre-committed outcomes not presented here are given in Ordóñez and Ruiz (2013). The pre-analysis plan included the study of spillover effects using the specification given in Equation (2).

3.3. Attrition and Balance.

3.3.1. Attrition.

This study considers infrastructural outcomes at the level of the structure, not the resident. For this reason we are less concerned with tracking the same households than with tracking the same houses. If at followup the survey teams were unable to find the same household, they were

⁸ The data from the evaluation survey are posted at <http://www.2006-2012.sedesol.gob.mx/es/SEDESOL/ProgramaHabitat>

instructed first to survey the new residents of the same house, so as to provide a panel on changes to that specific structure, and if they were not able to find residents in the same house then they were to randomly sample a new house and household from the same block.

The analysis sample begins with 10,670 baseline household observations. Two distinct factors cause us to lose observations from the study. First, implementation problems arose with 5 of the original 65 municipalities in the sample (the municipal governments did not meet the matching requirements).⁹ Since Hábitat could not treat the polygons in these municipalities, we have removed them from the study altogether, treatment and control alike. This causes us to lose 748 observations, almost 7% of the sample. Second, in forming the block-level panel we lose 220 observations. The dataset used for analysis thus consists of 19,417 panel household surveys that provide two periods of data at the block level. We also see two additional forms of replacement that do not cause attrition from the study, but alter the interpretation of impacts. First, we have 17.6% of houses whereby the surveyors could not locate anyone to survey in the same house as was surveyed at baseline, and hence they replaced the baseline house with a different house on the same block. In 25.7% of cases where the survey teams were able to locate the same house, the household currently residing in the structure had changed since baseline.

Table III tests for whether four distinct types of attrition prove to be correlated with the treatment. In columns 1-2, we begin with the sample of inhabited blocks and examine the attrition caused by the dropping of the five municipalities in which treatment was not possible. While this attrition represents a large part of the original sample, there appears to be no systematic correlation between original treatment status and the polygons in which Hábitat was able to administer treatment. Columns 3-4 then examine the attrition driven by the success of COLEF field teams in conducting a panel block-level survey. Overall attrition at the block level was low (98.5% of the potential panel blocks were successfully tracked) and appears similarly to be balanced by treatment. When we look at the success of field teams at locating first the same house (Columns 5-6), and then the same household (Columns 7-8), we begin to see evidence of significant differences across the treatment and control. The probability of being unable to find any resident in the baseline-surveyed house is 3.6% lower in the treatment than the control, although this difference is statistically insignificant. Examining attrition at the household level, the survey teams were substantially more successful at tracking the same household again in the treatment than the control. More than a

⁹ These five municipalities are Cuajimpala de Morelos, La Magdalena Contreras, Xochimilco, Almoloya de Juarez, and Ecatepec de Morelos.

quarter of the houses that were panel tracked saw the resident household change in the three years of the study, indicating a very high rate of residential churn in the study. More importantly, the treatment had a strong effect on this rate of churn; in treatment neighborhoods this rate of churn dropped by 7 percentage points, or a quarter of the control-group rate. While we are concerned only with the attrition through Column 4 for the basic analysis of infrastructure impacts, we return to a discussion of differential attrition of households when analyzing changes in private investment in the housing stock.

3.3.2. Balance at the Neighborhood Level.

Table IV examines the baseline treatment-control comparison within the final analysis sample. The overall balance of the experiment looks very good. There is some evidence (10% significant) that the treatment went into locations with worse access to lighting, but an overall index of infrastructural quality is slightly higher in the treatment than the control. The other variable here displaying some imbalance is the index of satisfaction with social conditions, indicating that the treatment fares slightly worse. In a broader analysis of balance (not reported), baseline balance was checked using the entire battery of 65 variables designated in the pre-analysis plan as central. We find $5/65 = 7.6\%$ of the outcomes are unbalanced at the 5% level, very close to what we should observe by random chance. Overall, there do not appear to be ‘families’ of variables that are systematically different between treatment and control. One implication of this good overall balance is that the results prove very robust to control structure: a post-treatment single-difference, a simple difference-in-differences, a DID using FE at the municipality level and a DID using FE at the block level give nearly identical results.

4. RESULTS.

4.1. Flypaper effects at the municipality level.

A very simple way of analyzing flypaper effects is to begin with municipal-level infrastructure expenditure data and run the following regression:

$$\Delta MS_i = \alpha + \eta FS_i + \varepsilon_i,$$

where ΔMS_i is the change in municipal spending on infrastructure once the experiment has begun, and FS_i gives the federal spending in municipality i arising through the experiment. If FS_i were directly randomized, we could simply estimate the municipal response. An estimate of $\hat{\eta} = -1$

would imply perfect crowdout, $\hat{\eta} > -1$ would indicate some flypaper effect, $\hat{\eta} = 0$ indicates no strategic response, and $\hat{\eta} > 0$ indicates crowd-in.

The problem with this regression in practice is that actual Hábitat spending per municipality has an endogenous component arising from the fraction of neighborhoods in a municipality that are eligible for the program. To address this, we instrument for federal spending with the assigned saturations. Figure II illustrates the instrumentation strategy using two sets of scatterplots. The first plots the *true* population treatment saturation of a municipality against the *assigned* treatment saturation that was directly randomized. There is substantial variation in the true saturations not explained by the assigned, arising mostly from the fact that poorer municipalities will have a larger share of their population eligible for Hábitat. The right-hand figure plots the key right-hand side measure of FS_i (namely federal Hábitat spending as a fraction of baseline municipal infrastructure budgets); the fitted line then represents variation that can be exploited by an instrumentation of federal spending with the randomized saturations. The conclusion from this graph is that while Hábitat spending is overall small relative to municipal infrastructure budgets, the saturations alone can explain a properly randomized fraction of spending that varies from 1% to 9% of baseline annual municipal budgets.

Figure III provides a visual take on the reduced-form variation in the IV regression, plotting the dependent variable of ‘% change in municipal spending, pre- to post-experiment’ against the treatment saturations. From inspection of this figure, Tijuana emerges as a major outlier in the regression. This municipality saw a huge increase in infrastructural spending related largely to long-planned main road construction, not an activity with which Hábitat is directly involved. Tijuana is also a high-saturation municipality in the study, meaning that its inclusion tends strongly to increase the apparent marginal effect of treatment saturations on spending changes. When we move to presenting the ‘flypaper’ results in Table V, therefore, we show all results with and without Tijuana in the sample so that the reader can gauge the effect of this data point on the overall relationship.¹⁰

The first column in Table V validates the cross-municipality experiment, showing the variation in saturations to be orthogonal to baseline municipal expenditure levels. Columns 2 and 3 show the reduced-form impacts depicted in Figure III; namely the percent change in municipal

¹⁰ Tijuana is not an outlier in the other regressions in this paper that consider treatment versus control changes at the neighborhood level; its exclusion does not affect other results.

infrastructure spending by the assigned treatment saturation.¹¹ Point estimates are positive but insignificant, indicating a mild crowd-in effect in spending, even when Tijuana is excluded. The next two columns present the simplest way in which to measure the magnitude of crowd-in, by regressing the raw change in municipal expenditures on the raw value of Hábitat investment in the municipality. Because the latter is endogenous, we instrument for it using the assigned saturation as depicted in Figure II. Here again we get positive and insignificant results, but the magnitude of the effect is worthy of comment: the result from column 5 indicates that for every dollar spent in a municipality by Hábitat, local infrastructural spending rises by 5.6 dollars. While this regression on 58 observations is certainly not adequately powered to detect the difference between 0 (no strategic response) and -1 (perfect crowdout), including Tijuana we are almost able to reject that this coefficient is negative. The last two columns of Table V try to further remove municipal scale effects by regressing the percent change in municipal spending on the instrumented Hábitat investment as a percentage of baseline municipal spending. The column excluding Tijuana indicates that when Hábitat spending as a fraction of municipal spending increases by 1%, municipal spending increases by 2%.

Clearly, this analysis of flypaper effects in municipal infrastructure spending suffers from low power. Nonetheless, we can exploit access to an unusual source of randomized variation in the magnitude of federal investment within municipalities. Given that the average annual municipal budget is \$23 million, our IV-randomized federal expenditure varies from \$230,000 to \$2,140,000 per municipality. Using this variation in spending we are unable to reject perfect crowdout or a lack of strategic response, recovering marginal effects consistent with a relatively strong *crowd-in* effect of federal infrastructure spending on the infrastructure expenditures of municipalities.¹²

4.2. Neighborhood-level Impacts on Basic Infrastructure.

We now transition to the more granular consideration of impacts at the neighborhood level. To measure this, we calculate neighborhood (polygon)-level averages of the 10 infrastructure variables indicated by our pre-analysis plan as the core indicators of the program. These neighborhood averages are then analyzed with a fixed-effects difference-in-differences regression

¹¹ Note that here we do not weight regressions since the intent of Table V is to be representative for municipality decision-makers rather than for the inhabitants of municipalities. All variables used in this analysis enter directly at the municipal level and do not require the construction of weighted averages within municipalities.

¹² A similar IV analysis on the size of municipal debt (not reported) found no significant relationship with federal spending through Hábitat.

(Equation (1) in Section 2). This regression is weighted by the product of two sets of weights in order to make it representative of the average household in the study. The first is the standard survey weight, the number of households in the neighborhood (and neighborhood-level averages are calculated weighting by the number of households per block). Secondly we use ‘saturation weights’ (Baird et al. 2013) to undo the structural weighting caused by the randomized saturation design: by definition we observe more treated neighborhoods and fewer untreated neighborhoods as saturations increase. To make it so that each potential outcome is given equal weight across the saturation distribution, we must weight treatment observations by the product of the sampling weights and $.5*(1/\text{saturation})$, and each control outcome by the sampling weights times $.5*(1/(1-\text{saturation}))$. Standard errors are clustered at the municipal level to reflect the component of the design effect that enters through the randomized saturation experiment.

Table VI presents these core infrastructure results. We first discuss the variables used for the stratification of the randomization: availability of piped water, sewerage, and electric lighting. These variables all feature high baseline control means, (from 82.9% for sewerage to 98.9% for electricity). The treatment estimate on water is negative, and sewerage indicates an insignificant increase of almost 2%. Electric lighting improved by just less than a percentage point, significant at the 10% level. When we examine infrastructure to which baseline access was less universal, strongly significant positive effects are apparent. Streetlights, sidewalks, medians, and road paving all see dramatic improvements; the fraction of houses with sidewalks in front of them was 59% at baseline, rising to 62.5% in the control at followup, but increased to almost 70% in the treatment. An index of basic infrastructure improves in the treatment at triple the rate of the control, significant at the 99% level. Reported satisfaction of residents with the quality of infrastructure improves, but not significantly.

In summary, for this project in which \$68 million was spent building infrastructure for 118,000 households in treatment-eligible neighborhoods (\$567 per household), significant improvements in the quality of infrastructure enjoyed by the average resident were achieved.

4.3. Spillover Effects and Causal Inference at the Neighborhood Level.

Section 2 showed that causal inference can be undermined if local governments re-optimize around the experimental design. Before proceeding farther with the analysis, we therefore provide a set of empirical tests that exploit the randomized saturation design to measure the extent to which

crowdout and spillover effects appear to be biasing our results, and show how the estimated bias can be used to correct the ITT.

We analyze these infrastructure construction spillovers using Equation (2) from Section 2. Table VII provides the results of the spillover regression using the core infrastructural outcomes as dependent variables. Table VII reports the differential saturation slope in the treatment in the first row (μ_2), the saturation slope in the control in the second row (μ_1), the treatment effect at zero saturation in the third row (β), and the estimated intercept in the fourth row (δ^B), which gives the linearized projected outcome at zero saturation. For the purpose of visual comparison, at the bottom of the table we also reproduce the average change estimated in the control group from the previous impact regression (δ^A) and the simple ITT estimate (γ), as well as the resulting estimates of the spillover to the control and the corrected ITT.

The core concern with spillover effects from the perspective of evaluation is to determine whether our counterfactual may have been polluted. To this end we focus first on the second row of results (μ_2), which give the extent to which control neighborhood outcomes are a function of municipal-level treatment saturations. These results provide little evidence of strong spillover effects of the program, although the majority of coefficients are negative. Consistent with a lack of strong spillover effects, the Treatment on the Uniquely Treated given by the Treatment * R2 interaction (which projects what the treatment effect would be at zero saturation, where no spillovers should occur) in general look similar to the simple ITT effects presented in the previous table. The sole significant control group saturation slope term (on road paving) is negative, and the sign of this term on the overall index and the satisfaction index are both negative. The general picture is therefore one of mild crowd-in, meaning that control outcomes become slightly worse as the intensity of treatment within a municipality rises.

We can use these parameters to estimate the magnitude of the implied bias, and to provide spillover-corrected estimates of program effects following the methodology in Section 2 and Figure I. To this end, we are interested in the comparison between the counterfactual actually used in the impact regressions (the 'Round 2' dummy δ^A from Table VI, which gives the change in the control) and the desired counterfactual implied by linearization of the saturation effects as in Equation 2 (the zero-saturation intercept δ^B from Table VII). The actual minus the desired counterfactual gives a

measure of the bias in the actual estimate of the ITT, and so we can then subtract this bias off the estimated ITT to get the ‘corrected ITT’, presented in the final row of Table VII.¹³

When we compare the corrected ITT at the bottom of Table VII to the uncorrected ITT estimated in Table VI, the results suggest that several very large-footprint activities such as water and sewer installation had positive spillover effects on control neighborhoods. Consequently the control outcome is distorted upwards, and so the corrected ITT for these types of infrastructure is larger than the uncorrected. For several highly localized and easily divertable types of construction such as the installation of medians and sidewalks and the paving of roads, on the other hand, it appears that improvements in the treatment came *at the expense* of control neighborhoods, meaning that the counterfactual has been depressed and hence the naïve ITT is overestimated. When we correct for this, several of the very strong impacts of the program disappear, and the index of infrastructure itself is barely significant.¹⁴ Correction for spillover effects therefore increases the apparent impact of the program on large-footprint infrastructure, and decreases the apparent impact on more localized types of investment such as sidewalks, medians, and road paving. Nonetheless, the absolute magnitude of spillovers in this study is muted.

We can also relate the results of Table VI back to the hypotheses related to inframarginality in Section 2. The presence of strong treatment effects rules out the possibility that the entire federal program was inframarginal, because clearly complete crowdout did not occur. To distinguish whether we have local inframarginality or extramarginality in the sample, we should examine the magnitudes of the saturation slope terms μ_1 and μ_2 . Not a single differential slope term μ_2 is significant, suggesting that the sample is not extramarginal: if the control was being taxed to meet the matching requirement in the treatment we should see a gap open up between treatment and control outcomes as the saturation increases, and we do not. Similarly, with local inframarginal constraints the control outcome should be increasing consistently with the treatment saturation by the net budget effect, and instead we see a range of signs and values across different types of infrastructure. The combination of strong positive overall treatment effects with saturation effects

¹³ The standard error for the corrected ITT can be calculated using Seemingly Unrelated Regression, or using two-step GMM. For purposes of comparability we use the unadjusted standard errors from Table VI to calculate p-values at the bottom of Table VII; cross-equation standard errors are larger.

¹⁴ It is interesting to refer again to Figure I and to consider the fact that the Mathematica evaluation of Hâbitat conducted in an environment in which they treated 100% of eligible neighborhoods found no treatment effect. The treatment-control differential in the infrastructure index is decreasing as the saturation increases, and it appears they would converge very close to a saturation of one. This implies that we only detected significant average ITTs in this study because the use of the RS design held average saturations below 100%.

that are both muted and varied across types of infrastructure leads us to conclude that the data are most consistent with a lack of strategic response on the part of municipal governments. It does not appear that local infrastructure investment was re-optimized across space in a manner that violates causal inference in a systematic way.

4.4. Impact on Private Investment.

The surge in public investment induced by the Hábitat experiment provides an interesting environment in which to investigate potential complementarities between public and private investment. The program places public resources in communities under-served by past infrastructural investments, and yet in which property rights are robust. Further, 84.4% of households in the baseline reported owning their own homes, and 74% own their homes outright (mortgage financing is difficult to obtain in poor Mexican neighborhoods even with clear property title). Thus, there appears to be substantial scope for the amenity value created by Hábitat investments to pass into the hands of the residents of these neighborhoods. We investigate this interplay between private and public investment by examining privately-financed investments in the housing stock of Hábitat neighborhoods.

Table VIII provides evidence of complementarities between private and public investment.¹⁵ Every measure of the private housing stock has improved, suggesting that public investment is crowding in private investment from households. The only negative coefficient is on the use of a septic system, but because this is an inferior substitute to connection to a sewer line this indicates increasing use of centralized infrastructure. Households are significantly more likely to have installed concrete floors, and to have working flush toilets. The improvement in indoor plumbing is particularly interesting given that we did not see significant impacts on sewerage in Section 4.1; in this case private investment appears to have outstripped the measurable improvements in public infrastructure. Home ownership rates in the treatment rise by 2%, although this difference is not significant. The coefficient on having obtained a mortgage from a private bank is very small in absolute magnitude but is almost significant.

Returning to the analysis of attrition in Section 3.3.1, recall that the rate of residential relocation between the two waves of the survey fell from 39% in the control to 30% in the

¹⁵ Having found only weak spillover effects on the first-order infrastructural impacts, we now return to a more standard experimental analysis using only sampling weights (not saturation weights) and we do not provide full spillover-corrected ITT estimates for the remaining analysis. Unreported analysis confirms that spillover effects on the outcomes analyzed in Table VIII are also very small.

treatment. Could this lower rate of turnover itself be an explanation for the greater willingness to invest in houses, and the slight uptick in home ownership and mortgages? A simple way of testing for this is a mediation analysis, in which we control for the share of the houses in the neighborhood that changed owners between the two periods. Results available on request show that the significance level of the significant coefficients in Table VIII are almost completely unchanged by the inclusion of this variable, indicating that even *within* those who stayed and those who moved, the Hábitat investment induced a meaningful increase in private investment.

The last column of Table VIII shows the impact on rents for the 16% of households that do not own their own homes, and indicates a substantial \$17 jump in monthly rents, a nearly 20% increase over the baseline control-group average rent of \$88. Hence, Hábitat investment does appear to have been successful both at crowding private investment into the housing stock in intervention neighborhoods and at increasing rental prices.

4.5. Impacts on Real Estate Values.

Significant increases in rents in treatment neighborhoods provide enticing evidence that rising public and private investment are translating into a meaningful capitalization of improvements in property values. Particularly because of the high rates of home ownership in Hábitat neighborhoods, the most natural way to examine this is through raw land prices. Real estate prices should capitalize the net present value of a flow of amenities from improved infrastructure, and thus provide a particularly interesting way of comparing the net costs of an intervention to the net benefits realized by residents. To the extent that a public investment yields total property price increases that are greater than the amount of the investment itself, residents would wish to be taxed to make these investments. The presence of net positive returns suggests ‘money left on the table’, and points to a friction in the political economy of infrastructure delivery.

Measurement of the improvement in property values, however, presents several empirical challenges. First, increases in private investment (such as installation of concrete floors or bathrooms with indoor plumbing) confound the measure of increases in property values because the housing stock itself improves because of private, not public investment. Value increases driven by private expenditures are a valid causal effect of the program, but they complicate an accounting of the per-dollar returns to public investment. Secondly, recent empirical work suggests that urban Mexican households typically provide over-estimates of the sale value of their own properties (Gonzales-Navarro & Quintana-Domeque, 2009). To overcome the first of these issues, we use

sales prices only on empty lots that have no construction on them as of the baseline, so our estimate of price per square meter of raw land is not polluted by changes in the nature of the private housing stock. In order to get a high-quality estimate of sales prices in an environment in which there is no regular recording of sales prices, we used professional property assessors from the Instituto de Administración Avaluos de Bienes Nacionales (INDAABIN), the Mexican government's institute of real estate valuation.

These assessors provided estimates of the value of every one of the 464 un-built lots that were for sale in the study polygons at baseline, and then returned to the same lots at the time of follow-up and provided new estimates of the raw land value of the lot at that time (whether or not a structure had by then been built). In each round, the assessors assembled information from comparable sales and put together estimates according to established INDAABIN methodology. Assessors were blinded to the treatment design (meaning that they did not know whether they were providing estimates in treatment or control communities). While the total number of empty lots for sale at baseline was small, this analysis provides a precise and readily interpretable impact on land values.

Of the 342 baseline polygons used in this analysis, just over 40% had any empty lots for sale at baseline. The average baseline lot had 1.25 lots for sale, with a maximum of 23 lots per polygon. The intervention sample provides us with 437 lots located in 138 polygons. Column 1 of Table IX shows that these neighborhoods are not representative of the overall study, being both larger and poorer than the average study neighborhood. However, the sample selection in the real estate analysis arising from polygons in which at least one lot was for sale is balanced across treatment and control, and the baseline means of polygon-level average prices per square meter in this attrited sample are comparable between the treatment and the control. Hence, our analysis of real estate prices takes place in an unrepresentative sample, but appears to be well balanced and internally valid.

When we turn to the difference-in-differences impacts in Table IX, we see substantial improvements in prices being induced by the treatment. Relative to a baseline control value of \$86.11 per square meter and a real control group appreciation of \$3.02 between 2009 and 2012, the treatment effect of the program was an additional \$5.76 per square meter, meaning that the treatment group had almost triple the real rate of appreciation as the control. Figure IV shows the CDF of the changes in real property prices in treatment and control polygons, demonstrating that improvements in the treatment first-order stochastically dominate the control. Perhaps the most

meaningful way to put this number in context is to consider that the treatment polygons contain 118,491 lots with an average of 218 square meters each, for a total of 25.9 million square meters of property total. If the marginal effect estimated above is applied to all inhabited property in the treatment polygons, the resulting increase in total value is \$150 million, more than two times the \$68 million invested by all three levels of government in the program. The average residence would have enjoyed \$1,157 in appreciation from Hábitat investment during 2009 to 2012, while having had \$574 spent on it. Thus, every dollar of public money invested in infrastructure improvement in a polygon yielded two dollar of improvement in the total privately-held value of land there.

4.6. Impacts on Political Behavior.

4.6.1. Attribution.

We motivated the multi-level budgeting game in a model of electoral competition; we now examine directly whether the flow of resources had an effect on political attribution and on voting. A first issue in the political economy of the program is the extent to which residents who had large investments made in their neighborhood are aware of the Hábitat program, and the extent to which they correctly attribute improvements in their local environment to the program. To examine this, we define a dummy for households that had heard of the program, and a dummy for households that had heard of any off a list of *other* organizations that might be working in the local neighborhood. We then construct the same variable for whether a household reports having benefitted from the program, first examining Hábitat and then examining all other programs. The results in Table X show quite clearly that while those in program areas are substantially more likely to have heard of Hábitat (19% in the treatment versus 12% in the control), a vanishingly small fraction of households report having benefitted directly from the program (0.8%) and this fraction is actually slightly lower in the treatment than in the control. This number stands in stark contrast to the beneficiary numbers provided by Hábitat itself, whereby they use GIS maps with ‘buffers’ around the locations of investments to suggest that 30.5% of household benefitted from street paving, 16.7% from CDCs, 8.3% from sewerage, 8.1% from sidewalks and medians, 6.5% from street lighting, and 5.4% from drinking water. In short, while the program is both creating real benefits and effectively ‘spreading the word’ as to its own existence, it appears to be generating no positive attribution effects for Hábitat itself as virtually no-one is aware of having benefitted directly from the program.

4.6.2. *Voting in the 2012 Elections.*

To test the causal relationship between infrastructure spending and political behavior, we examine voting behavior in the 2012 presidential elections. These elections were conveniently timed to occur exactly as the randomized phase was drawing to a close. Since Hábitat is a federal program, we examine the extent to which the incumbent National Action Party (PAN) reaped rewards at the ballot box in national elections at the end of the experimental phase of the program. While the 2012 election saw the PAN lose to the once-dominant Institutional Revolutionary Party (PRI), we can use fine-grained electoral data to test whether treatment regions display an elevated vote share for the PAN. To the extent that voters in treatment polygons were attributing to the incumbent national party some of the benefits seen in terms of infrastructure, safety, and property value improvements, we would expect this to improve the vote share for the PAN party relative to other parties in treatment areas

In order to be able to conduct this analysis, it was necessary to map the Hábitat-defined polygons onto the ‘secciones’, which are the most disaggregated level at which the Federal Electoral Institute (IFE) provides shapefiles of electoral districts. IFE provides voting data all the way down to the precinct level, and so we first aggregated the electoral data to calculate vote shares for PAN and PRI at the seccion level, and we then overlaid GIS shapefiles of the Hábitat polygons with the electoral *secciones*. By calculating the fraction of each polygon that lies within each *seccion*, we can then calculate a weighted average of the vote shares in all of the relevant *secciones* to estimate what the vote share for each candidate was in each Hábitat polygon. Table XI present the cross-sectional differences between treatment and control polygons in the PAN and PRI vote shares at the presidential (national), senatorial (state), and deputy (district) levels.

Consistent with the complete lack of ability to attribute benefits to Hábitat, there is no evidence that treatment polygons turned out to vote more strongly for the incumbent PAN party at the national level. The vote share for PAN in treatment polygons was 0.14% higher than in the control, but this result is far from significant and the increase in the vote share for the (ultimately victorious) PRI party was almost as large. At the senate and the deputy level the analysis similarly shows no evidence that the program has altered party affiliation at these levels.

5. CONCLUSION

This paper presents the results of a large experiment conducted by the Mexican federal government in the construction of infrastructure for low-income neighborhoods. In this

examination of the effects of \$68 million of spending spread across 118,000 treatment households, we find evidence that infrastructure investment is at sub-optimal levels in these areas. Treatment induces a large improvement in the access to well-functioning public lighting, paved roads, and sidewalks, private investment in the housing stock increases, neighborhood churn in real estate decreases by a quarter, and the total increase in the value of the property in intervention neighborhoods is more than twice the cost of the program. On the other hand, a program that spent an average of \$550 per beneficiary household did not improve access to water or sewerage (despite having spent more than 10% of their budget on these items). Residents did not reward the national party that oversaw Hábitat at the polls. In short Hábitat appears to have been a highly effective program fiscally and yet to have served absolutely no role as a piece of political patronage at the federal level. This disconnect is most likely due to the poor ability to attribute infrastructure improvements to the correct government entity.

Our study paid particular attention to the possibility of spillover effects. We presented a framework with which to classify the possible responses of municipal governments to an experiment in federal spending, and exploit the randomized saturation design to analyze these responses at the aggregate municipal level as well at the neighborhood level. The simple takeaway from this analysis is that there are no substantial spillover effects, and hence standard causal inference is unbiased. Nonetheless, an adjustment of the simple impact estimates for the bias uncovered by the saturation variation is interesting. The spillovers recovered vary substantially across different types of infrastructure, and ultimately appear to relate more to the unique spatial externality of the intervention than to a single underlying budgeting spillover. Large-footprint investments typically drive up outcomes in the control as saturations increase, suggesting positive spillovers and underestimated treatment effects. Granular and easily diverted investments in things like street paving create a negative spillover to the control, meaning that the adjusted treatment effects are smaller than the unadjusted.

A reasonable criticism of the spillover analysis in this paper would be that it is underpowered because the Hábitat-eligible neighborhoods prove to be a relatively small fraction of the study municipalities. Saturation variation that is very large in the study sample is quite muted in the total infrastructure budgets of the municipal governments. We do in fact detect some significant spillover effects, however, and the standard errors on our overall index of infrastructural quality indicates that we would have been able to detect a spillover improvement of less than .5 over a baseline mean of 2.74 and a baseline standard deviation of 1.4. A minimum detectable spillover effect of $1/3^{\text{rd}}$ of a

standard deviation on our core outcome suggests that the study is relatively well powered to detect even spillover effects. Seen in a different light, the very conclusion that the treatment regions are too small to perturb outcomes in the control group indicates that SUTVA is satisfied in this program. The use of the randomized saturation design provides quite conclusive evidence that spillovers did not occur in this case, and hence helps to bolster the internal validity of the study even using specifications that do not exploit the saturations.

Then, there is the credibility of the very large increases in the value of private real estate we estimate to have been induced by the program. While this doubling of value appears very large, Cellini et al. (2010) find an increase of \$1.50 in the willingness to pay of homebuyers for every \$1 invested in public schools in California, and lay out a simple political theory that says while marginal returns on public investment should be zero, they may be positive in equilibrium because individuals within the community who don't value those things (or already have them) will be unable to support additional spending on the margin. Pereira and Flores de Frutos (1999) use a vector auto-regression model on public spending in the US, finding that every dollar invested returns 65 cents in private investments. Given that we may expect infrastructure spending in poor Mexican neighborhoods to be farther below efficient levels than in the US, a figure of \$2 may not be unreasonable.

Our results should bolster the argument that we not overlook large-scale spending on macro programs in the face of proven micro-interventions such as conditional cash transfer (CCT) programs. Given that the flagship CCT was also experimentally tested in Mexico, the *Oportunidades* program provides an interesting point of comparison. *Oportunidades* pays an average of \$71 per month to beneficiary households. This means that the Hábitat investment of \$550 per household would represent fewer than eight months of cash transfers, and has resulted in an increase in the asset wealth of the household of twice this sum as well as a broader set of benefits on social trust and the physical conditions of the urban environment, as documented in Ordóñez and Ruiz (2013) and Ordóñez et al. (2013). CCT programs are designed to create a temporary flow of consumption benefits that leave behind an improved stock of human capital; here we see infrastructure spending generating flow improvements in the quality of life and leaving behind a substantially improved stock of property value. Improving infrastructure in underserved locations can deliver real social benefits as well as a substantial surge in household wealth.

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TABLES.

Table I. Hábitat Expenditures by Activity.

Total Investments in Treatment Polygons, 2009-2011 (US Dollars)

Name of Program (Subprogram)	2009-2011				Households Benefitted
	Total Investment	Federal	State	Municipal	
Social and Community Development	13,922,853	7,026,328	373,053	6,523,472	256,443
Improvement of Urban Environment:	53,729,286	26,359,409	4,978,304	20,857,825	169,607
Paving	32,850,121	15,905,294	3,586,772	12,246,184	43,054
Sewers	4,877,761	2,465,322	301,398	2,047,825	7,672
Drinking water	2,644,150	1,320,621	93,867	1,160,632	5,071
Community Development Centers	2,842,852	1,397,310	198,192	1,160,519	17,536
Sidewalks and medians	2,459,935	1,300,516	260,256	830,340	4,447
Public lighting	1,752,960	881,141	30,248	824,506	5,327
Trash collection	1,801,580	915,702	63,868	767,860	72,370
Total spending	67,743,983	33,431,659	5,364,410	27,414,167	428,590

Source: SEDESOL

Table II. Locations of Hábitat Projects by State.

State:	Control Neighborhoods	Treatment Neighborhoods	Total
Baja California	6	14	20
Campeche	3	1	4
Chiapas	2	1	3
Chihuahua	6	5	11
Coahuila	3	3	6
Distrito Federal	16	20	36
Guanajuato	7	13	20
Guerrero	9	7	16
Jalisco	14	10	24
México	46	40	86
Michoacán	6	13	19
Morelos	4	3	7
Nuevo León	4	3	7
Puebla	24	15	39
Quintana Roo	12	1	13
Sinaloa	6	7	13
Sonora	6	1	7
Tamaulipas	8	12	20
Veracruz	9	5	14
Yucatán	3	2	5
Total	194	176	370

Table III. Attrition.

Attrition Between Rounds 1 and 2:

	Attrition at municipal level (municipality selected to be part of study but removed by Habitat)		Attrition at block level (block sampled at baseline and in study municipalities, but panel dependant variable not observed)		Attrition at House level (baseline sampled house replaced with alternate at followup)		Attrition at Household level (baseline sampled household replaced with alternate at followup)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Baseline values of:								
Treatment	-0.014 (0.048)	-0.00996 (0.049)	-0.00412 (0.005)	0.000965 (0.001)	-0.0363 (0.030)	-0.0297 (0.028)	-0.0702** (0.030)	-0.0612** (0.026)
Index of Basic Services		-0.0000749 (0.001)		-0.0000254 (0.000)		0.000614 (0.000)		0.000647 (0.001)
Satisfaction with Social Infrastructure		0.00166 (0.008)		-0.000922* (0.000)		-0.0029 (0.005)		0.0123** (0.005)
Observation Weight		0.0000488 (0.000)		-1.22e-05*** (0.000)		0.000260* (0.000)		0.000352* (0.000)
Average fraction attrited in control group:	0.095		0.016		0.176		0.257	
# of Obs:	10,670	10,436	9,922	9,745	9,702	9,702	8,302	8,302

Regressions include fixed effects at the municipality level, and are weighted to be representative of all residents in the study neighborhoods. Standard Errors in parentheses are clustered at the polygon level to account for the design effect. Stars indicate significance at * 90%, ** 95%, and *** 99%.

Table IV. Balance.

	Average in Control Group	Treatment/ Control Differential	Standard Error of Difference
Piped Water	0.926	-0.0163	(0.016)
Sewerage Service	0.829	-0.011	(0.027)
Electric Lighting	0.989	-0.00884*	(0.005)
Use Water to Bathe	0.287	0.00801	(0.028)
Flush Toilet	0.613	-0.0325	(0.023)
Diarrea in Past 12 Months	0.178	-0.0169	(0.016)
Street Lighting Always Works	0.555	-0.0255	(0.021)
Street is Paved	0.664	0.0172	(0.025)
Index of Basic Services	91.492	-1.204	(1.303)
Index of Basic Infrastructure	68.512	1.097	(2.057)
Availability of Services + Infrastructure	78.361	0.111	(1.506)
Satisfaction with Physical Environment	2.844	-0.106	(0.084)
Satisfaction with Social Environment	83.308	-2.320*	(1.215)
Knowledge of Public Programs	39.358	-1.322	(0.965)

Regressions on 9,702 observations include fixed effects at the municipality level, and are weighted to be representative of all residents in the study neighborhoods. Standard Errors in parentheses are clustered at the polygon level to account for the design effect. Stars indicate significance at * 90%, ** 95%, and *** 99%.

Table V. The Flypaper Effect in Total Municipal Infrastructure Spending

	Municipal Spending on Public Works & Social Action, 2007-09 versus 2010-11						
	Baseline Municipal Spending, millions of dollars	Percent change in annual Municipal Spending		Raw change in Annual Municipal Spending, millions of dollars		Percent change in annual Municipal Spending	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Assigned Municipal Treatment Saturation (0-1)	0.252 (9.7)	56.27 (36.8)	18.74 (29.7)				
Federal Spending, millions of dollars (instrumented with saturation)				28.76 (18.7)	5.615 (8.6)		
Federal Spending as % of baseline municipal spending (instrumented with saturation)						6.438 (4.3)	2.002 (3.0)
Constant (spending at zero saturation)	18.99*** (5.3)	5.161 (20.1)	17.61 (16.0)	-9.804 (10.0)	-0.304 (4.5)	3.752 (21.3)	17.58 (15.1)
# of Obs:	60 0	59 0	58 0	59	58 0	59	58 0
Instrumental Variables Regression	N	N	N	Y	Y	Y	Y
Includes Tijuana?	Y	Y	N	Y	N	Y	N

Municipal-level analysis, not weighted by population. Standard Errors in Parentheses, Stars indicate significance at * 90%, ** 95%, and *** 99%.

Table VI. Polygon-level Infrastructure Impacts.

		Piped Water	Sewerage Service	Electric Lighting	Street Lights	Medians	Sidewalks	Paved Roads	Trash Collection	Index of Basic Infrastructure	Satisfaction with Physical Infrastructure
Intention to Treat	(γ)	-0.0193 (0.020)	0.018 (0.030)	0.00900* (0.005)	0.0684** (0.030)	0.0997*** (0.033)	0.0702** (0.027)	0.0601*** (0.020)	-0.0000452 (0.017)	0.220*** (0.067)	0.694 (0.541)
Dummy for R2	(δ^A)	0.0225** (0.011)	0.0269* (0.015)	0.00404 (0.003)	-0.00714 (0.029)	0.0214 (0.019)	0.0362* (0.020)	0.0502*** (0.014)	0.0188 (0.013)	0.115** (0.056)	-0.16 (0.488)
Baseline control mean:		0.926	0.829	0.989	0.555	0.588	0.589	0.664	0.971	2.740	8.825
Observations		684	684	684	682	684	684	684	684	684	684
R-squared		0.024	0.051	0.036	0.029	0.14	0.13	0.209	0.049	0.18	0.02
Number of polygons		342	342	342	342	342	342	342	342	342	342

Polygon-level analysis with polygon fixed effects and standard errors clustered at the municipal level. Regressions weighted by saturation weights and by polygon populations to make them representative of all inhabitants of study areas. Standard Errors in Parentheses, Stars indicate significance at * 90%, ** 95%, and *** 99%.

Table VII. Spillover Effect Estimates.

		Piped Water	Sewerage Service	Electric Lighting	Street Lights	Medians	Sidewalks	Paved Roads	Trash Collection	Index of Basic Infrastructure	Satisfaction with Physical Infrastructure
Municipal Saturation * Treatment * R2 (differential saturation slope term in treatment)	(μ_2)	-0.0172 (0.063)	-0.0303 (0.136)	-0.0164 (0.020)	-0.0353 (0.126)	-0.168 (0.155)	-0.0585 (0.122)	0.0384 (0.105)	-0.126 (0.076)	-0.107 (0.328)	1.158 (2.255)
Municipal Saturation * R2 (saturation slope term in control)	(μ_1)	0.081 (0.050)	0.0236 (0.059)	-0.0149 (0.013)	-0.00921 (0.125)	-0.0479 (0.084)	-0.0475 (0.092)	-0.121** (0.055)	0.0856 (0.072)	-0.245 (0.232)	-0.304 (1.724)
Treatment * R2: (treatment effect at 0 saturation)	(β)	-0.00989 (0.034)	0.0322 (0.081)	0.0161 (0.013)	0.0842 (0.070)	0.174** (0.086)	0.0956 (0.058)	0.0403 (0.058)	0.0587* (0.031)	0.264* (0.155)	0.166 (0.991)
R2 (trend in control)	(δ^B)	-0.0157 (0.017)	0.0157 (0.022)	0.0110* (0.006)	-0.0028 (0.064)	0.0439 (0.038)	0.0586* (0.034)	0.107*** (0.028)	-0.0215 (0.023)	0.230** (0.099)	-0.0165 (0.627)
# of Obs:		684	684	684	682	684	684	684	684	684	684
Baseline control mean:		0.926	0.829	0.989	0.555	0.588	0.589	0.664	0.971	2.740	8.825
Simple ITT	(γ)	-0.0193 (0.020)	0.018 (0.030)	0.00900* (0.005)	0.0684** (0.030)	0.0997*** (0.033)	0.0702** (0.027)	0.0601*** (0.020)	-0.0000452 (0.017)	0.220*** (0.067)	0.694 (0.541)
SE of Simple ITT											
Average Control Change:	(δ^A)	0.0225**	0.0269*	0.00404	-0.00714	0.0214	0.0362*	0.0502***	0.0188	0.115**	-0.16
Average Estimated Spillover in Control	$(\delta^A - \delta^B)$	0.0382	0.0112	-0.00696	-0.00434	-0.0225	-0.0224	-0.0568	0.0403	-0.115	-0.1435
Corrected ITT	$\gamma + (\delta^A - \delta^B)$	0.019	0.029	0.002	0.064**	0.077**	0.0478*	0.003	0.0402548**	0.105*	0.551

Polygon-level analysis with polygon fixed effects and standard errors clustered at the municipal level. Regressions weighted by saturation weights and by polygon populations to make them representative of all inhabitants of study areas. Standard Errors in Parentheses, Stars indicate significance at * 90%, ** 95%, and *** 99%.

Table VIII. Private Housing Investment.

	Brick Walls	Concrete Floors	Separate Kitchen	Separate Bathroom	Flush Toilet	Septic System	Piped Water	Home Owner	Private Bank Mortgage	Monthly Rent, US\$ (for renters only)
Treatment * Round 2	0.00337 (0.008)	0.0229** (0.009)	0.0112 (0.016)	0.00416 (0.014)	0.0707** (0.031)	-0.0273** (0.013)	0.0146 (0.023)	0.0208 (0.022)	0.00962 (0.006)	16.68* (9.697)
Round 2	0.00763 (0.006)	0.00743 (0.005)	0.0307** (0.012)	0.0184** (0.008)	-0.0475* (0.025)	0.00162 (0.012)	0.0628*** (0.015)	0.00557 (0.009)	-0.0134** (0.005)	-0.667 (7.176)
Baseline control mean:	0.942	0.965	0.876	0.930	0.608	0.113	0.703	0.844	0.019	88.4
Observations	684	684	684	684	684	684	684	684	683	530
R-squared	0.012	0.065	0.089	0.033	0.037	0.014	0.105	0.019	0.034	0.047
Number of polygons	342	342	342	342	342	342	342	342	342	299

Polygon-level analysis with polygon fixed effects and standard errors clustered at the municipal level. Regressions weighted by polygon populations to make them representative of all inhabitants of study areas. Standard Errors in Parentheses, Stars indicate significance at * 90%, ** 95%, and *** 99%.

Table IX. Real Estate Value Impacts.

Dependent Variable: Changes in real estate price per square meter, real 2012 US Dollars.

	Attrition:	Baseline Balance:		Impact:		
	Polygon has Observation on Prices	Baseline Price, Simple Weighted Difference	Baseline Price, Weighted Difference + Municipality FE	Change in Price per square meter, 2009-2012	Price Change, Weighting by number of viviendas per polygon	Price Change with Weighting + Municipality Fixed Effects
Treatment	-0.0986 (0.06)	2.409 (14.83)	3.207 (10.72)	6.523*** (2.31)	8.196** (3.79)	5.756** (2.87)
Baseline Index of Services	0.0556 (0.081)					
Baseline Index of Infrastructure	-0.0786** (0.035)					
Total # of Residences	6.07e-05*** (0.000)					
Constant	0.474** (0.20)	86.11*** (8.44)	44.27*** (4.02)	3.017* (1.54)	2.108 (2.37)	-30.75*** (5.38)
Observations	342	138	138	138	138	138
R-squared	0.216	0.001	0.788	0.055	0.080	0.637

All prices are in US Dollars per square meter. Analysis of unbuilt lots as polygon averages; dependent variable is price as assessed by professionals from IDAABIN. Standard Errors in parentheses; stars indicate significance at * 90%, ** 95%, and *** 99%.

Table X. Attribution.

	Heard of Habitat	Heard of non- Habitat programs	Benefited from Habitat	Benefitted from non-Habitat programs
Treatment * R2	0.0765*** (0.027)	0.244 (0.497)	-0.000558 (0.004)	-0.00892 (0.071)
Treat	-0.0267 (0.017)	-0.281 (0.316)	0.000881 (0.002)	-0.0567 (0.053)
R2	-0.0994*** (0.022)	-1.641*** (0.452)	0.00309 (0.003)	-0.0281 (0.052)
R2 Mean in Control:	0.115	7.602	0.008	0.753
# of Obs:	19,417	19,417	19,417	14,394

Regressions include fixed effects at the municipality level, and are weighted to be representative of all residents in the study neighborhoods. Standard Errors in parentheses are clustered at the polygon level to account for the design effect. Stars indicate significance at * 90%, ** 95%, and *** 99%.

Table XI. Impacts on Voting Behavior.

	Presidential (National) Election		Senatorial (State) Election		Diputado (District) Election	
	Share voting for PAN	Share voting for PRI	Share voting for PAN	Share voting for PRI	Share voting for PAN	Share voting for PRI
Treatment Effect	0.00135 (0.005)	0.000976 (0.005)	-0.00106 (0.005)	0.000322 (0.005)	-0.0016 (0.005)	0.00344 (0.006)
Mean in Control group	0.217	0.280	0.229	0.294	0.228	0.294
Observations	341	341	341	341	341	341
R-squared	0.876	0.82	0.886	0.832	0.878	0.832

Analysis at the polygon level, using weighted averages of the vote outcomes from the polling precincts that overlap with treatment polygons. Regression is a simple difference in the 2012 vote shares. Standard Errors in Parentheses, stars indicate significance at * 90%, ** 95%, and *** 99%.

FIGURES.

Figure I. Correction of the ITT for Spillover Effects.

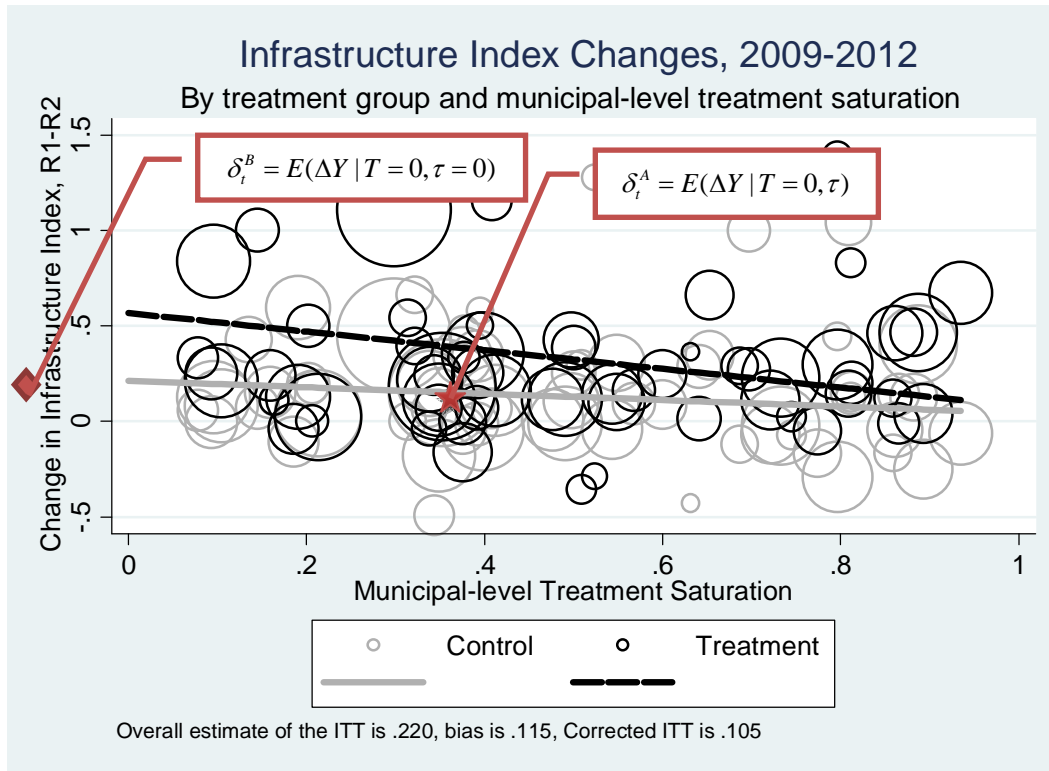


Figure II. Does Aggregate Municipal Infrastructure Spending Change with Federal Spending?

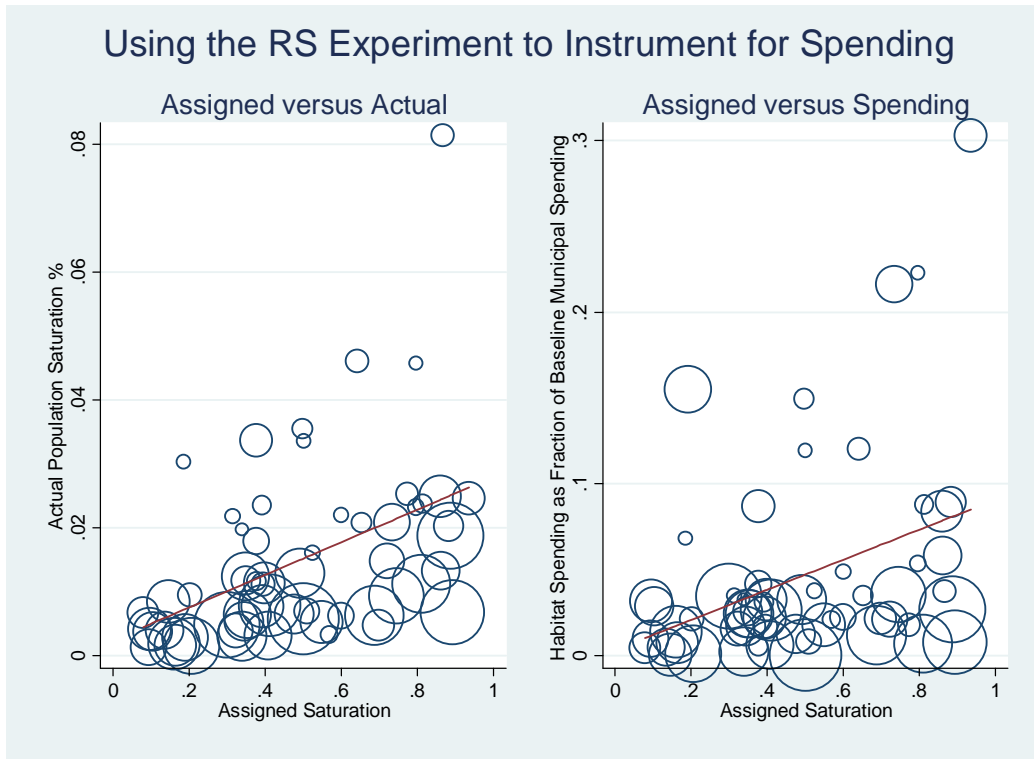


Figure III. Does Aggregate Municipal Infrastructure Spending Change with Federal Spending?

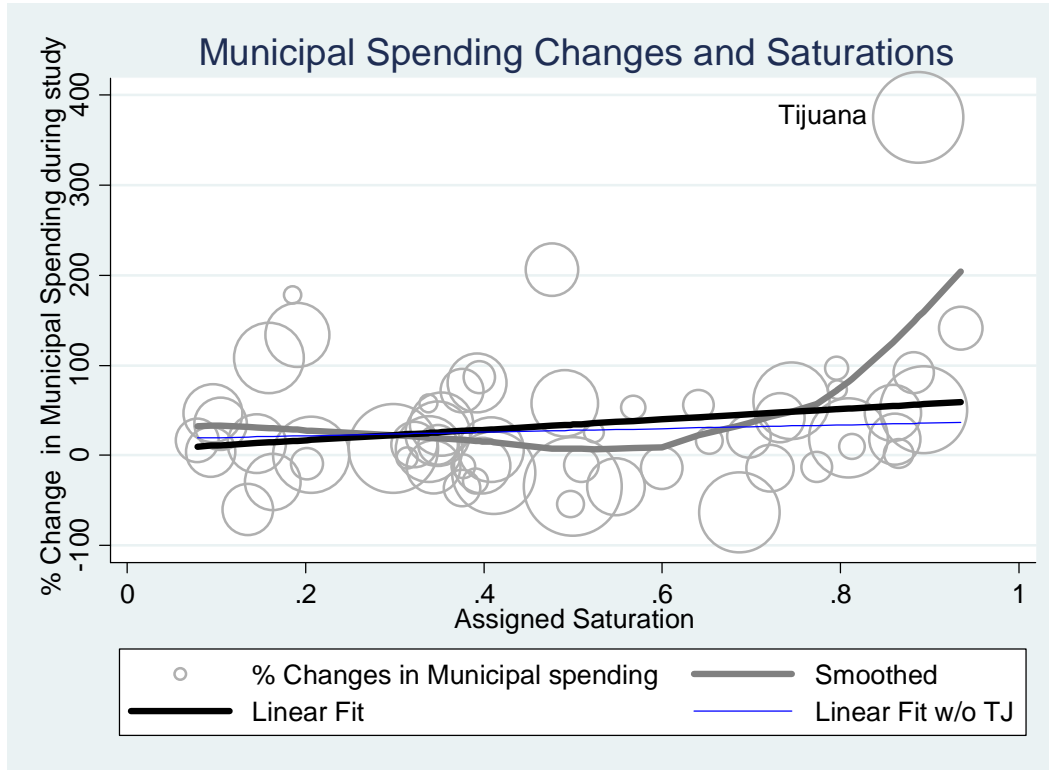


Figure IV. Cumulative Distribution Functions of Property Price Changes.

