Urban Expansion, Drought Risk, and Willingness-to-pay for Piped Water

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Abstract

Cities in the global south are rapidly expanding into areas that are not serviced by public utilities such as piped water, relying instead on private substitutes like groundwater. We examine rising groundwater drought risk to investigate how a shock to the quality of these private substitutes impacts demand for public utilities. We estimate that a major groundwater drought in Bangalore permanently increased residents' willingness-to-pay to live near the pipe network by 0.4% of monthly rents per 100m. We show consequently that new residential construction projects that are close to the piped water network increased by 25-51% relative to those that are farther. Using a structural model of housing demand, we find that housing market adjustment recover 20% of the welfare gains of expanded pipe access at just 2.4% the cost. Our findings highlight both that public infrastructure quality governs urban expansion and that housing markets enable adaptation to local environmental hazards.

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1 Introduction

The urban population in the Global South is projected to expand 81% from 2020 to 2050 (World Resources Institute, 2021). While this urbanization is driving economic growth, it is also pushing housing to suburbanize faster than public infrastructure can expand (George, Kaldany and Losavio, 2019). Governments are faced with a decision between making costly expansions to infrastructure or encouraging settlement in areas that already have infrastructure. This decision has implications for a city's congestion, productivity, and climate resilience (Akbar et al., 2023*a*,*b*; Harari, 2020; Ahlfeldt, Baum-Snow and Jedwab, 2023; Rosenthal-Kay, 2025).

Suburban households without access to public infrastructure often turn to private substitutes. These private substitutes frequently are of higher risk or lower quality than their public counterparts (Filion and Keil, 2016). Despite widespread reliance on privately-supplied roads, electricity, internet, transport, water, garbage collection, and security, the role of this quality disparity in driving urban expansion is largely unquantified.

In this paper, we study how consumers and real estate developers respond to a climate-driven change in the risk of relying on privately-supplied borewell groundwater.[1] We conduct our study using Bangalore's 2024 water crisis. During this crisis, the half of Bangalore's 14 million residents without access to publicly-supplied piped water experienced groundwater shortages for 2 months. Residents without piped water were subjected to rations, increased prices, and detrimental health impacts during this period. Residents with piped water were largely unaffected during this crisis and are likewise insulated from the risk of future droughts.[2]

[1] The risk of urban groundwater shortage is rapidly increasing worldwide. Experts estimate that 97% of the cities located in the global south have higher chances of experiencing droughts, which are also becoming 73- 88% more intense (Stolte et al., 2023).

[2] Households relying on piped water are insulated from drought risk in Bangalore because Bangalore's pipes draw from surface water sources outside the city that are resilient to depletion. This does not necessarily reflect the situation for individuals residing in cities where the piped water system draws from groundwater (e.g. Mexico City) who are not insulated from groundwater shortages.

We first analyze a novel dataset of monthly rental listings across Bangalore to show that the water crisis increased demand for piped water access. We observe each listing's exact location, monthly price, and amenities. This allows us to link proximity to the piped water network with rental prices conditional on a set of other characteristics. Hedonic valuations find that residents' willingness-to-pay (WTP) to live 100 meters closer to the pipe network permanently increased by 0.4% of monthly rents following the drought.[3] This premium is permanent for long-term listings but lasts only during the drought for short-term leases that are less exposed to future drought risk. We find that the estimate is particularly large (0.5% per 0.1km) for units occupied by families, highlighting the uneven distribution of impacts from drought across households.

To explain this shift in demand, we then combine original household survey data with administrative data on hospitalizations to show that groundwater shortages have negative impacts to human health. Out-patient hospitalizations spike at the beginning of the drought and in-patient hospitalizations remain at elevated levels throughout the water crisis[4]. Heterogeneity analysis of the household survey finds that the health effects were attributable to the water crisis. We observe reported health issues that are 3 percentage points higher for those who reported relying on tanker water – which has high contamination risk – during the crisis.

With demand shifting to favor housing with access to piped water, we show that long-run supply of housing adjusted to areas near water pipes. We divide Bangalore into 50 distinct geographic areas and classify each area by its access to water pipes. We use a difference-in-difference approach to compare areas close to the piped water network relative to those

[3]Listings range in distance from under 0.1km to up to 3km, implying that the listings farthest from water pipes experience a predicted rent decrease of 12%.

[4]The water crisis also corresponds to reports of cholera outbreak in the city at the time: https://economictimes.indiatimes.com/small-biz/sustainability/from-dump-to-data-how-this-start-up-is-fixing-indias-waste-management-issue/articleshow/121205721.cms

farther from the piped water network. We estimate with this approach that construction increased by 25-51% in areas near the piped water network relative to areas farther from the piped water network. This implies that adaptation via the housing market to some extent reduces the damages of urban droughts in the long-run, decreasing the necessity for utilities to make costly expansions to the pipe network.

Back-of-the-envelope calculations suggest that the housing market response is more cost-effective that pipe expansions. We conservatively estimate that the housing expansion increased consumer surplus by 20% as much as a counterfactual policy of expanding piped water access to be universal. The cost of the housing expansion, however, is only 2.4% of the cost of such a pipe expansion. This finding highlights that encouraging housing development in areas serviced by public utilities (e.g. via zoning policy, information campaigns, or subsidies) is a cost-effective policy approach for governments to improve social welfare for cities with limited public infrastructure.

Our paper contributes to the literature on urban expansion in developing countries by examining how the relative quality of public infrastructure influences such expansion. Many paper have previously studied the *effects* of the way a city expands (Harari, 2020; Ahlfeldt, Baum-Snow and Jedwab, 2023; Akbar et al., 2023*a*,*b*). Fewer studies have examined the *causes* of the way a city expands, largely focusing on roads or public transport (Balboni et al., 2020; Pratama, Yudhistira and Koomen, 2022; Rosenthal-Kay, 2025; Sorin Le Guével, 2025). We contribute to this literature in two ways. First, we contribute by examining the role of a change in relative quality of the publicly-provided amenity in driving urban expansion. Second, we contribute as the first to study piped water access in driving urban expansion. In particular, we show that rising drought risk limits the extent to which cities will expand into the suburbs, a finding which has important implications for cities with similar water infrastructure to Bangalore, such as Mumbai, Jakarta, New Delhi, Lima, and Nairobi.

We also contribute to the literature on adaptation to environmental disamenities by examining highly localized housing demand and supply responses. The conceptualization of consumer valuation of their surrounding environment dates back to Rosen (1974) and Roback (1982) and has been empirically examined in many settings (Chay and Greenstone, 2005; Greenstone and Gallagher, 2008; Haninger, Ma and Timmins, 2017; Hornbeck, 2012; Hornbeck and Naidu, 2014; Desmet and Rossi-Hansberg, 2015; Desmet et al., 2018; Cruz and Rossi-Hansberg, 2024; Aron-Dine, 2024). We contribute to this literature in two ways. First, we examine the extent to which a natural disaster with spatially differentiating impacts can lead consumers to weigh intra-city migration versus other available adaptation mechanisms. Second, we are among the first to study how housing *supply* responds to these environmental shocks.

Finally, we contribute to the literature on water access in low- and medium-income contexts by estimating how groundwater drought risk influences WTP for piped water. A large body of work has examined demand for and impacts of piped water and other clean water alternatives (Galiani, Gertler and Schargrodsky, 2005; Gamper-Rabindran, Khan and Timmins, 2010; Devoto et al., 2012; Kremer et al., 2011; Luoto et al., 2011; Szabo, 2015; Dupas et al., 2016; Null et al., 2018; Alsan and Goldin, 2019; Haushofer et al., 2021; dos Santos and Guidetti, 2024; Burlig, Jina and Sudarshan, 2025). These papers have little focus on the role of rising drought risk. One paper which does focus on drought risk is Abajian et al. (2025), who examine "Day Zero" where *piped* water was nearly entirely depleted in Cape Town, South Africa. Our paper contributes beyond Abajian et al. (2025) in two ways. First, we study the impacts of groundwater drying up, as opposed to piped water being depleted. While borewells and piped water are substitutes for each other, it is much more difficult for households with drying wells to obtain new access to piped water (without migrating) than it is for households with drying pipes to drill new wells. Second, we contribute by analyzing WTP as an outcome, allowing us to quantify in standard terms residential valuations of piped water in the face of drought risk.

The rest of the paper proceeds as follows: Section 2 provides background details, Section 3 describes our data, Section 4 presents reduced form results, Section 5 conducts simple back-of-the-envelope calculations, and Section 6 concludes.

2 Background

2.1 Bangalore Water Supply

There are two sources of water used to meet the needs of Bangalore's residents: (1) piped water and (2) borewell groundwater. Piped water comes from the Cauvery river and is available in the center of Bangalore. Borewell water supplies groundwater to residents in Bangalore's suburban periphery.

The pipe system was largely developed around the historical city center of Bangalore (Castán Broto, Sudhira and Unnikrishnan, 2021) and is managed by the Bangalore Water Supply and Sewage Board (BWSSB). Residents of single-family homes that have access to BWSSB pipes pay a metered fee each month for water usage. Residents of apartment buildings that have access to BWSSB pay a fixed building maintenance fee each month which encompasses the cost of water.[5] An alternate way to access river water is to utilize public pumps, which are connected to the pipe system. The BWSSB pipe system services about 50% of the city (Kulranjan, Palur and Nesi, 2023).

Bangalore's suburban population relies on groundwater, which is obtained from privately-managed borewells. Groundwater reliance occurs in areas where housing developments outstripped the pace of pipe infrastructure expansion– typically in newly developed peripheral

[5]The building maintenance fee can change month-to-month as water usage does change between the dry and wet seasons.

areas or in buildings commissioned by individual developers.[6] Residents can also access groundwater from public borewells. While BWSSB manages around 6,000 public borewells, the overwhelming majority of borewells are drilled privately for personal use (Castán Broto, Sudhira and Unnikrishnan, 2021).[7]

The presence of piped water only in the urban downtown of Bangalore creates disparities in water access between those residing downtown and those residing in the suburbs. Figure 2 overlays on a map of Bangalore the location of water pipes throughout the city, depicting that water pipes are densely populated throughout the urban center of the city. Many portions of Bangalore's suburban outskirts have minimal access to this piped water and instead must rely predominantly on groundwater. This yields many rental listings which are distant from water pipes. Figure 3 displays the number of rental listings' distances from the nearest pipe, highlighting the fact that thousands of listings are distant from the nearest water pipe.

Water pipes can be expanded, but these expansions are costly, difficult, and take a large amount of time. A recent expansion of water pipes into Bangalore's suburbs is depicted by the red lines in Figure 2. This expansion was announced in 2014 and only began supplying water in limited capacities from September 2024. The expansion is estimated to have cost approximately $500 million to provide water connections for a planned 500,000 individuals (Japan International Cooperation Agency, 2024).

2.2 2024 Bangalore Water Crisis

From late February to late April of 2024, Bangalore experienced its worst drought in decades. A combination of below-average monsoon rainfall, reductions in natural replenishment rates, and increasing suburban demand led to severe water shortages for those relying on ground-

[6]Like many cities in the Global South, Bangalore has experienced rapid urbanization over the past several decades. The city's population has surged from approximately 8.5 million in 2011 to an estimated 14 million in 2024. This surge in population has led to increased demand for housing, infrastructure, and amenities, particularly in the city's suburban outskirts (Bangalore Mirror Bureau, 2024).

[7]Some experts suspect there are up to 500,000 total borewells in Bangalore (Cave, 2024).

water. Groundwater reservoirs supplying Bangalore reached critically low levels, forcing BWSSB to impose water rationing measures. Despite these measures, around 7,000 of the cities 16,000 borewells ran dry (Mogul, Jha and Farooqui, 2024).

This drought primarily affected households and businesses without access to piped water, as the Cauvery's river supply was unaffected.[8] Individuals without access to the pipe network were forced to ration water, with many reporting that they were unable to flush toilets, wash dishes, wash laundry, or take showers (Cave, 2024). Impacted residents spent time waiting in long queues for tanker water, searching for public borewells that had not dried up, and purchasing bottled water for drinking and cooking. We estimate with survey data that median monthly water expenditures during the crisis increase by ₹642 for those reporting no access to piped water, with a more modest ₹250 increase among those reporting having a pipe connection.[9]

3 Data

We combine data from four sources to investigate housing demand, housing supply, water amenities, and micro-level impacts of the water crisis.

3.1 Housing Demand

We collect data on rental prices and housing amenities comes from Housing.com. Once each month, from May 2023 to April 2025, we scrape every active housing rental listing for Bangalore that is present on the site. The scrapes occur during the middle of each month and capture an average of 14,500 units each month. After omitting all listings outside of Bangalore's city limits, we observe a total of 347,426 listings across 24 months. Our analysis only includes listings which are residential.[10] In total, our analysis sample has 323,655 listings.

[8] Appendix Table A1 summarizes several other major water crises which have occurred worldwide.
[9] The increase is driven by households that rely on water tanker water to supplement their pipe connection. Removing households that rely on water tankers yields an increase of ₹652 for those reporting not having a pipe connection and ₹0 for those reporting having a pipe connection.
[10] Approximately 24,000 listings are meant for companies.

For each rental listing, we observe the exact location, monthly rent price, other monetary expenses associated with renting there (security deposit, brokerage, and maintenance), as well as a rich set of characteristics about the listing (furnishing, bathroom count, building age, etc.). Table 1 provides summary data on these amenities.[11]

Figure 1 displays a map of wards in Bangalore along with dots indicating our scraped listings for four months – one well before the crisis (July 2023), one just before the crisis (December 2023), one during the crisis (March 2024), and one after the crisis (August 2024). Our data captures listings across Bangalore's urban downtown and suburban sprawl. The listings include both low-price and high-price units, reflecting that the site captures a range of listings for all types of renters.

3.2 Long-Run Housing Supply

Our data on long-run housing supply comes from Karnataka's Department of Housing, which collects data on in-progress construction to adhere to the 2016 Real Estate Regulatory Authority (RERA) Act. This act, meant to ease grievances of housing stakeholders, requires that all real estate projects of at lesat 500 square meters or at least 8 apartments be registered with the respective state RERA authority. RERA requires that each real estate developer submit an application to the relevant state authority with estimated costs and duration of construction.

We scrape data on each submitted real estate project application from January 2023 to April 2025. Each application includes details of the constructing enterprise, project start and pro-

[11]For many listings, characteristics such as building height, building age, and balcony count are optional to include in the Housing.com posting. This leads to a large amount of missing data for important characteristics that are likely correlated with both piped water proximity and the price of a listing. Fortunately, we observe a rich set of characteristics for every single listing – including bedroom count, square footage, and listing type (e.g. "flat", "apartment", "independent builder floor", etc.). We thus handle missing characteristics data by employing a multiple imputation strategy that uses observed characteristics to predict missing characteristics within each listing. This strategy is discussed in more detail in Appendix Section A1.

posed end dates, progress reports, building specifications, and the exact project location. We also observe cost of construction, area measures, and a description of the listings to be provided within the building. The data also includes details on whether the application was rejected or approved, though rejections are rare in practice.[12]

Table 2 provides summaries of key variables for all registered development sites within Bangalore's governing limits. The average construction duration is approximately 3.5 years, reflecting the importance of monitoring in-progress construction to understand long-run housing supply adjustments to the water crisis.

3.3 Water Infrastructure & Other Public Amenities

We generate measures of access to piped water by utilizing the geographic locations of all water pipes managed by the Bangalore Water Supply and Sewage Board (BWSSB). The water pipe location data comes from a shapefile that was generated by Karnataka State Remote Sensing Applications Centre (KSRSAC) and updated in October of 2024.[13]

We use the distance from a residential building to proxy for the cost of receiving piped Cauvery River water during a groundwater shortage. Buildings that are close to the pipe network are more likely to be connected to the network. Additionally, pipes are also known to leak into groundwater reservoirs, potentially dampening the effects of the water crisis for households near the pipe network even for buildings without a BWSSB connection.

We also generate access to other public amenities such as shops, parks, office buildings, and transit stops by using data from OpenStreetMap.[14] Table 1 provides summary statistics for

[12] Data is available on the RERA website dating back to 2017. However, the data from 2017 through 2022 is inconsistent and often missing key data, particularly location. As such, we focus on the data from 2023 and later.

[13] We sourced the shapefile from Open City, a public repository that aggregates data compiled by other government agencies.

[14] OpenStreetMap is a collaborative open-source mapping software which is considered as up-to-date or more up-to-date than other API tools such as Google Maps in urban and suburban areas. We access the data using the OverPass Turbo API.

our key public-amenity control variables. In particular, we calculate the distance of each listing from the nearest transit stop as a measure of access to the public transit network. We additionally calculate distances of each listing from the nearest park, office building, and shop to gauge neighborhood amenities. Finally, as a measure of density we calculate the numbers of shops within 500 meters of each listing. These provide a rich set of amenities which we control for in our regression analysis.

3.4 Survey Data

Our final data source is a household survey of renters in urban and suburban Bangalore, which allows us to understand residential moving patterns as well as the crisis' impact to health, water expenditures, and adaptive measures.

We generate a geographically representative sample of renters by randomly selecting 300 out of 2,423 locales in which we observe apartments. Locales were stratified by proximity to the nearest water pipe and whether the September 2024 pipe expansion yielded their closest pipe. Each of these 300 locales was visited by survey enumerators. At each location, the survey enumerators approached individuals outside and asked if they were renters are living within a 3-minute walk and who were residing in Bangalore continuously since January 2024.

The survey was conducted over the time frame August 4-18, 2025 and collected a total of 1,251 responses. For each individual respondent, we collect address history from January 2024 to August 2025, pre- and post-crisis perceptions of drought risk, self-reported health issues during the crisis, adaptation behaviors, and demographics. Summary statistics of survey respondents are presented in Table 3.

4 Results

We use a hedonic approach to uncover the change in WTP to be closer to the piped water network. We estimate an increase in WTP of 0.4% of rents per 100m proximity to the nearest pipe. As a consequence, we show with a difference-in-difference that long-run supply of housing increased by 25-51% in areas near pipes compared to areas far from pipes.

4.1 Demand for Housing

4.1.1 Raw Price Trends

Baseline trends in rental prices suggest that the water crisis made listings that are farther from the piped water network less appealing. Figure 4 plots trends in average rental price separately based on proximity of the listings to the piped water network before and after the 2024 pipe expansion. The average prices of listings that are farther from water pipes tend to be higher before the crisis, likely reflecting a difference in amenities. Prices appear to trend in parallel until the crisis begins, at which point there is sharp drop in prices for listings that were far from pipes. The duration of this gap is dependent on anticipation of future water pipe access, as locations that anticipate the September 2024 pipe expansion immediately rebound, whereas listings that remain far from pipes do not.

Figure 4 highlights three facts which motivate our analysis. First, absent of any crisis units that are farther from water pipes tend to be priced higher. This likely reflects preferences for other attributes that are correlated with distance to pipes, highlighting the importance of controlling for listing characteristics in our analysis. Second, the crisis was associated with an immediate and large decrease in price for units that did not have access to piped water. Third, this decrease in rent prices was permanent for areas not expecting to gain pipe access in the near future, but only temporary for those that were. This highlights that future drought risk seems to drive down rental prices, as units with new access to piped water are insulated from future water shortages.

4.1.2 Empirical Specification

We run a hedonic analysis which isolates the impact of piped water access on rental prices of listed units[15] before, during, and after the crisis (Rosen, 1974; Roback, 1982). In particular, our estimates are interpretable as WTP to have piped water access in a given month. In order to uncover this value, we run the following specification for listing i which resides in ward w during month t:

$$\ln(P_{it}) = \beta_0 + \left(\sum_{t'=1}^{T} \beta_{t'} \mathbb{I}_{[t=t']} KM_{it} \right) + \alpha A_{it} + \gamma_{wt} + \varepsilon_{it} \tag{1}$$

where P_{it} is the monthly rental price in INR, $\mathbb{I}_{[t=t']}$ is an indicator for being month t, KM_{it} is the distance (in kilometers) of a listing from the nearest BWSSB water pipe[16], A_{it} is a vector of listing-specific characteristics, and γ_{wt} is a ward-by-month fixed effect.

Our coefficients of interest are $\beta_{t'}$ which capture WTP to be 0.1 kilometers closer to the nearest BWSSB water pipe separately each month. The inclusion of a variety of building-level control variables ensures that our estimates account for potential correlates of pipe distance that drive price, such as building age, building height, number of bedrooms, and other characteristics. Similarly, the inclusion of ward-by-month fixed effects[17] ensures that we utilize only variation within a ward in a given month to estimate the effect. This implies that all characteristics of a ward which do not vary more rapidly than on a monthly basis (e.g. infrastructure, public utilities, and other amenities) do not bias our results. Finally, the inclusion of other listing-specific amenities like nearby shop count and distance to the nearest park ensures that important within-ward correlates do not bias our estimates.

[15] Importantly, our data is not structured as a panel dataset because we do not observe listings once they are no longer posted. In Appendix Figure A3, we present results that create a building-level panel and show that, while underpowered, the results are quantitatively similar.

[16] For all listings prior to September 2024, this distance is calculated using distance from the nearest old pipe. From September 2024, all pipes – including newly expanded pipes – are included.

[17] Note that there are 243 wards in Bangalore. Average ward size is approximately 9 square kilometers (about 3.5 square miles).

4.1.3 Average WTP Effects

We plot estimates of consumer WTP for the overall sample in Figure 5, showing that WTP for piped water increases as a result of the crisis. When the crisis begins, WTP for piped water increases by 0.4% of rents per 0.1 kilometers of distance from the piped water network. This implies that a listing that is directly on top of the piped water network is predicted to be approximately 1.0% cheaper than a listing that is the average distance (0.25km) from the nearest pipe. This premium appears relatively permanent, only attenuating slightly for a few months during Bangalore's wet season. The premium again sees a modest spike upon the advent of Bangalore's drought season in 2025, potentially reflecting fears of another crisis arising in early 2025.

4.1.4 WTP Effects by Lease Length

Figure 5 captures the preferences of all renters, including those on short-term leases, meaning it may underestimate the true impacts of long-term drought risk on WTP for piped water. Housing.com facilitates both short-term leases ($\sim$ 1-3 months) and long-term leases (up to a year), though we do not explicitly observe lease length in our data. As drought risk in Bangalore is seasonal (primarily high in February-April), many individuals signing short-term leases following the 2024 crisis may not have had any need to internalize future drought risk. This may attenuate our estimates in Figure 5 relative to individuals on long-term leases.

We present Figure 6 which depicts that individuals on longer-term leases have larger WTP increases for piped water due to the crisis. In the left panel, we present the estimates only for listings which have security deposits worth at least 5 months of rent, the median in Bangalore. The right figure presents the results for listings which have security deposits of less than 5 months worth of rent. These security deposit sizes are likely highly correlated with lease length, with the left figure thus portraying mainly long-term leases and the right figure mainly short-term leases. We show that the effects for long-term leases are relatively permanent, whereas short-term leases show rent premiums that exist only during drought season. This figure thus shows more concretely that future drought risk is a large driver in the sizes of observed WTP for piped water.

4.1.5 WTP Effects by Household Size

Figure 7 shows that WTP increases for piped water are also larger among large units than small units. In this figure, we depict the estimated WTP for piped water by month separately for listings that are at least three bedrooms (left) versus those that are two bedrooms or less (right). The estimated effects are much larger (0.5% per 0.1km) for multi-bedroom units that tend to be occupied by families. Effects for small bachelor-style units appear to be muted, with notable spikes only occurring during drought months. This highlights that the impacts of drought risk are not borne evenly by the population and are particularly large for families more impacted by rations and price spikes.

4.2 Health as a Driver of WTP

To complement our WTP exercise and provide a more thorough understanding of the impacts from the water crisis, we show that the water crisis had detrimental health impacts. We do so using a combination of publicly available hospital visits data from the Government of Karnataka and self-reported health from our survey. Hospitals visit data is available on a daily basis for two of Bangalore's nine major hospitals. For each day, we observe the total number of in-patient visits, out-patient visits, diagnostic tests, and surgeries.

In Figure 8, we show that hospital visits increase during the crisis. The crisis was accompanied by an immediate temporary spike in out-patient visits as well as a lasting increase in in-patient visits. Encouragingly, diagnostics and surgeries being performed do not change during this period, suggesting that these increases in in-patient and out-patient visits do not reflect general increases in demand for these two hospitals (e.g. from openings or closings in other hospitals). Moreover, we do not observe similar increases in in-patient nor out-patient visits during other dry seasons, suggesting that seasonality is not driving the increases during the crisis.

However, it is difficult to causally attribute these hospital visits to the water crisis, so we supplement these findings with our survey data. Two mechanisms primarily could explain health issues from a water crisis: decreased water usage (rationing) and substitution to using more low-quality water sources (water tankers). Table 4 presents regression estimates of these two mechanisms on health issues during the crisis. As can be seen, reliance upon often-contaminated tanker water[18] is associated with more health issues during the crisis. Rationing, while having a positive point estimate, is not significantly associated with increasing health issues. These findings suggests that climate-change induced groundwater shortages may lead households to substitute to less clean water sources (e.g. water tankers) from unregulated private markets that could have negative health impacts.

4.3 Short-run Housing Supply Effects

A crucial assumption of our WTP analysis is that short-run housing supply is not impacted by the crisis, which we find support of. In particular, our estimated relative increases in price could reflect either (i) an increase in the supply of housing with piped water at the start of the crisis or (ii) landlords of groundwater-dependent residences strategically refraining from listing their most expensive units during the crisis[19] In Appendix FigureA2 we plot the total number of listings as well as trends in several key characteristics of these listings that determine pricing: building age, height, and bedroom count. We observe no sharp increase to the number of listings and no differential trends in any housing characteristics for listings. This seems to indicate that short-run supply is unchanged by the crisis.

[18]Water from tankers has been shown to contain heavy metals and bacteria, thus being unfit for human consumption (Sarkar, n.d.)

[19]This may be done if, for instance, landlords are worried about temporary decreases to demand during the crisis and are worried about the Housing.com algorithm de-prioritizing listings that have been unfilled for multiple months.

4.4 Long-run Housing Supply Effects

We analyze the universe of in-progress residential construction listed on the RERA website and show that the crisis increased long-run housing supply in areas near the piped water network. Figure 9 depicts the trends of residential builds in the RERA system by month, separated by whether the build is within 100 meters of the nearest pipe or not. The beginning of the water crisis immediately preceded an approximate doubling of the number of residential projects being built within 100 meters of the nearest pipe. In contrast, the number of residential projects being built more than 100 meters from the nearest pipe appears unchanged following the crisis.

To causally estimate the change in residential construction for areas with piped water access, we convert the entirety of Bangalore into a set of 50 subsections of equal land area. We then calculate the distance of each subsection's centroid from the nearest water pipe.[20] Our estimation utilizes the following difference-in-difference regression to compare sub-sections b at time t that are close to pipes to those that are far:

$$y_{bt} = g(\eta_0 + \eta_1 D_{bt} + \eta_2 D_{bt} E_t + \lambda_b) \tag{2}$$

where y_{bt} is the count of new builds that began construction in subsection b during month-year t, D_{bt} is an indicator taking on 1 if the subsection is within a certain range of the nearest water pipe, E_t is an indicator taking on one for months past the beginning of the water crisis, and λ_b is a subsection fixed effect. As y_{bt} is a count variable, we assume that the link function is $g(x) = \exp(x)$, equivalent to Poisson regression[21].

[20] In Appendix Table A2, we consider an alternative measure of pipe access which captures the proportion of a bubble's area within 100m, 200m, and 300m of a pipe. We show that our estimates are robust to this alternative measure.

[21] An overdispersion test for the suitability of Poisson regression yields a p value of 0.57. This is an encouraging sign that Poisson regression is suitable for the data. Nevertheless, we present quantitatively similar results in Appendix Table A3 that employ Negative Binomial regression.

We persistently estimate values of η_2 that indicate increases in the rate of construction among units close to water pipes which are statistically significant at conventional levels. The estimates for these coefficients are presented in Table 5, which includes difference-in-difference estimates on construction for ranges of 100 meters, 200 meters, and 300 meters. The magnitude of the estimated effect ranges from a 25% increase for 100 meters to a 51% increase for 300 meters. The estimates for η_1 are generally small and statistically insignificant, indicating that construction rates did not change for plots that are far from piped water sources.

5 Adaptation Via the Housing Market

To estimate counterfactual welfare measures under increased housing supply near pipes compared to pipe expansions, we make use of a structural model. We argue that housing supply expansions are cost-effective means of enhancing welfare.

We have established that demand and long-run supply for housing near water pipes increased following the 2024 crisis, but an exercise which benchmarks welfare impacts of pipe expansions versus this new construction is useful. We note that we are unable to directly evaluate welfare effects of an increase in the supply of housing closer to the piped water network because these units are not yet listed.[22] Our estimates suggest though that the shift in long-run housing is non-marginal, as construction increased by up to 51% within 300 meters of the piped network. Evaluating the welfare effects of this long-run supply shift and other counterfactuals requires evaluating non-marginal shifts in the distance to the piped water network, where the hedonic price schedule along is not sufficient by itself (Greenstone, 2017).

We estimate the hedonic price schedule using difference-in-differences estimates which are sufficient to construct a lower bound of the welfare effects of housing supply expansions

[22] According to the RERA data, the average construction completion time in Bangalore is roughly 3.6 years.

(Banzhaf, 2021).[23] We construct a lower bound on the counterfactual consumer surplus for non-marginal changes in a consumer's distance to the piped water network. We consider a two-way fixed effect estimator:

$$\ln(P_{it}) = \beta_1 KM_i + \beta_2 Crisis_t + \beta_3 KM_i \times Crisis_t + \alpha A_{it} + \gamma_w + \delta_t + \varepsilon_{it} \quad (1)$$

Equation 1 is equivalent to a difference-in-difference with a continuous treatment. The estimated coefficient β_3 represent the "capitalization effect," which Banzhaf (2021) shows is a lower bound on the Hicksian equivalent surplus (ES).

Our lower bound estimates of welfare echo the estimates which were found in Figure 5. Prior to the crisis, we do not observe any effects of distance to the piped water network on rents. After the crisis, listings that are 1 km closer to the piped network are roughly 2.8% more expensive (roughly ₹1008 over the average).[24] We use this elasticity to construct bounds on the welfare effects of counterfactual shifts.

To capture sizable expansions to the piped water network, we consider a counterfactual that expands the piped water network such that every listing that is more than 0.2 kms away from the piped water network is exactly 0.2 kms away. We estimate that this implies a capitalization effect of roughly ₹17 million (~ $195,000) for the 12 months after the start of the crisis. This suggests an average capitalization effect of roughly $10 per listing (among the 20,000 listings that are further than 0.2kms away).

We next consider our estimate that there is a 39% increase in new construction builds within 0.2 km of the piped water network. This is equivalent to 25 additional construction builds in the year after the crisis within 0.2 km of the piped water network, which translates into 3,625

[23] These results complement our monthly estimates WTP from Section 4.1, but are a difference-in-difference rather than event study.

[24] As Figure 5 shows, we find no evidence of differential pre-trends between "more exposed" vs. "less exposed" listings.

additional listings.[25] We assume that households that move into this increased number of listings are randomly drawn from the distribution of distances outside of the 0.2km radius, and that the listings are distributed uniformly within the 0.2km. This implies that the lower bound of the gains in consumer surplus is roughly ₹3.4 million ($\sim$ \$39,000). Note that since this approach does not take the heterogeneity in MWTP into account, the lower bound on the average surplus is the same as above. This represents 20% of the total gain in surplus compared to the counterfactual of universal pipe expansion.

To assess the cost-effectiveness of the market-adjustment relative to universal piped water access, we consider the costs of both alternatives. The most recent Cauvery stage V project cost ₹43 billion (\$490 million) to lay roughly 1,500 km of pipes, which translates to ₹28 million per km of pipe. To ensure universal pipe connection, we estimate that an additional 250km of pipes will be required.[26] This implies that universal piped water access would cost an additional ₹7 billion in expenditures. We use the reported total project costs in the RERA data to estimate the cost of constructing *closer* to the piped water network. The average listing is more expensive to build within 0.2kms by ₹47,000, so the total additional incurred cost is ₹170 million.

These back-of-the-envelope calculations suggest that market adjustments from private developers could represent an efficient manner of adaptation compared to the large-scale policy intervention of expanding the piped water networks. We find that the lower bound on the consumer surplus from the increase in housing supply near the piped water network is 20% that of the counterfactual of universal piped water expansion—but we estimate the costs to

[25] The average construction in the pre-period has an average of 145 units per construction. We make the conservative assumption that the 39% is the growth over the baseline number of construction in areas within 0.2km of the piped water network, which is 64.

[26] To estimate this, we first group all 26,457 listings that are further than 0.2km away from the current piped water network into clusters that are within 0.2km from each other, which implies that each listing within this cluster would be served by the same pipe extension. We estimate 521 such clusters. We calculate the length of the pipe extension that would be needed to reach the centroid of each cluster. Appendix Figure A7 shows the grouped listings.

be 2.4% that expanding universal piped water access. These figures suggest that subsidies for developers to build closer to piped water networks might be a cost-efficient way of ensuring piped water access, rather than the physical expansion of the network footprint.

6 Conclusion

We have leveraged a natural experiment which provides three main findings in an analysis in residential WTP for publicly-supplied urban piped water. We have first shown that consumer WTP for piped water increases when groundwater drought risk increases. We show that rental listings experienced a 0.4% increase in price per every 0.1km closer to the piped water network following the drought. This effect is permanent for long-term leases, emphasizing the role of future drought risk in driving residential sorting. The effect is particularly large (0.5%) for units housing families. We show that the shift in demand for housing is likely driven in part by health impacts from the drought, as the crisis corresponded to increased hospital visits and self-reported health episodes.

We have then analyzed the impacts to housing supply from rising drought risk. We observe that the drought had minimal changes in short-run supply of housing, measured as the number of rental listings posted. However, using a difference-in-difference approach we estimate an immediate 25-51% increase in construction of rental listings in areas near the piped water network relative to areas far from the piped water network. This result implies that the long-run supply of rental listings is elastic, indicating that the demand shock presented by the drought increased quantity of apartments near a water pipe. As a result, the housing market in part allows individuals to adapt to future drought risk by moving to areas closer to water pipes, mitigating the need for piped water expansion into previously unserviced suburbs.

Our reduced-form estimates have a natural structural interpretation as they form lower bounds on consumer surplus (Banzhaf, 2021). We find that the long-run response from the housing market delivers 20% of the consumer surplus relative to a counterfactual of universal piped water expansion for only 2.4% of the cost. These findings suggest that policies that encourage housing market responses could be cost-effective in settings with limited public infrastructure.

Such results enhance our knowledge of urban expansion in the Global South. In particular, many Southern cities are experiencing an influx of migrants. Consequently, Southern cities have tended to expand into suburban outskirts with minimal access to publicly-provided goods, including piped water. The privately-provided substitutes for many of these utilities are of low quality or come with poorly understood risks. Our estimates help illuminate the extent to which risk surrounding these substitutes - in our case groundwater - drive outwards expansion of these cities.

Several other open questions may be interesting for future research. First, we analyze only one public good, whereas many others may be of interest. In particular, electricity, phone/internet connectivity, waste collection, transportation, and sewerage, are often differentially accessible within a city. Understanding the role of quality or perceptions about quality of their substitutes is of interest. Analyzing the role of formal markets, informal markets, and other forms of adaptation will likely illuminate the extent to which each utility requires expansion.

Second, our analysis has focused primarily on renters, who face different incentives for movement than do homeowners. Homeowners likely face higher expenses to move to a new residence, but also likely internalize future drought risk to a greater extent than do renters. As such, it is ambiguous whether homeowner demand for housing will shift more or less than does demand for renters. Future analysis that considers homeowners is likely important, as they make up the majority of residents in Bangalore and many other cities.

Finally, we believe a more robust analysis of the health impacts of acute water shortages is necessary. To the best of our knowledge, relatively little literature analyzes the mortality or morbidity impacts of water shortages in economics or other fields. A thorough causal analysis of water shortages on these health outcomes, along with linking these estimates to adaptation, would provide policymakers and planners with a more clear understanding of the overall social benefits of expanded pipe provision.

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Tables

Table 1: **Summary Statistics of Key Amenities**

Variable	Mean	SD	Min	Q1	Median	Q3	Max	N
Rent Price	36,007	29,701	200	17,000	28,000	45,000	270,000	323,655
Security Deposit	188,027	195,599	0	70,000	150,000	250,000	3,000,000	323,193
Brokerage	28,317	32,598	0	0.00	23,000	40,003	300,000	323,378
Maintenance	3,786	8,027	1	1,000	2,500	5,000	700,000	137,961
Square Footage	1,202	748	10	650	1,120	1,500	24,000	323,019
Furnished (yes = 1)	0.17	0.38	0	0.00	0.00	0.00	1.00	323,646
Bedrooms	2.01	0.90	1	1.00	2.00	3.00	10.00	323,536
Bathrooms	1.93	0.91	1	1.00	2.00	2.00	11.00	294,745
Balconies	1.14	1.01	0	0.00	1.00	2.00	9.00	295,792
Building Age	4.47	4.27	0	1.00	4.00	6.00	99.00	241,820
Gated Community (yes = 1)	0.21	0.41	0	0.00	0.00	0.00	1.00	323,655
Parking Spots	1.28	0.87	0	1.00	1.00	2.00	10.00	281,125
Building Height (Floors)	7.44	6.68	1	4.00	5.00	7.00	69.00	247,641
Nearest Park Dist. (km)	0.31	0.28	0	0.10	0.24	0.42	2.42	323,655
Nearest Office Dist. (km)	0.59	0.61	0	0.18	0.36	0.76	4.63	323,655
Nearest Transit Stop Dist. (km)	0.42	0.35	0	0.19	0.31	0.52	2.66	323,655
Nearest Shop Dist. (km)	0.26	0.29	0	0.08	0.16	0.32	3.14	323,655
Shops Within 500m	29.42	41.96	0	3.00	10.00	37.00	266.00	323,655

Notes: Table depicts key summary statistics for a variety of listing-specific variables in our data. All monetary characteristics are in nominal INR. The column 'N' reflects the number of listings for which the pertinent characteristic is not missing.

Table 2: **Summary Statistics of Key Characteristics of Construction Projects**

Variable	Mean	SD	Min	Q1	Median	Q3	Max	N
Est. Completion Time (Years)	3.58	1.63	0.24	2.42	3.41	4.68	11.77	645
Promoter Project Count	2.09	3.03	1.00	1.00	1.00	2.00	18.00	645
Total Land Area (sq. mtr.)	14,117	20,814	557	4,012	8,328	16,444	289,573	464
Total Land Cost (Million INR)	422	1,112	0	62	146	361	18,747	616
Est. Total Cost (Million INR)	1,731	3,978	0	230	569	1,655	59,690	596

Notes: Table depicts key summary statistics for a variety of variables in our construction projects data. All monetary characteristics are in nominal INR. The column 'N' reflects the number of listings for which the pertinent characteristic is not missing.

Table 3: **Summary Statistics of Survey Respondents**

Variable	Mean	SD	Min	Q1	Median	Q3	Max	N
Usual Water Spend (INR)	2,588	2,867	0	608	1,738	4,345	21,726	1,229
Crisis Water Spend (INR)	2,691	2,371	0	826	2,173	4,345	8,951	1,225
Moved 2024-Aug 2025 (=1)	0.12	0.33	0	0	0.00	0.00	1.00	1,250
Annual Lease (=1)	0.55	0.50	0	0	1.00	1.00	1.00	1,250
BWSSB Water (=1)	0.58	0.49	0	0	1.00	1.00	1.00	1,250
Distance to Pipes (km)	0.13	0.37	0	0	0.01	0.05	2.54	1,250
Crisis Health Issue (=1)	0.04	0.20	0	0	0.00	0.00	1.00	1,250
Unit Occupants	3.98	1.14	1	3	4.00	5.00	8.00	1,250
Secondary School (=1)	0.93	0.26	0	1	1.00	1.00	1.00	1,250
Bachelor's Degree (=1)	0.67	0.47	0	0	1.00	1.00	1.00	1,250
Unit Bedrooms	3.70	1.31	0	3	4.00	4.00	10.00	1,248
Inc. > 50,000 INR (=1)	0.65	0.48	0	0	1.00	1.00	1.00	1,250
Inc. > 100,000 INR (=1)	0.26	0.44	0	0	0.00	1.00	1.00	1,250

Notes: Table depicts key summary statistics for a variety of variables in our survey data. All monetary characteristics are in nominal INR and capture monthly values. The column 'N' reflects the number of respondents for which the pertinent characteristic is not missing.

Table 4: **The Impacts of Urban Drought on Health Outcomes**

	(1)	(2)	(3)
Annual Lease (=1)	0.011	0.019	0.009
	(0.010)	(0.012)	(0.008)
Secondary School (=1)	-0.013	-0.018	-0.013
	(0.065)	(0.023)	(0.040)
Bachelor's Degree (=1)	0.013	0.020	0.014
	(0.031)	(0.014)	(0.020)
Unit Bedrooms	-0.015	-0.004	-0.017
	(0.013)	(0.004)	(0.013)
Inc. >50,000 INR (=1)	-0.013***	-0.030**	-0.014***
	(0.005)	(0.013)	(0.005)
Independent House (=1)	-0.003	-0.006	-0.004
	(0.010)	(0.014)	(0.010)
Tanker Water (=1)	0.031	0.037***	0.029*
	(0.026)	(0.012)	(0.017)
Rationed (=1)	0.002	0.008	0.002
	(0.005)	(0.013)	(0.005)
Observations	914	914	914
Model	Logit	LPM	Probit

Notes: Table depicts regressions of health events during the 2024 water crisis on an array of demographics, including water tanker usage. Column (1) does so using logistic regression. Column (2) uses a linear probability model. Column (3) uses a probit regression. All effects are interpretable as average impacts to probability of a health event. For instance, the estimate on annual lease in column (1) is 0.011, which is interpretable as 1.1 percentage point higher prevalence of health events during the crisis among those with an annual lease. Health events include dizziness, nausea, diarrhea, and hospital visits. Standard errors are reported in parentheses below the estimated coefficient.

Table 5: **The Impacts of Urban Drought on New Residential Construction**

	(1) 100m cutoff	(2) 200m cutoff	(3) 300m cutoff
Event	0.204 (0.144)	0.069 (0.185)	-0.019 (0.185)
Closer than 100m × Event	0.250*** (0.089)		
Closer than 200m × Event		0.391*** (0.166)	
Closer than 300m × Event			0.513*** (0.176)
Observations	1,680	1,680	1,680
Mean of build	0.12	0.12	0.12
Fixed effects	Subsection	Subsection	Subsection

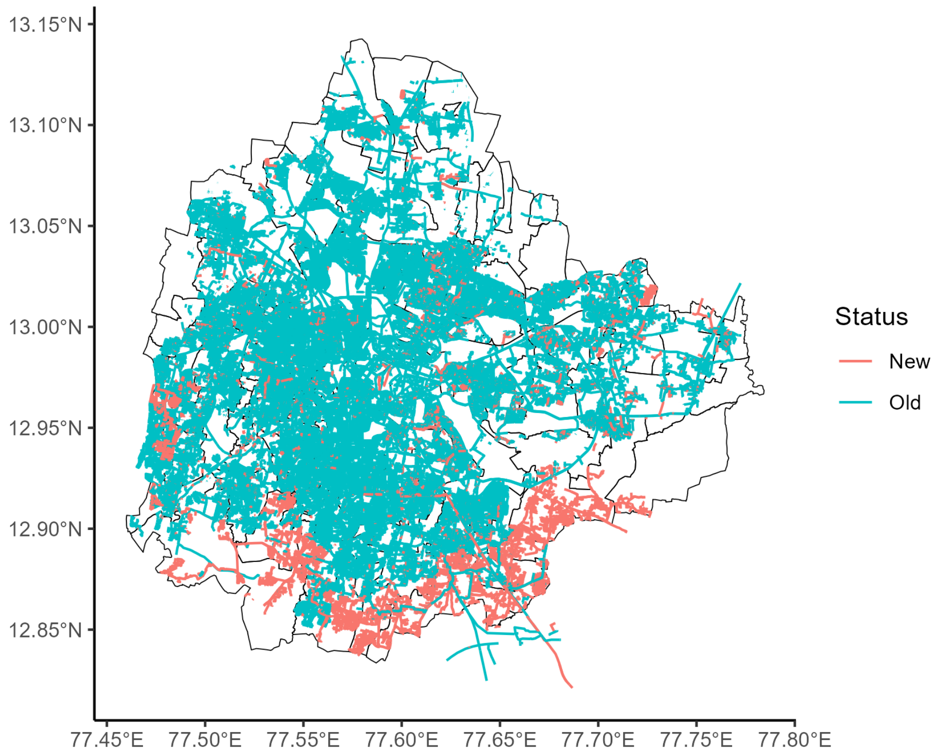
Notes: Table depicts estimates of the change in construction frequency for areas close to piped water following the 2024 drought. Column (1) does so comparing areas within 100m of the nearest pipe to those outside of 100m. Column (2) does the same except with a 200m cutoff. Column (3) does the same except with a 300m cutoff. Estimates are interpreted as percent increases after being scaled by 100. For instance, column (3) finds an estimate of 0.513, which is a 51.3% increase in construction in areas closer to water pipes than 300m following the drought. Standard errors are clustered at the subsection and date levels and reported in parentheses below the pertinent estimate.

Figures

Figure 1: **Locations of Scraped Rental Listings by Month**

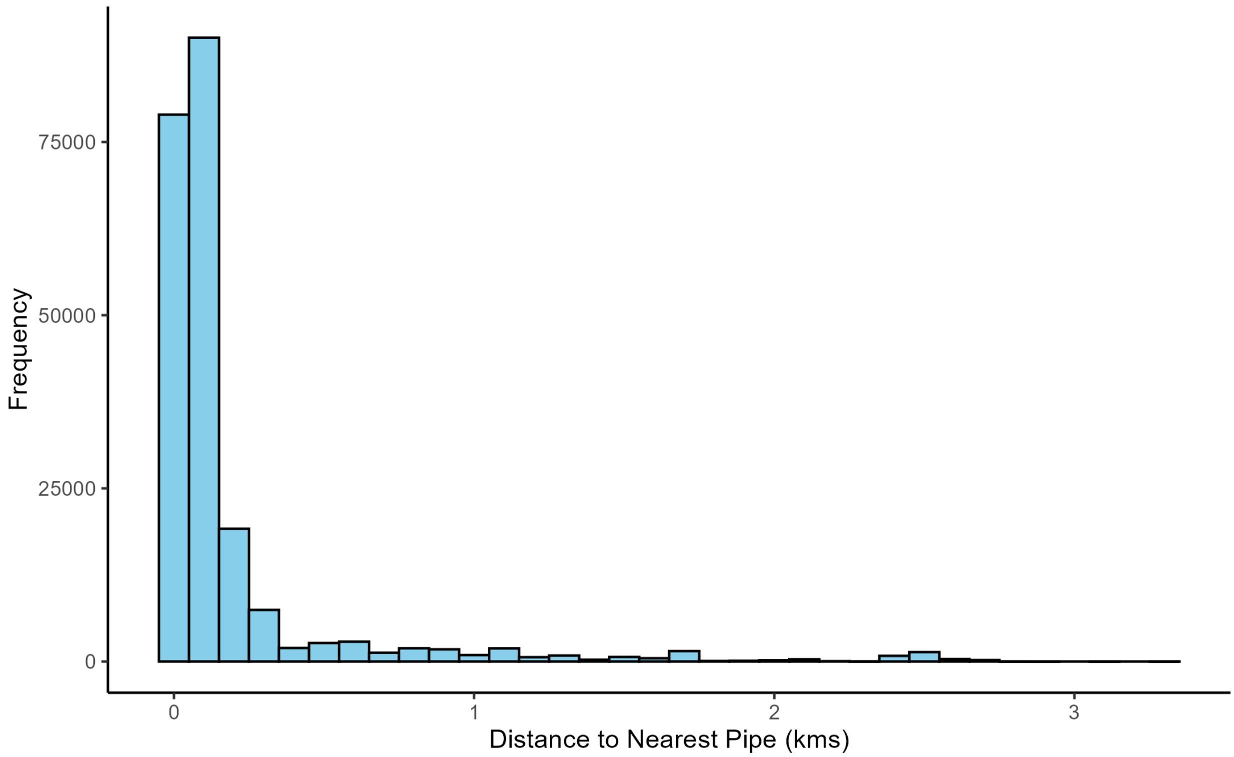
Notes: Figure depicts all scraped rental listings from Housing.com for four separate months. The water crisis occured from February to April of 2024. Red outlines delineate utility in Bangalore and each dot is a scraped listing for that month. Dots vary by color based off the log of the monthly rental price of the listing. All listings outside the outer edge of utility wards are removed from the analysis.

Figure 2: **Water Pipe Locations**



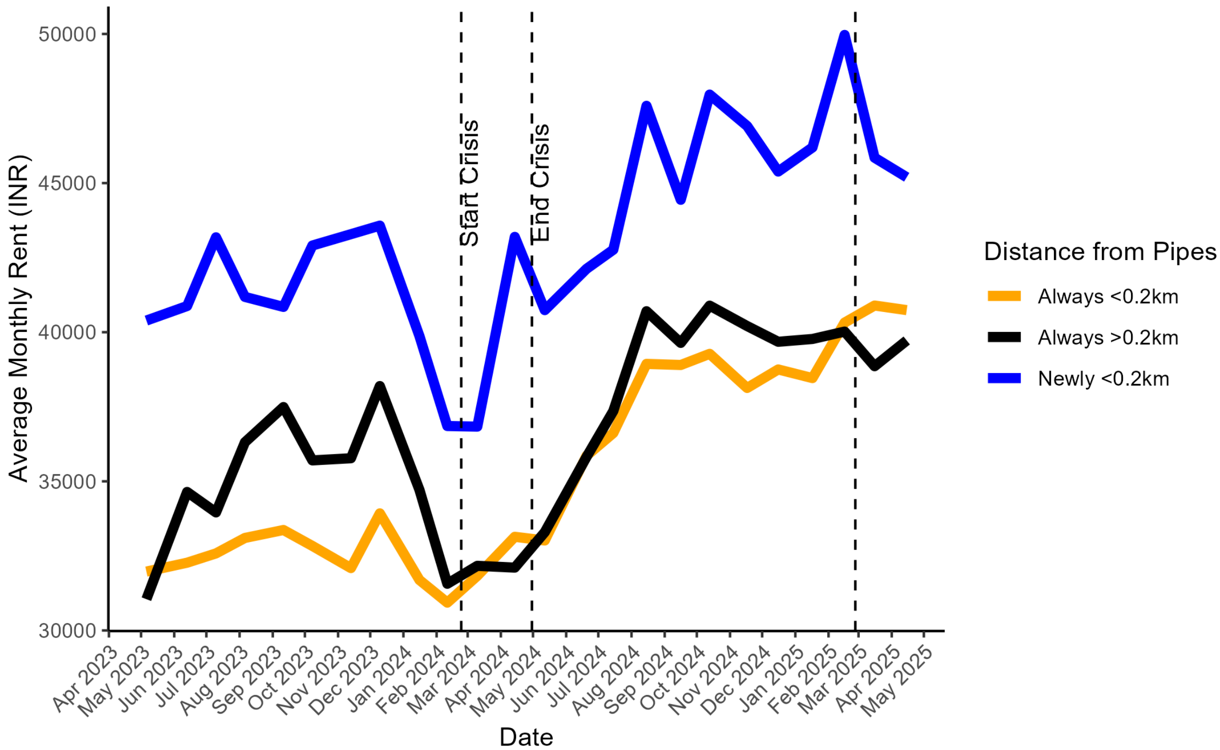
Notes: Figure depicts the map of all pipes in the publicly provided piped water network within Bangalore. Black outlines are utility wards in Bangalore. Blue and red lines depict water pipes, with red lines indicating pipes which were created in the September 2024 expansion and blue lines indicating which existed as of the prior expansion in 2014.

Figure 3: **Listing Distances from Nearest Water Pipe**



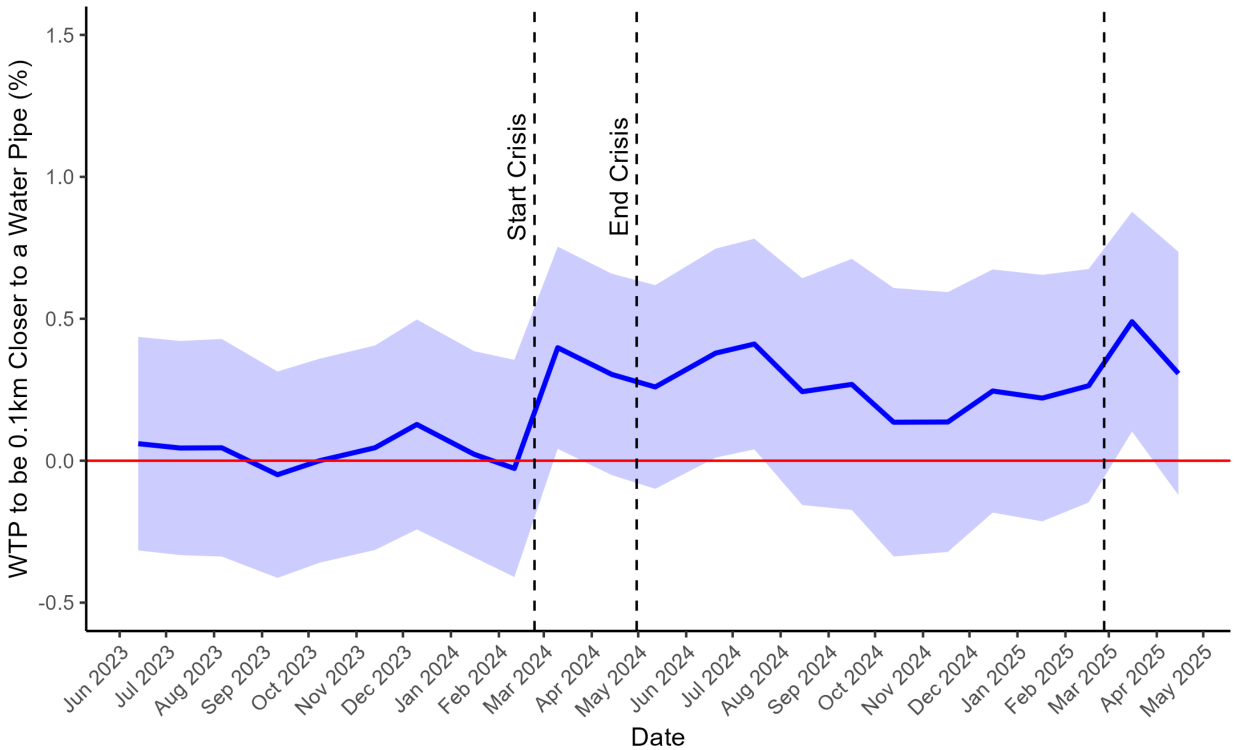
Notes: Figure depicts a histogram of distances of listings to the closest water pipe. Distance is measured in kilometers. The vertical axis is a count of listings. Listings across all months in our data are included.

Figure 4: **Average Price Trends by Distance from Water Pipes**



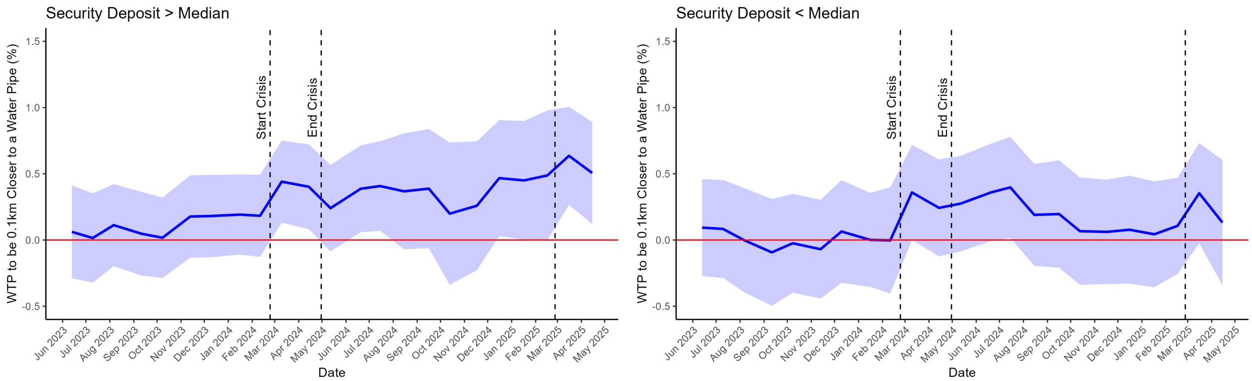
Notes: Figure depicts raw trends in average monthly prices to rent listings in our data. The vertical axis is average monthly rent measured in nominal INR. The orange trend line is for listings less than 0.2km away from the nearest water pipe at all times before and after the September 2024 pipe expansion. The black trend line is for listings always at least 0.2km away from the nearest pipe both before and after the 2024 expansion. The blue line is for listings that were originally more than 0.2km away from the nearest pipe but moved within 0.2km of the nearest pipe due to the 2024 expansion. Vertical dashed lines indicate roughly the beginning and end of the water crisis.

Figure 5: **The Impact of an Urban Water Crisis on Housing Rents**



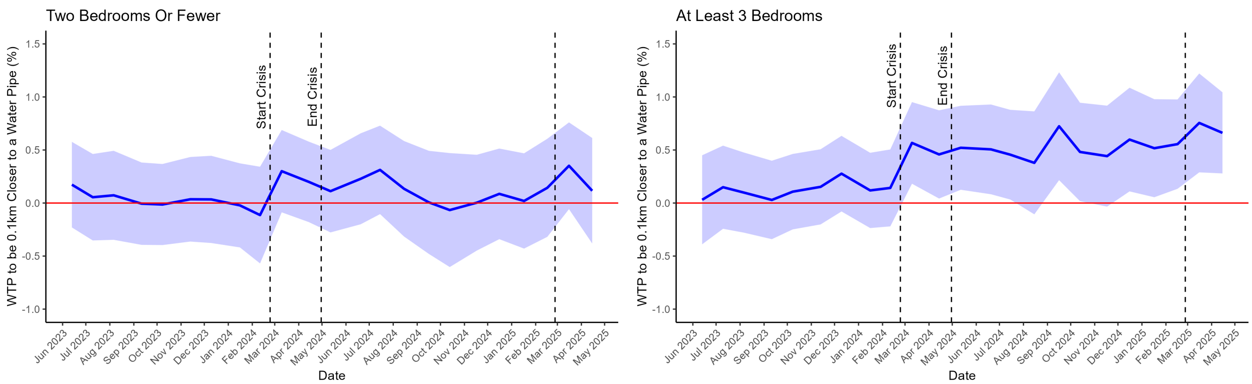
Notes: Figure depicts estimated rent premium for rental listings being 0.1km closer to the nearest pipe in each month of our data. Estimates are generated by running regressions of the log of monthly rent prices on the distance (km) from the nearest water pipe, interacted by month. Regressions control for a rich set of listing-level characteristics and include ward and year-month fixed effects. Standard errors are clustered at the ward and year-month levels. The shaded blue area represents a 95% confidence interval, whereas the solid blue line represents point estimates. Vertical dashed lines indicate roughly the beginning and end of the water crisis.

Figure 6: **The Impact of an Urban Water Crisis on Housing Rents by Lease Length**



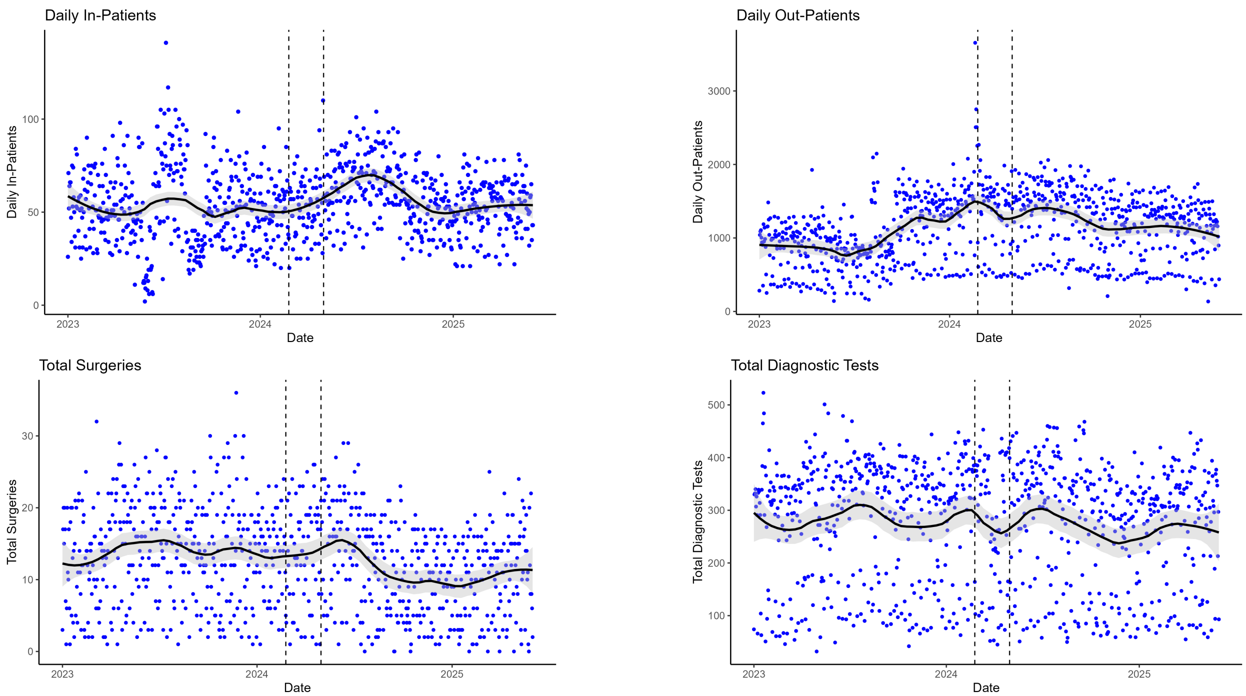
Notes: Figure depicts estimated rent premium for rental listings being 0.1km closer to the nearest pipe in each month of our data separately for listings that have an above median security deposit size (left) and those that have a below median security deposit size (right). Median security deposit size is roughly 5 months worth of rent. Security deposit size is meant to proxy for lease length, as higher deposits correspond to longer leases. Estimates are generated by running regressions of the log of monthly rent prices on the distance (km) from the nearest water pipe, interacted by month. Regressions control for a rich set of listing-level characteristics and include ward and year-month fixed effects. Standard errors are clustered at the ward and year-month levels. The shaded blue area represents a 95% confidence interval, whereas the solid blue line represents point estimates. Vertical dashed lines indicate roughly the beginning and end of the water crisis.

Figure 7: **The Impact of an Urban Water Crisis on Housing Rents by Size**



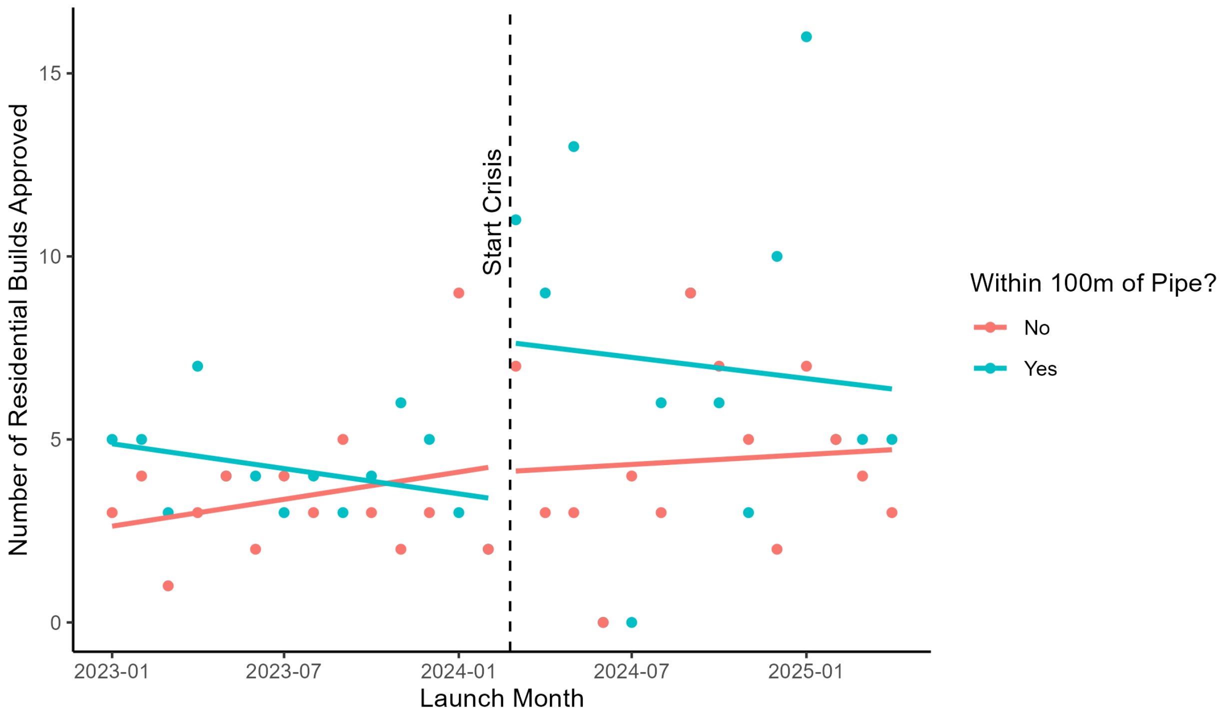
Notes: Figure depicts estimated rent premium for rental listings being 0.1km closer to the nearest pipe in each month of our data. Figure does so separately for listings with two bedrooms or fewer (left) and those with three bedrooms or more (right). Estimates are generated by running regressions of the log of monthly rent prices on the distance (km) from the nearest water pipe, interacted by month. Regressions control for a rich set of listing-level characteristics and include ward and year-month fixed effects. Standard errors are clustered at the ward and year-month levels. The shaded blue area represents a 95% confidence interval, whereas the solid blue line represents point estimates. Vertical dashed lines indicate roughly the beginning and end of the water crisis.

Figure 8: **The Impact of an Urban Water Crisis on Housing Rents by Size**



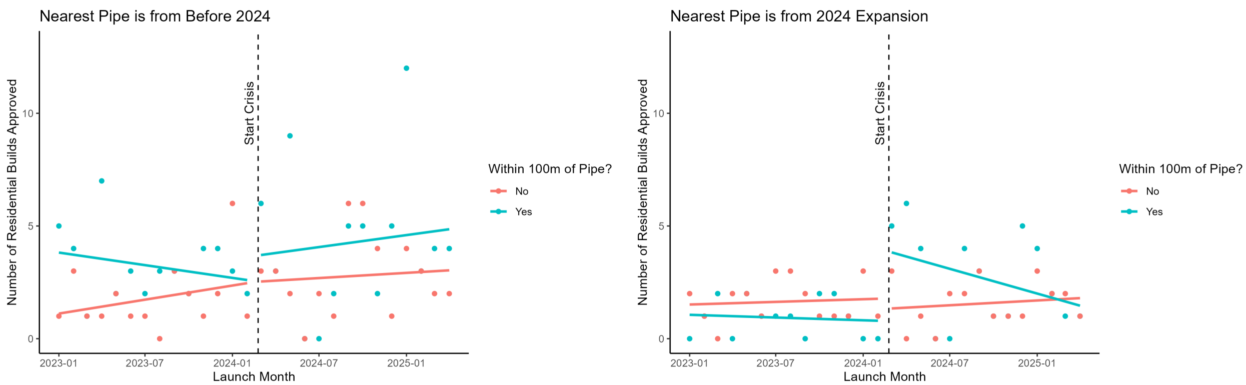
Notes: Figure depicts trends in hospital visits for two major hospitals in Bangalore. Figure does so for in-patient visits (top left), out-patient visits (top right), performed surgeries (bottom left), and diagnostic tests performed (bottom right). Note that y-axis scale varies for each panel. Blue dots indicate daily values, whereas black lines indicate locally smoothed trends with 95% confidence intervals.

Figure 9: **The Impact of an Urban Water Crisis on Residential Construction**



Notes: Figure depicts trends in monthly new residential construction projects for areas that are within 100m (blue) of the nearest water pipe versus those that are not (red). The black vertical dashed line depicts the beginning month of the water crisis. The horizontal axis corresponds with approval/launch month.

Figure 10: **The Impact of an Urban Water Crisis on Residential Construction: New Pipes and Old Pipes**



Notes: Figure depicts trends in monthly new residential construction projects for areas that are within 100m (blue) of the nearest water pipe versus those that are not (red). Figure does so separately for locations in which the closest pipe is from before the 2024 expansion (left) and for those for which the nearest pipe comes from the expansion (right). The black vertical dashed line depicts the beginning month of the water crisis. The horizontal axis corresponds with approval/launch month.

Supplemental Appendix - Not for Publishing

A1 Discussion of Missing Data Imputation

Because a large share of listing characteristics (e.g. number of bathrooms, number of balconies, building height, etc.) are optional for listing on Housing.com, we observe a non-trivial number of missing data. Fortunately, we observe a large number of characteristics for every single observation. In particular, we can observe presence in a gated community, furnishing level, number of bedrooms, listing type (e.g. "flat" or "independent house"), listing date, and listing ward for every single listing. As such, we can use these characteristics to impute the missing characteristics of each row.

We do so using predictive mean matching (PMM) as in (**??**). Consider a variable x which contains missing values in some observations and a set of variables z which are observed in each observation. The PMM algorithm works as follows (**?**):

1. With observations that are not missing x, run a regression of x on z, producing estimated coefficients $\hat{\beta}$
2. Make some random draw of coefficients $\hat{\beta}'$ based off the estimated distribution of $\hat{\beta}$
3. Use $\hat{\beta}'$ to generate predicted values of x for all observations, including those that have values of x
4. For each observation that has missing x, identify observations with observed x whose predicted values of x are closest to the predicted value of x for the observation. Define these as 'close cases.'
5. Randomly assign one observed value of x from the close cases as the missing value of x
6. Repeat 2-5 for all completed data

Notably, the choice of how many close cases are considered in the above algorithm is important for generating valid imputation. We choose to consider the 5 closest cases in our main results. In Appendix Figure A1, we depict results that instead use 1 case and 10 cases. As can be seen, the results are largely unchanged from our main result, suggesting that our findings are robust to imputing under different specifications for PMM.

A2 Additional Survey Findings

A2.1 Information Frictions on Water Sources

We find that residents in Bangalore are unaware in many cases where their water is sourced from. We measure in our survey that 69% of people were at most only somewhat aware of where a building sources its water from before the crisis, a percentage which is largely unchanged at 70% post-crisis. This mirrors the fact that many renters do not directly interact with BWSSB, nor with individuals who manage their supplying borewells. It further mirrors that listing sites such as Housing.com do not explicitly advertise the sources of water for each listing.

We show that individuals who live far from the piped water network incorrectly believe that they have a piped water connection. In Figure A4, we plot locally estimated regression lines which link the probability that a respondent reported having a piped water connection to their distance from the pipe network. Panel A does so including the entire sample, whereas Panel B omits individuals who are less aware of their pipe connection status. We estimate that 40% of individuals living more than 0.5kms away from the nearest pipe report having a piped water connection, falling to 0% when omitting those who are unsure.

Because individuals incorrectly believe that areas far from the pipe network have pipe connections, our estimates of the change to WTP for pipes following the crisis are likely attenuated relative to what they would be under full information. This motivates future analysis which considers removing these informational barriers to understand how consumers respond under better information sets.

A2.2 Risk Perceptions Pre- and Post-Crisis

We find that residents in Bangalore had perceptions of drought risk which increased as a result of the water crisis. We present the results of belief elicitation using Likert scales in Figure A5, with 5 indicating high perceived risk and 1 indicating low perceived risk. Despite likely recall bias in measuring pre-crisis risk perceptions, we observe that perceived risks are higher for a drought to occur within 5 years of the survey date. This is particularly pronounced at the tails – fewer individuals believe a crisis is very unlikely and more believe that a crisis is very likely. These results suggest that long-term perceived drought risk has increased in Bangalore, which we have argued is tied to our estimates of WTP for water pipes.

A2.3 Micro-level Migration Patterns

We observe in our survey data that individuals who migrated within Bangalore after the 2024 water crisis tended to move closer to water pipes. We present pre- and post-crisis distances from pipes in Figure A6. A mass of individuals migrate from being 0.1-0.5km from the nearest pipe to being less than 0.1km. This has resulted in the first quartile of distance from nearest pipe decreasing by roughly 40% and the median distance falling by 22%. This lends support to our estimates that WTP to be nearer to the piped water network increased following the crisis.

Appendix Tables

Table A1: **Summary of Other Water Crises**

Panel A: Utility Piped Water Impacted		
City	**Dates**	**Piped Water Access (%)**
Barcelona, Spain	Mid 2008, Mid 2023	>95%
Cape Town, South Africa	Mid 2017, Mid 2018	80-85%
Chennai, India	Mid 2019	40-50%
Karachi, Pakistan	Early 2022, Early 2025	90-95%
São Paulo, Brazil	Late 2014, Late 2015	85%
San Antonio, Texas	Early 2025	>95%
Sana'a, Yemen	Early 2024, Early 2025	50-55%
Tehran, Iran	Early 2025	80-90%
Panel B: Only Private Water Supply Impacted		
City	**Dates**	**Piped Water Access (%)**
Bangalore, India	Early 2024	50-60%
Jakarta, Indonesia	Late 2023	60-65%
Lima, Peru	Early 2025	90-95%
Mumbai, India	Early 2025	40-45%
Nairobi, Kenya	Late 2019	50-60%
New Delhi, India	Mid 2019	90%

Notes: Table depicts details on an array of water crises which have occurred across the world. Details are collected from a variety of sources, including Wikipedia pages, utility websites, NGO documents, and academic articles.

Table A2: **Proportional Coverage Estimates on New Residential Construction**

	100m cutoff	200m cutoff	300m cutoff
Event	-0.034	-0.063	-0.068
	(0.201)	(0.226)	(0.242)
Prop. Within 100m × Event	0.691**		
	(0.286)		
Prop. Within 200m × Event		0.595**	
		(0.285)	
Prop. Within 300m × Event			0.540*
			(0.295)
Observations	1,680	1,680	1,680
Mean of build	0.12	0.12	0.12
Fixed effects	Subsection	Subsection	Subsection

Notes: Table depicts estimates of the change in construction frequency for areas with piped water access versus those without. Column (1) does using the proportion of an area that is within 100m of a pipe. Column (2) does the same except with a 200m cutoff. Column (3) does the same except with a 300m cutoff. Estimates are interpreted as percent increases after being scaled by 100. For instance, column (3) finds an estimate of 0.540, which indicates a 54.0% larger increase in construction in areas that are 100% within 300m of a pipe compared to areas that are 0% within 300m of a pipe. Standard errors are clustered at the subsection and date levels and reported in parentheses below the pertinent estimate.

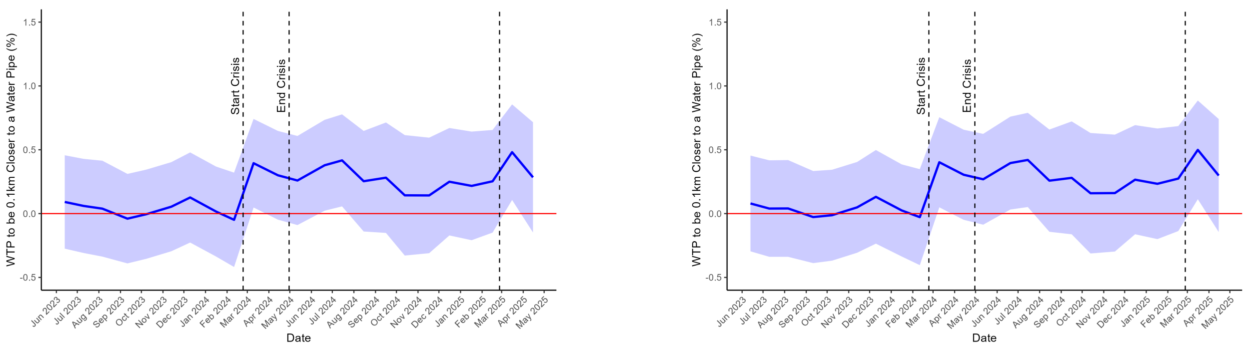
Table A3: **Negative Binomial Estimates on New Residential Construction**

	(1) 100m cutoff	(2) 200m cutoff	(3) 300m cutoff
Event	0.203	0.068	-0.023
	(0.147)	(0.188)	(0.191)
Closer than 100m × Event	0.251***		
	(0.095)		
Closer than 200m × Event		0.392**	
		(0.167)	
Closer than 300m × Event			0.517***
			(0.181)
Observations	1,680	1,680	1,680
Mean of build	0.12	0.12	0.12
Fixed effects	Subsection	Subsection	Subsection

Notes: Table depicts estimates of the change in construction frequency for areas close to piped water following the 2024 drought, generated using Negative Binomial regression. Column (1) does so comparing areas within 100m of the nearest pipe to those outside of 100m. Column (2) does the same except with a 200m cutoff. Column (3) does the same except with a 300m cutoff. Estimates are interpreted as percent increases after being scaled by 100. For instance, column (3) finds an estimate of 0.513, which is a 51.3% increase in construction in areas closer to water pipes than 300m following the drought. Standard errors are clustered at the subsection and date levels and reported in parentheses below the pertinent estimate.

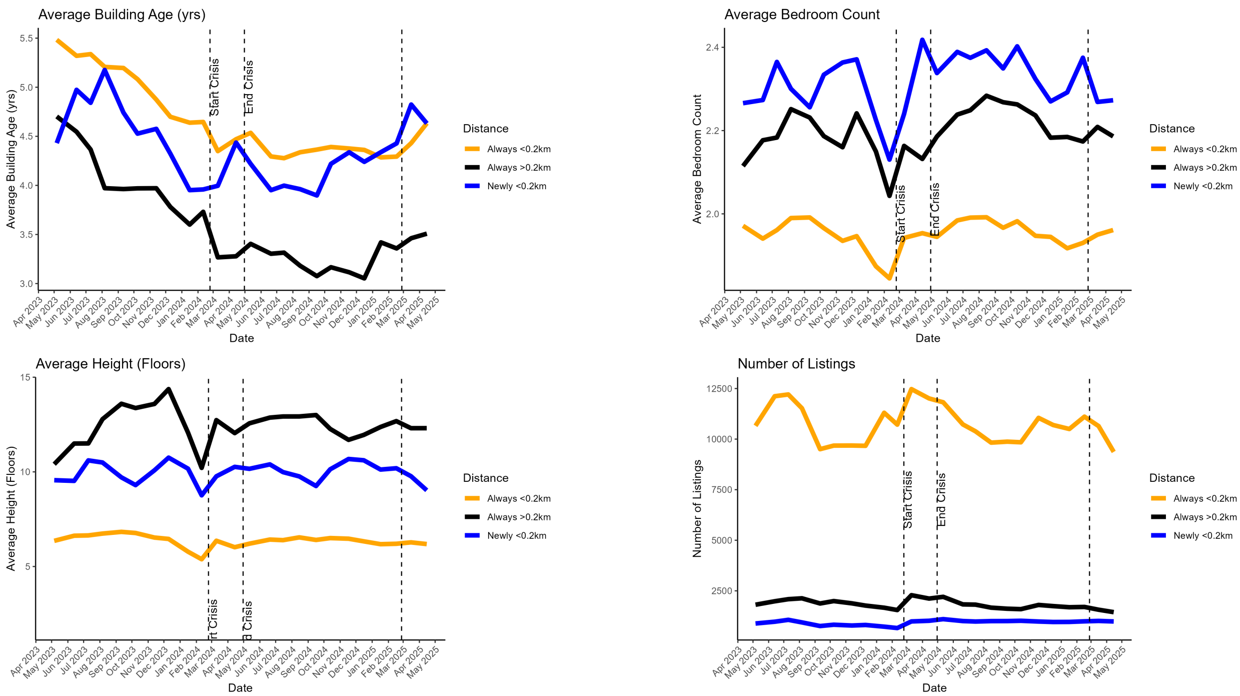
Appendix Figures

Figure A1: **Hedonic Estimates with $m = 1$ and $m = 10$ PMM Imputation**



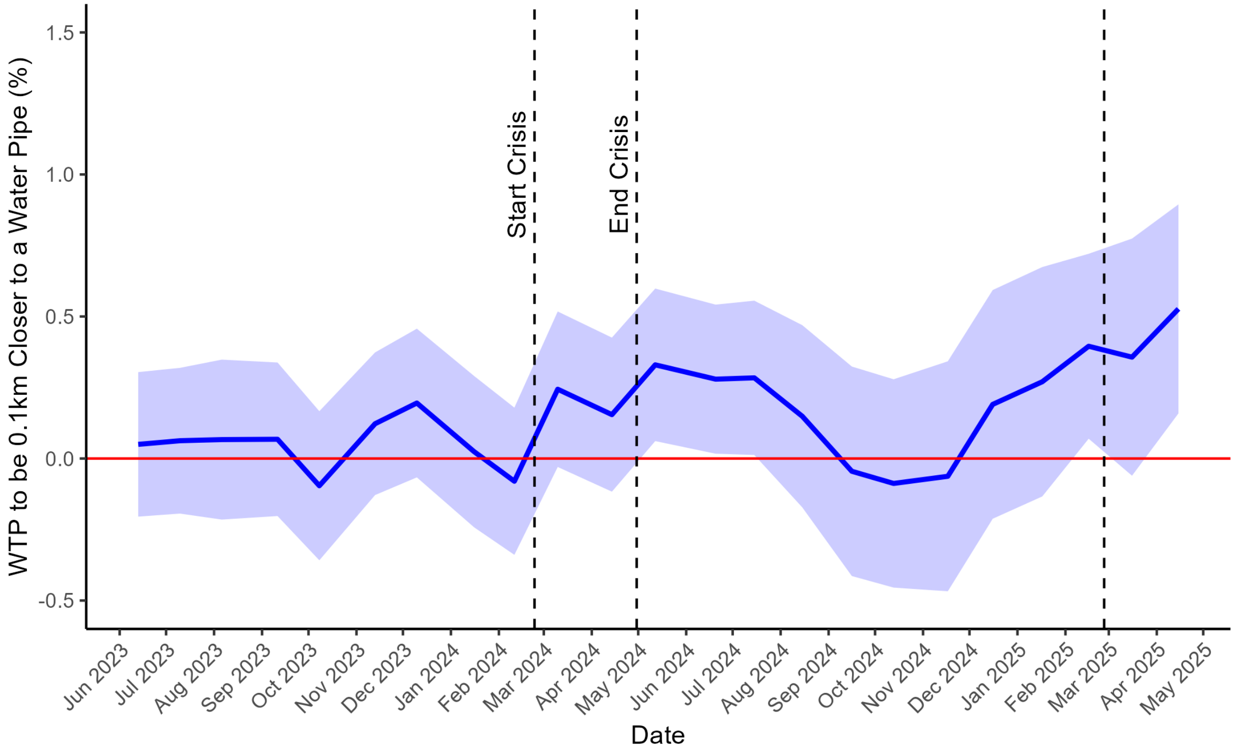
Notes: Figure depicts estimated rent premium for rental listings being 0.1km closer to the nearest pipe in each month of our data. The left panel does so relying on data imputation from predictive mean matching (PMM) with $m = 1$ closest candidates. The right panel does so relying on data imputation from PMM with $m = 10$ closest candidates. Estimates are generated by running regressions of the log of monthly rent prices on the distance (km) from the nearest water pipe, interacted by month. Regressions control for a rich set of listing-level characteristics and include ward and year-month fixed effects. Standard errors are clustered at the ward and year-month levels. The shaded blue area represents a 95% confidence interval, whereas the solid blue line represents point estimates. Vertical dashed lines indicate roughly the beginning and end of the water crisis.

Figure A2: **Trends in Listing Characteristics and Count by Distance**



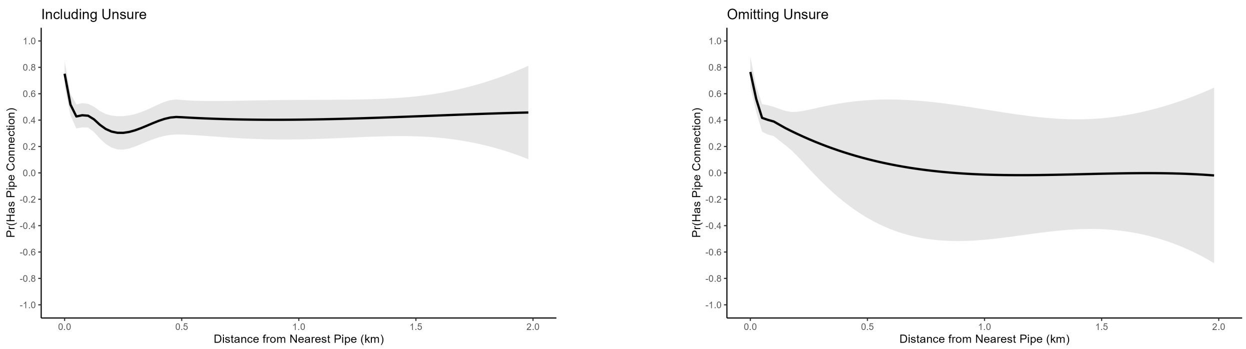
Notes: This figure depicts the average building age (top left), average bedroom count (top right), average building floor count (bottom left), and total number of listings (bottom right) by month. Red lines are for listings less than 0.2km from the nearest water valve and blue lines are for listings at least 0.2km away. The orange trend line is for listings less than 0.2km away from the nearest water pipe at all times before and after the September 2024 pipe expansion. The black trend line is for listings always at least 0.2km away from the nearest pipe both before and after the 2024 expansion. The blue line is for listings that were originally more than 0.2km away from the nearest pipe but moved within 0.2km of the nearest pipe due to the 2024 expansion. Vertical dashed lines indicate roughly the beginning and end of the water crisis.

Figure A3: **The Impact of an Urban Water Crisis on Housing Rents: Building-level Panel**



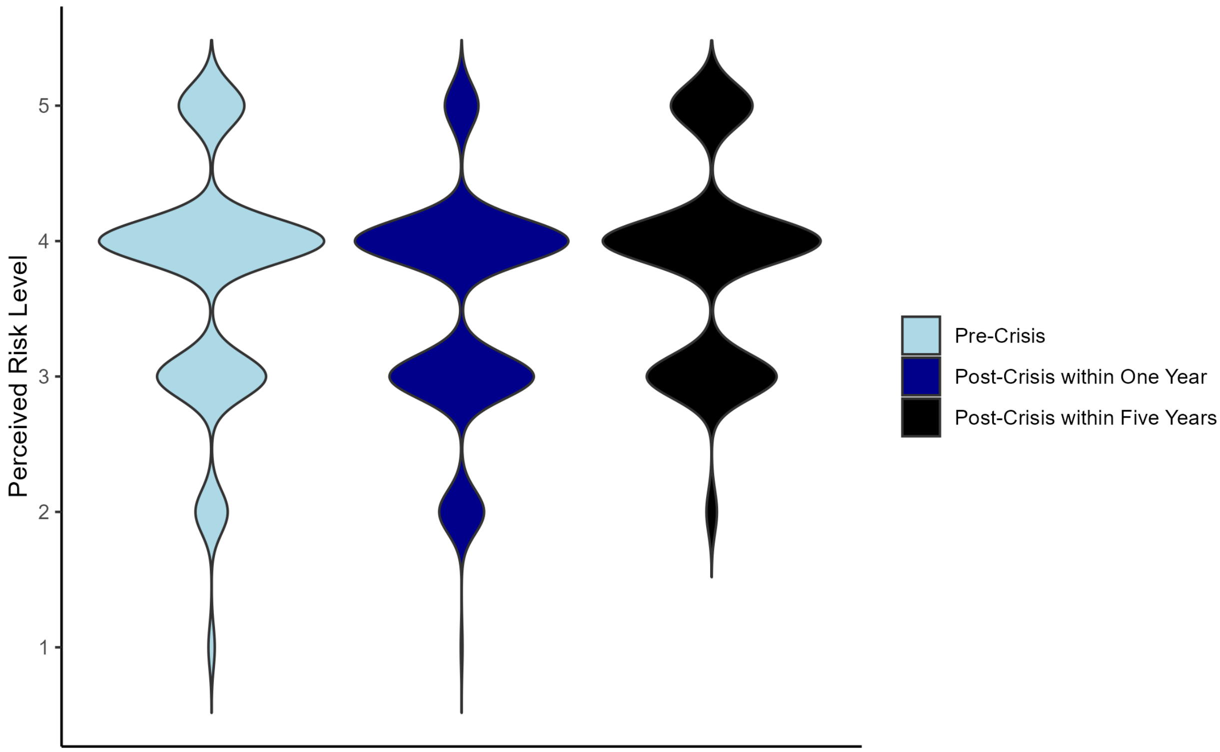
Notes: Figure depicts estimated rent premium for rental listings being 0.1km closer to the nearest pipe in each month of our data, where data is aggregated to a building by month panel. Estimates are generated by running regressions of the log of monthly rent prices on the distance (km) from the nearest water pipe, interacted by month. Regressions control for a rich set of listing-level characteristics and include ward and year-month fixed effects. All characteristics average across a building's listings within that month. Standard errors are clustered at the ward and year-month levels. The shaded blue area represents a 95% confidence interval, whereas the solid blue line represents point estimates. Vertical dashed lines indicate roughly the beginning and end of the water crisis.

Figure A4: **Self-reported Pipe Access by Distance to Nearest Pipe**



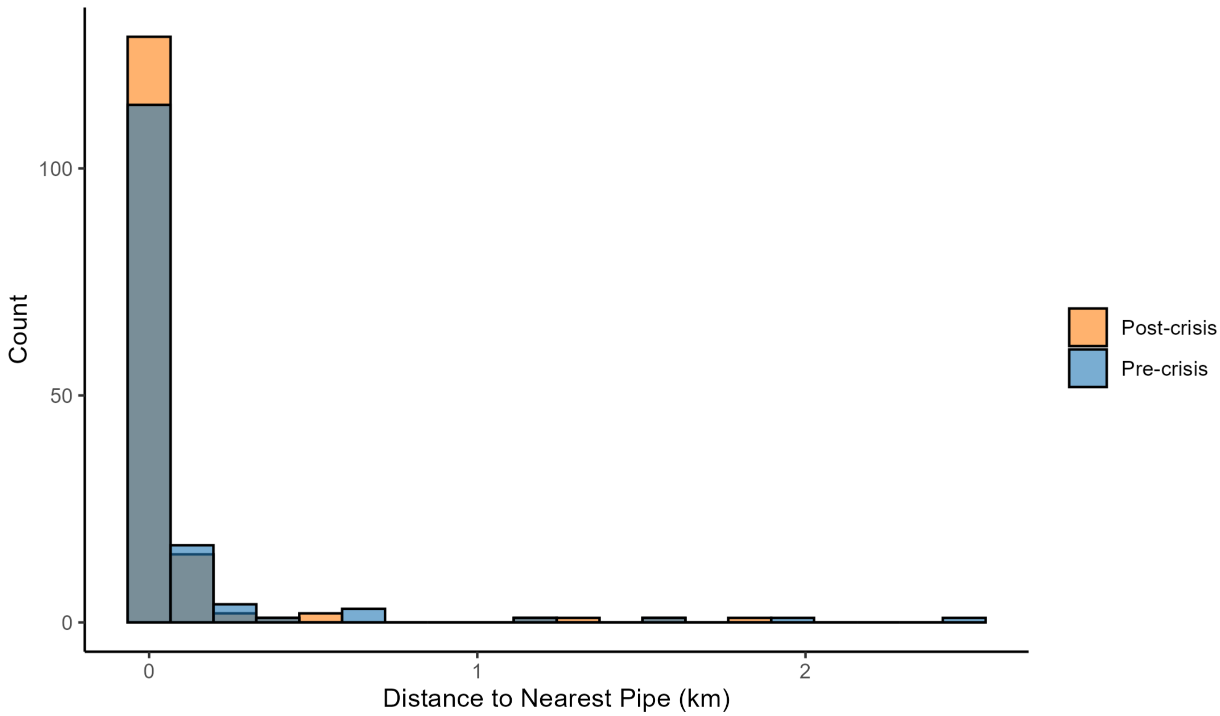
Notes: Figure depicts locally estimated regression lines of probability that a respondent reports having pipes by their distance from the nearest pipe. The left figure does so with the whole sample, whereas the right figure does so omitting those who report not being sure about pipe access in their area.

Figure A5: **Perceptions of Drought Risk**



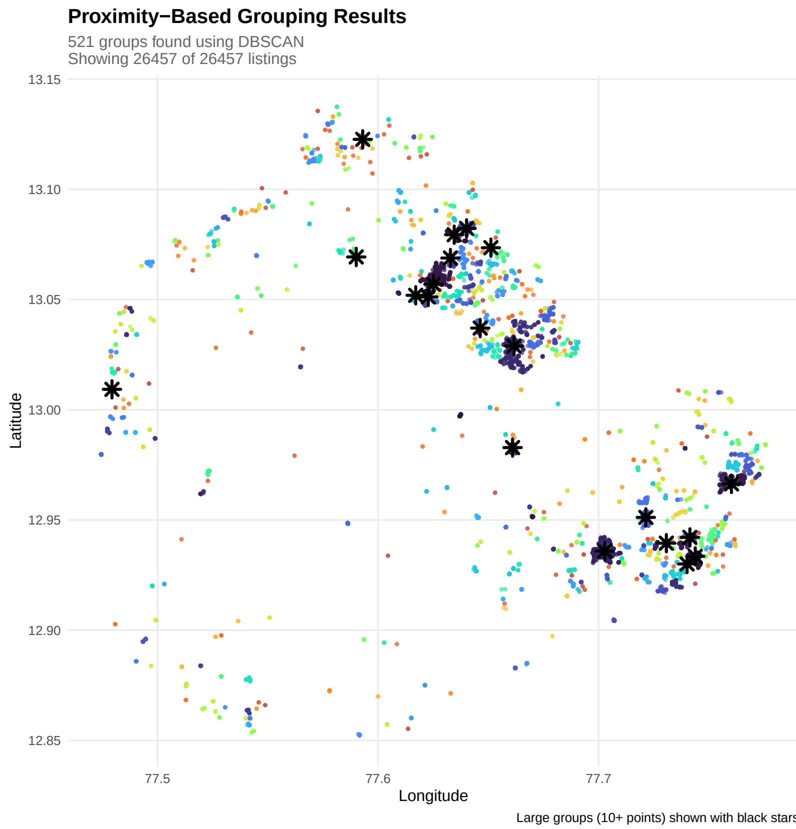
Notes: Figure depicts violin plots of Likert scales measuring perceived drought risks, where 5 indicates high perceived risk and 1 indicates low perceived risk. The leftmost violin asks individuals to recall their perceptions of risk prior to the crisis. The middle violin asks individuals about their current perceptions of a crisis happening within one year. The rightmost violin asks individuals about their current perceptions of a crisis happening within five years.

Figure A6: **Surveyed Distance from Nearest Pipe**



Notes: Figure depicts distance from the nearest pipe for individuals who migrated within Bangalore between January 2024 and August 2025. Figure does so for initial location (blue) and for destination location (orange). Overlap in the two distributions is depicted in gray. Distance to nearest pipe is calculated by capturing coordinates of locations either via Google Maps pins or Google Maps geolocating of provided addresses.

Figure A7: **The Grouping of Listings More Than 0.2 km Away from Piped Water**



Notes: Figure depicts the distribution of listings in Bangalore post-crisis that are more than 0.2 km away from the piped water network. We use the density-based spatial clustering of applications with noise (DBSCAN) algorithm to cluster listings together that are within 0.2km of each other. The figure classifies listings in the same cluster by using different colors; clusters that contain more than 10 listings are represented as a large star.

Figure A8: **Estimated Price Gradient Before and After Water Crisis**

Notes: Figure depicts the estimated price gradient along distance to the piped water network using the method described in Bishop and Timmins (2019) and Robinson (1988). We estimate a locally qudratric polynomial: We let f_t be locally quadratic and estimate: $P(Z_{it}, H_{it}, \varepsilon_{it}; \beta_t); \beta_t) - H'_{it}\hat{\beta}^H_t = \beta_{0,i^*,t} + \beta_{1,i^*,t}Z_{it} + \beta_{2,i^*,t}Z^2_{it} + \varepsilon_{it}$.