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Do Announcement and Implementation of Prices and Subsidies Differentially Affect Water Consumption

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The Effects of Policy Announcement, Prices, and Subsidies on Water Consumption

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Abstract

In this study, we investigate the effects of price and subsidy increases on water conservation in Singapore. Using monthly billing data over 10 years on water consumption for 2.2 million residential accounts, our difference-in-differences estimates show that the announcement of water price increase alone reduces water consumption by 3.7%, larger than the actual implementation of a 30% water price increase. Consumers with low water usage and price salience respond more to the announcement of price hike while consumers with high usage respond more to its implementation. An increase in low-salient utility subsidy could reduce the financial burden on low-income households without affecting water consumption. Our results suggest that the traditional market-based policy instruments, such as price and subsidy, could be combined with information salience to achieve sustainable outcomes efficiently, effectively, and fairly with minimal requirement on technology advancement and institutional innovation.

Cities worldwide are facing increasing water security challenges due to misalignment between rising water demand and diminishing or uncertain resource availability. Supply-side solutions often involve costly infrastructure development and technology advancement. As such, a wide range of policy instruments have been implemented to reduce water demand, including rationing, mandated technology, efficiency rebate, education, social norms, etc. Water pricing is one of the most cost-effective[1–3] and easy to implement[4] policy tool for demand management, but is viewed by many utility managers as a merely tool for cost recovery due to the low price elasticity and welfare implications. In this study, we evaluate the impacts of increases in relatively salient water price and inconspicuous utility subsidies on water consumption. We show that improving the salience of water price increase through information provision enhances its effectiveness on water conservation, while reducing the salience of utility subsidy through automatic transactions minimizes the financial burdens of price increase on the low-income household without undermining their conservations efforts.

The effectiveness of price as a lever of water demand depends on its elasticity or how demand changes when price changes. Traditionally, residential water consumers exhibit low price elasticity of demand[5–7]. This has been attributed to the lack of information and understanding on price and quantity consumed[8,9]. On the price side, several factors may obscure price signals and make it difficult for consumers to perceive water price accurately – for example non-linear pricing structure (i.e., increasing block rate, which is the most common tariff structure)[7,10,11], inattentiveness to price and its components[12], and automatic payments[13,14]. On the quantity consumed, passive tracking of water use, as a result of infrequent billing[15,16] and systematically biased beliefs (i.e., underestimation of water use)[17–20], also prevents consumers from adjusting consumption according to price changes. Therefore, improved understanding of price[11] and water usage[9,15,16,19] could both increase price elasticity of demand for residential water users.

We investigate the effect of water price increase on water consumption using the case of Singapore. In February 2017, the Government of Singapore announced a two-stage 30% water price increase to be implemented in July 2017 and July 2018. This is the first-time that water prices were increased in about two decades. The announcement drew substantial media attention, which led to improved public awareness of the water price increase. Using monthly billing data on water consumption for more than 2.2 million accounts from all non-landed premises that houses 95% of the population, our difference-in-differences estimates show that the monthly water consumption for an average household decreased by 3.7% after the policy announcement and further drops by 2.1% and 2.8% respectively after the actual price increase in July 2017 and again in July 2018. The announcement accounts for 64% of the overall effects, likely due to enhanced price salience. We observed that households with lower water usage responded more to the announcement while those with higher usage responded more to the price increase. This is consistent with the literature which shows that consumers with low water demand tend to pay less attention to prices and are thus more responsive to information[11] brought by the announcement of price increase.

As low-income households spend a greater proportion of their income on water, they may be disproportionately affected by price increase.[4,21] To address the potentially regressive distributional effects, utility subsidies of various forms are often implemented alongside price increase.[22–24] The subsidy, though intended to cope with rising utility costs, also reduces the effective water price and may unintentionally increase water consumption.

In Singapore, the utility subsidy is implemented as a rebate through the existing tax system with automatic eligibility, disbursement, and usage, which could potentially reduce the salience of the program.[25,26] Our empirical analysis finds no credible evidence that the residential water consumption responded to the increases in the inconspicuous utility subsidy between 2011 and 2019. This suggests that the effect of utility subsidy on water usage, like that of price, is dependent upon the salience of information.

Our results shed light on the role of information and salience in determining price perception and price elasticity of demand. We show that information provision via policy announcement could improve price salience and effectively reduce residential water consumption. Although the announcement effect on consumer spending, consistent with the permanent income hypothesis that consumption decisions are based upon expected long-term average income, has been documented in other context[27], its effect on conservation and residential water use is unclear. Given that the cost of water constitutes a very small proportion of household income, the mechanism of announcement effect is likely to differ from the existing studies. Our empirical evidence suggests that the salience of policies may leave policymakers some room to maneuver to achieve desired behavioral outcomes. We also contribute to a broader literature that shows salience could improve the effectiveness of market-based environmental policies in correcting externality[28] and informative interventions could influence conservation behavior.[29–31]

Results

Effect of price increase announcement and implementation

In Singapore, water price, including water tariff, conservation tax, and waterborne fee, takes the form of an increasing block tariff. Before the price increase, it costed 2.1 Singapore Dollar (S$) per cubic meter ($m^3$) if the monthly household water consumption was below 40 m^3 and S$2.61 for each unit consumed above this cutoff. Only less than 3% of the households were affected by the second block price. In February 2017, the Government of Singapore announced a two-stage 30% water price increases to be implemented in July 2017 and July 2018 (see Supplementary Table 1 for details).

When a policy change only affects part of the population, the empirical identification could stem from the difference in consumption before and after the change for those who are affected relative to those who are not. In our case, however, the price change applies to the entire population. We therefore leverage on the potential differences in the elasticity of demand for water among the residents of public housing versus private apartments to identify the effect of price change using a difference-in-differences approach.

In Singapore, over 80% of the population lives in public housing developed and managed by the Housing and Development Board (HDB) and about 15% lives in private apartments. The average income for residents of HDB flats, ranging from S$2,521 for 1-/2-room flats to S$11,244 for 5-room and Executive flats, is much lower than private apartments at S$21,830 (Supplementary Table 2 Column (2)). Despite the income disparity, the monthly water bill for residents of HDB flats (S$25 to S$44 before the price increase) and private apartments (S$33) are similar (Supplementary Table 2 Column (3)), which could result in heterogeneous responses to price changes.

Figure 1 shows the unconditional mean of monthly water consumption, from January 2015 to December 2018, for HDB flats (panel (a)) and private apartments (panel (b)). We observe a discontinuity in water consumption around the announcement of water price increases for HDB flats but not private apartments. Using a regression discontinuity in time (RDIT) approach, we formally compare the monthly water consumption before and after the announcement of water price increase (equation (1) in Methods) for HDB flats and private apartments respectively. We find the discontinuity in water consumption to be statistically significant for HDB flats only (-4.7%, P<0.001, 95% CI [-0.06, -0.04]). We further divide the time periods after the announcement of price changes into three windows, i.e., announcement period (March to July 2017), first price increase (August 2017 to July 2018) and second price increase (August 2018 to December 2018). We compare the mean water consumption during each window to that of the pre-announcement period (January 2015 to February 2017) by estimating equation (2). Again, we find statistically significant differences for HDB flats only (-3.1%, P<0.001, 95% CI [-0.05, -0.01]; -5.2%, P<0.001, 95% CI [-0.06, -0.04]; and -5.1%, P<0.001, 95% CI [-0.06, -0.04]) in Supplementary Table 3. The estimates are robust to alternative specifications, sample restrictions, and bandwidth (Supplementary Table 4).

As there is no credible evidence that water consumption responds to price increase by private apartments, we focus on evaluating its effect on HDB flats hereafter. The RDIT design alone, however, is not sufficient as it is unable to eliminate the effect of other concomitant external shocks. We therefore turn to a difference-in-differences approach comparing the water consumption before and after the price increase for HDB flats (treatment group), relative to private apartments (control group), to account for coincidental changes that are common to both. The treatment and control groups follow an otherwise similar pre-trend in monthly water consumption (Supplementary Figure 1).

Table 1 column (1) shows the average effect of price change on HDB flats, relative to private apartments, by estimating equation (3) using observations from January 2015 to December 2018. Overall, the average water consumption for HDB flats has dropped by 5.8% (P<0.001, 95% CI [-0.07, -0.05]) after the announcement of the price increase. This effect is both statistically and economically significant. Evaluated at the mean (17.32 m^3 for the treatment group before price change), this 5.8% reduction translates to almost 10 litres of water saved per capita per day, considering an average household size of 3.16 persons. This is equivalent to 56% of Singapore's goal to reduce residential per capita consumption from 148 litres in 2016 to 130 litres per capita/day by 2030.

Table 1 column (2) decomposes the overall effects into the announcement effect and additional effects of the first and second price increases by estimating equation (4). The estimated announcement effect is 3.7% (P<0.001, 95% CI [-0.05, -0.02]), accounting for 64% of the overall effect. In comparison, the effect of the first and second price increases are 2.1% (P=0.001, 95% CI [-0.04, -0.01]) and 2.8% (P<0.001, 95% CI [-0.04, -0.01]), respectively. As the two price increases for the first consumption block (less than 40 m^3 per month per household) are similar in percentage terms (13.8% and 14.6%) and 97% of the households are only affected by the first block price, the difference in the effect sizes of the two price increases are not statistically significant (P=0.565). The estimated effects remain similar across model specifications and sample restrictions (Supplementary Table 5). Event study that compares water consumption between the treatment and control groups by quarter (equation (5) in Methods) shows no credible evidence of rebound in effect over time (Supplementary Figure 2).

The relatively large announcement effect is likely due to the increased price salience. Between the time of policy announcement and its actual implementation, consumers do not actually bear the burden of the water price hike. However, the announcement, along with the subsequent information provision via state newspapers and various social media platforms has elicited significant attention from the population. There is not only passive absorption of information, but also active search of related information. As shown in Figure 2(a), the number of Google searches on “water price” reached its highest in a decade in February 2017, when the price increase was announced. We expect this heightened attention on water price brought by the policy announcement to change consumer behavior.

If the announcement effect on water consumption is a result of changes in price salience, it would likely to differ for households with different baseline price salience. To test this, we divide our sample into quartiles by households’ baseline water consumption, as the literature shows that consumers with low water demand tends to pay less attention on price.[11] We estimate the heterogeneous announcement effect (equation (6) in Methods) and find it to decrease from a 4.8% (P<0.001, 95% CI [-0.07, -0.03]) reduction in water consumption for consumers with the lowest quartile of water demand to 2.5% (P=0.004, 95% CI [-0.04, -0.01]) for consumers with the highest quartile of water demand (Figure 3(a)). Similar trend of decreasing announcement effect with increasing water demand is observed across HDB flat types (Supplementary Figure 3). Consistent with the salience theory, we find that the announcement of the price increase is more effective in reducing water consumption for households with relatively low water demand regardless of household income.

Similarly, households with higher water demand tend to pay more attention to price information and could be more aware of the implementation of price increase. We find the effect of actual price increase to be the largest for consumers with higher water demand (quartile 4), 3.8% (P<0.001, 95% CI [-0.06, -0.02]) and 5.6% (P<0.001, 95% CI [-0.07, -0.04]) for the first and second price increase respectively, comparing to 0.72% (P=0.46, 95% CI [-0.03, 0.01]) and 0.14% (P=0.86, 95% CI [-0.02, 0.01]) for consumers with lowest quartile of water demand (Figure 3(b)-(c)).

Although pricing policy is effective in reducing water consumption and the announcement of price increase could further enhance its effectiveness, one major concern remains as leveraging water price to manage residential water demand may be regressive. To understand the effect of price increase by income group, we estimate the heterogenous effect by HDB flat type (equation (6) in Methods), a proxy for income level, and find no clear trends in the effects of announcement as well as the first and second price increases across HDB flat type (Figure 3(d)-(f))). However, based on the estimated changes in water consumption by flat type, we find that the change in water bill as a percentage of income is larger for households with relatively lower income (Figure 4(a)).

Effect of utility subsidy increase

The utility subsidy in Singapore takes the form of a tax rebate, i.e., Goods and Services Tax Voucher - Utility-Save (GST Voucher - U-save). It aims at helping lower- to middle-income households offset increases in utility bills. To be eligible for the program, a household must reside in an HDB flat, with at least one Singaporean occupier and none of the household members should have interests in more than one property. The rebate is credited at the beginning of each quarter to the utility accounts of qualified households without any sign-up requirement and the utility bills are adjusted automatically. The remaining rebate amount can be carried over until account closure but cannot be withdrawn. The amount of rebate is determined by HDB flat size, in accordance with their respective income levels (Supplementary Table 6).

To address the regressive distributional effect, alongside the water price increase, Singapore government also announced, in February 2017, an increase in the utility subsidy to take effect in July 2017. The amount of increase in subsidy, ranging from S$10 per quarter for HDB Executive flats to S$30 per quarter for HDB 1-room flats, is larger for households with lower income. As shown in Figure 4(b), it is sufficient to cover the average increase in water bill for HDB 1-room to

3-room flats, based on the estimated changes in water consumption by flat type (Figure 3(d)-(f)), after the implementation of the two-stage price increase. As a result of the increase in utility subsidy, the net cost of water as a proportion of income for low-income households has also been reduced (Figure 4(c)). These results show that utility subsidy could be effective in reducing the regressivity of pricing policies. Contrary to standard theory that consumers respond to marginal prices, recent research has found that consumers facing nonlinear pricing, including residential water users, respond to average price instead.[10] Consumers derive the average price of water using the cost of water shown on water bills, which in our case is the cost after offsetting the utility subsidy. As a result, although utility subsidy could be effective in addressing the regressive distributional effect of price increase, it reduces the effective average price of water, which could lead to an increase in consumption and reverse the conservation achieved by pricing policies.

As we are unable to separately estimate the effect of price and subsidy increases that were implemented simultaneously in 2017, we focus on the other subsidy increases implemented in 2012 and 2019 to provide some insights on consumption responses to subsidy increase. The 2012 subsidy increase ranged from S$20 to S$35 per quarter for various flat types while the 2019 subsidy increase was S$5 per quarter for all flat types (Supplementary Table 6).

We use a difference-in-differences approach to compare the water consumption before and after the announcement and implementation of subsidy increase for HDB flats, relative to private apartments, by estimating equation (3) and (4). In 2019, 84% of all HDB flats received utility subsidy. However, we do not have information on household level eligibility status and our estimates should be viewed as an intent-to-treat effect.

The baseline sample we use to evaluate the effect of the 2012 subsidy increase is from January

2011 to December 2013. As shown in Table 1 Column (3), we find no credible evidence for a statistically significant change in water consumption for HDB flats in response to after the announcement of subsidy increase (0.5%, P=0.698, 95% CI [-0.02, 0.03], BF_{10}=0.0001). We further show in Table 1 Column (4) that there is no statistically significant effects of either the announcement (0.6%, P=0.646, 95% CI [-0.02, 0.03], BF_{10}=0.0002) or implementation of subsidy increase (0.6%, P=0.520, 95% CI [-0.01, 0.03], BF_{10}<0.0001), nor the combination of the two (1.2%, P=0.49, 95% CI [-0.02, 0.05], BF_{10}<0.0001).

We also find no credible evidence that water consumption responds to the 2019 subsidy increase. As the subsidy change, announced in February 2018 and implemented in January 2019, overlapped with the second water price increase (July 2018), we first evaluate the effect of announcement and subsidy increase separately using samples from August 2017 (after the first price increase) to July 2018 (before the second price increase) and from August 2018 (after the second price increase) to December 2019, respectively. As shown in Table 1 Columns (4)-(5), there is no credible evidence that either the announcement (0.2%, P=0.330, 95% CI [-0.06, 0.02], BF_{10}=0.0003) or the implementation of subsidy increase (-0.9%, P=0.413, 95% CI [-0.03, 0.01], BF_{10}=0.0003) affect water consumption for HDB flats. We then turn to jointly estimate the effect of the three above-mentioned changes using the sample from August 2017 to December 2019. The estimated effects of announcement (-0.2%, P=0.206, 95% CI [-0.05, 0.01], BF_{10}=0.0002) and implementation of subsidy increase (0.1%, P=0.964, 95% CI [-0.03, 0.03], BF_{10}=0.0003) remain statistically insignificant (Table 1 Columns (6)).

These results are robust to alternative specifications (Supplementary Table 7 and 8) and are consistent across income groups and water demand levels (Supplementary Figure 4 and 5). As we find no evidence that households respond to subsidy increases, the effects of price change and its announcement estimated earlier are unlikely to be driven by the subsidy increase.

The underlining mechanism for the null effect of subsidy could provide important lessons for protecting the vulnerable groups from environmental/social policies in the pursuit of sustainable growth. One possible explanation for the null effect is the low-salience program design for subsidy. GST Voucher – U-save is framed as a rebate, which is perceived as a forgone loss and elicit less attention and behavior responses.[26] It has no sign-up requirement, is automatically credited to the utility account for eligible households, and is applied to offset their utility cost with no individual actions required. The lack of action[25] significantly reduce the salience of subsidy and the consumptions responses. The number of Google searches on utility subsidy ("U-save") is much lower comparing to "water price" (Figure 2(a)) and other components of the GST Voucher scheme, such as GST Voucher – Cash, which requires active usage of the rebate (Figure 2(b)). The changes in the number of searches around the announcement and implementation of subsidy increase are also minimal, which indicates the lack of attention being paid on utility subsidy.

We find other possible explanations for the null effect less convincing. Firstly, the null result is not due to small sample size. Our sample includes 95% of the households (2.2 million) in the country with a minimal detectable effect size of 0.07% at 95% confidence level with 80% power, smaller than all estimates cross various models. Secondly, the null effect is not due to small amount of subsidy increase. Although the 2019 subsidy increase was small (S$5 per quarter as shown in Supplementary Table 6), the increase in 2012 was larger than the estimated change in water bill led by the price increase (Supplementary Figure 6). Thirdly, we find no evidence of a delayed effect as the null effect is persistent over time (Supplementary Figure 7) nor there is any evidence of the timing of subsidy disbursement (i.e., beginning of each quarter) affecting the results (Supplementary Figure 8). Lastly, the null effect is unlikely due to the increase in subsidy and dispensable income being used for other household items as we find no evidence of the subsidy increase affecting household's electricity consumption or grocery expenses (Supplementary Table 9).

Discussion

We show that improving the salience through the announcement of water price increases enhances the price elasticity of consumers and the effectiveness of price regulations. Using monthly billing data on residential water use for all non-landed premises in Singapore over 10 years, we show that the two-stage 30% increase in water price reduces monthly water consumption by 5.8% for an average HDB flat, relative to private apartments. The announcement of the price change alone contributes to a 3.7% decline in water consumption, accounting for 63% of the overall effects. We find that consumers who are less attentive to water price information respond more to the announcement or new information about water price increase, but less to the actual price increase. This finding, consistent across income groups, further confirms the role of information salience in altering price elasticity. Meanwhile, we find that with calibrated information provision and program design, utility subsidies could reduce the disproportionate burden on low-income households without reversing the water conservation achieved through price increase.

Comparing to alternative demand management initiatives, combining traditional market-based policy tools, such as increase water price increase and utility subsidy, with information salience could be more cost-effective in reducing residential water consumption. Research has shown that a nationwide peer comparison had no statistically significant effect on water consumption for an average household in Singapore and nationwide efficiency improvements of water fittings reduced water consumption by 3.5% at a much higher cost.[32] The implementation of this combination of policies also had minimal requirement on technology advancement and institutional innovation, as compared to many proposed solutions to urban water challenges.[33]

The findings in the study on the role of information and salience, have broader implications on the implementation of market-based conservation and environmental policies. E-payments and automatic deduction of utility bills are becoming increasingly popular, which would further reduce price salience. Policy makers and utility managers should consider the potential challenge this may impose on water and energy demand management. Countries that leverage carbon tax and trading to mitigate the impact of climate change could similarly benefit from policy designs that utilize the salience of price to improve its effectiveness.

There are some caveats to be considered. Firstly, for our evaluation on the effect of price change, we use private apartments as the control group. We investigate the water consumption around the time of price change, both graphically and empirically using RDIT, and find no evidence of discontinuity in water consumption for the private apartments. However, if there are other concurrent policies that affect water consumption for HDB flats and private apartments differently, our estimates would be biased. We are unaware of such policies upon extensive reviews. Secondly, as we cannot identify the 84% of HDB flats that receive the utility subsidy, we are only able to estimate the intent-to-treat effect. The average treatment effect on the eligible households and spillover effects, if any, on the non-eligible HDB flats remain unclear.

Methods

Data

The main data we used for this study comes from the monthly water consumption by account obtained from PUB, Singapore's national water agency. The dataset contains 126,123,832 observations of monthly water consumption based on water bills for 2,231,379 unique accounts, which covers all non-landed residential premises that houses 95% of the country's resident households, from January 2011 to December 2019. Meter-reading is conducted every two months in Singapore. Water consumption for the month without meter-reading is estimated using the previous two meter-readings. We exclude extreme values of the top and bottom 1% observations for each premise type to account for potential measurement errors caused by water leakage or problematic meter-readings.

The dataset includes anonymized account number that changes every time a household moves, block identifier/postal code, property type (HDB vs private apartments) and HDB flat type classified by the number of rooms (1-5 room flats and HDB executive flats). In our data, private apartments account for 20.1% of all accounts with a mean monthly water consumption of 15.6 m^3. Note that this is the mean water consumption of all private apartments of various sizes. Among the HDB flats, the monthly water consumption averages between 11.2 m^3 for HDB 1/2-room flats and 20.5 m^3 for the executive flats. Supplementary Figure 9 presents the distribution of accounts by flat type and their corresponding mean monthly water consumption.

As shown in Supplementary Table 10, the mean monthly water consumption reduced from 17.3 m^3 to15.4 m^3 for HDB flats and from 16.3 m^3 to 14.3 m^3 for private apartments.

Empirical method

To analyze the effect of water price and utility subsidy change on residential water consumption, we use a difference-in-differences regression approach with HDB flats as the treatment group and private apartments as the control group. However, the change in water price affects the entire population, including the control group. Our empirical estimation therefore relies on the assumption that households in private apartments do not respond to water price change the same way as the HDB flats. We start our empirical analysis by verifying this assumption.

Regression Discontinuity in Time

If households respond to the water price increase, we will observe a discontinuity in residential water consumption before and after its announcement or implementation. If the price change effects vary by property type (i.e., private vs HDB) as we hypothesize, the discontinuity in water consumption should also differ. Therefore, we first use a Regression Discontinuity in Time (RDIT) approach to formally evaluate the effect of price changes on the HDB flats and private apartments, respectively.

We use observations from January 2015 to December 2018 for private apartments and HDB flats as the respective baseline sample. We estimate the following equation:

$$ln\, W_{it} = \beta PostAnnouncement_t + f(t) + \alpha_i + \gamma_{t(m)} + \epsilon_{it} \tag{1}$$

The dependent variable is the natural logarithm of monthly water consumption plus one for account i in time period t. $PostAnnouncement_t$ is the indicator variable which takes the value of 1 for time periods after the announcement of price change in February 2017. $f(t)$ is a function of the running variable, which is time in our case. We use a first-degree polynomial and allow the slope to vary across the discontinuity. We include account fixed effects α_i to account for time-invariant household characteristics. We address the concern of seasonal or cyclical variation in water consumption by including month fixed effects $\gamma_{t(m)}$.

The coefficient of interest β measures the changes in water consumption before and after the announcement of price increase. We expect the coefficient to be statistically insignificant for the private apartments, providing some suggestive evidence that the price increase does not alter water consumption for this group.

We further divide the post-announcement period into three time-windows, namely announcement (March to July 2017), first price increase (August 2017 to July 2018), and second price increase (August 2018 to December 2018), to compare the water consumption in each time window with that of the pre-announcement period. We estimate the follow equation:

$$\ln W_{it} = \beta_1 Announcement_t + \beta_2 FirstIncrease_t + \beta_3 SecondIncrease_t + f(t) + \alpha_i + \gamma_{t(m)} + \epsilon_{it} \qquad (2)$$

where *Announcement, FirstIncrease* and *SecondIncrease* are indicator variables that take the value of 1 for each respective time windows. The coefficients β_1, β_2, and β_3 measure the difference in water consumption between each time window and the pre-announcement baseline.

As a robustness check, we use a semi-balanced sample or accounts with observations at least two months before the cutoff as an alternative sample. This is to address the concern of covariate balance and sorting in RDIT design. Other robustness checks include alternative specifications, such as varying the fix effects included and adding environmental/weather controls to account for spatial variations in temperature, rainfall, and air pollution; and use alternative bandwidth, i.e., evaluating the effect on bi-monthly water consumption instead of monthly.

Difference-in-differences analysis

We first investigate the overall effect of the price and subsidy change considering its announcement as the timing of treatment. For the water price change, although it was implemented in two stages, the announcement was made in February 2017. Therefore, in our baseline model, we consider January 2015 to February 2017 (26 months) to be the pre-announcement period and March 2017 to December 2018 (22 months) to be the post-announcement period. Similarly, for the subsidy change announced in 2012, we consider January 2011 to February 2012 (14 months) as the pre-announcement period, and March 2012 to December 2013 (22 months) as the post-announcement period.

To evaluate the overall effect of price and rebate change, we estimate the following specification:

$$\ln W_{it} = \delta_1 Pre_t \times HDB_i + \delta_2 PostAnnouncement_t \times HDB_i + \theta_k \tau + \alpha_i + \gamma_t + \epsilon_{it} \tag{3}$$

where Pre_t is an indicator variable that takes the value of 1 for the six months before the announcement of price or rebate change. $PostAnnouncement_t$ is the indicator variable which takes the value of 1 for time periods after the announcement of price or rebate change and HDB_i is an indicator variable for the treatment group, i.e., HDB flats. We allow the two groups to have different water consumption trend by including group-specific linear time trend τ. We include account fixed effects α_i to account for time-invariant household characteristics and time fixed effect γ_t to account for seasonality and other economy-wide common shocks. The standard errors are two-way clustered by block and year-month. The coefficient of interest δ_1 and δ_2 measures the differences in monthly water consumption for the treatment group relative to the control group before and after the announcement of price or rebate change.

As we are particularly interested in how information and policy announcement modify the effect of price and rebate change, we differentiate the effect of announcement and implementation by estimating the following equation:

$$\ln W_{it} = \delta_1 Pre_t \times HDB_i + \delta_2 PostAnnouncement_t \times HDB_i \tag{4}$$
$$+\Sigma_n^N \delta_{3n} PostImplementation_t \times HDB_i + \theta_k \tau + \alpha_i + \gamma_t + \epsilon_{it}$$

Specifically, $PostAnnouncement_t$ is an indicator variable that equals 1 for the time periods after the announcement of policy change; while $PostImplementation_t$ is an indicator variable that takes the value of 1 for the time periods after the actual policy change. N is the total number of stages a policy is implemented in, which is one for 2012 rebate change and two for 2017/18 price change.

The coefficient of interest δ_2 captures the average effect of the announcement on the water consumption for the treatment group, relative to the control group. The coefficients δ_{3n}(s) capture the additional effects of each phase of the subsidy/price increase. Note that the announcement of price change in February 2017 and the first stage of price increase in July 2017 are accompanied by an announcement and implementation of subsidy increase, therefore the corresponding coefficients measure a combined effect of price and subsidy change.

For robustness checks, we use alternative specifications such as excluding group specific time trend, including weather and pollution controls, controlling for block fixed effects instead of account fixed effects and lastly, controlling for year fixed effects and month fixed effects instead of year-month fixed effects. We also consider alternative samples, such as including observations with the top and bottom 1% of monthly water consumption and use alternative sample periods. To evaluate the effect of price change, we consider sample periods from January 2011 to December 2018, from January 2015 to December 2019 as well as the full sample of January 2011 to December 2019. To evaluate the effect of 2012 rebate change, we consider extending the sample periods to December 2016.

There was another utility subsidy increase announced in February 2018 that took effect in January

2019. As the timeline overlapped with the second water price increase, we are unable to estimate the overall effect of the subsidy change as cleanly as the 2012 rebate change. To overcome this estimate challenge, we estimate the following models: First, to capture the effect of announcement, we estimate equation (2) using sample period of August 2017 (after first price increase) to July 2018 (before second price change) with the indicator variable *PostAnnouncement* taking the value of 1 for time periods after February 2018 or the announcement of rebate change. Second, to evaluate the effect of the implementation of subsidy increase, we estimate an equation similar to equation (2) using sample period from Aug 2018 (after the second price change) to April 2019, with the policy change indicator taking the value of 1 for time periods after January 2019. Lastly, we use the sample from August 2017 (after the first price increase) to December 2019 and estimate equation (3). We include two separate *PostImplementation* indicators, one for the time periods after then second price increase and one for the time periods after the subsidy change in January 2019.

Evolutionary effect

We conduct event studies to estimate a non-parametric model that fully illustrates the evolutionary effect of price and subsidy change.

We consider the following equation:

$$\ln W_{it} = \Sigma_{j=-T}^{T} \delta_j D_t \times HDB_i + \theta_k \tau + \alpha_i + \gamma_t + \epsilon_{it} \tag{5}$$

where we interact the treatment indicator with the set of time dummies D_t that takes the value of 1 for time-period t. The coefficient of interest δ_0 shows the immediate effect of the policy announcement and coefficients δ_1 to δ_T measure the effect on consumption in each quarter post the announcement of price/subsidy increase, while the coefficients δ_{-T} to δ_{-1} measure the difference in water consumption between the treatment and control group in each quarter of the pre-announcement time-period.

Heterogeneous effect

We study the heterogeneous responses to the announcement and implementation of price and subsidy change by various groups of individuals (e.g. different levels of water consumption, HDB flat type, and the combination of the two) using the following specification:

$$\ln W_{it} = \Sigma_{m=-1}^{M} \delta_m PostAnnouncement_t \times HDB_i \times G_i + \Sigma_{n=1}^{N} \Sigma_{m=-1}^{M} \delta_{mn} PostImplementation_t \times HDB_i \times G_i + \theta_k \tau + \alpha_i + \gamma_t + \epsilon_{it} \quad (6)$$

where M is the number of subgroups we decompose into and G_i is subgroup indicator. Recall that N is the number implementation stages. The coefficients δ_1 to δ_m measure the heterogeneous response to announcement effects while coefficients δ_{n1} to δ_{nm} capture effects of the implementation of price and subsidy increase.

Data availability statement

Data on block-level housing characteristics, demographics, weather, and pollution conditions, and HDB resale transactions are available on GitHub. The water consumption data for this study is provided by PUB, Singapore's National Water Agency under non-disclosure agreement for the current study. Upon reasonable request to PUB and with the necessary non-disclosure agreements signed with NUS, it is available onsite at NUS to replicate all the results from the deposited Stata code.

Code availability statement

Stata code used for data analysis in this study is available on GitHub.

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Contribution

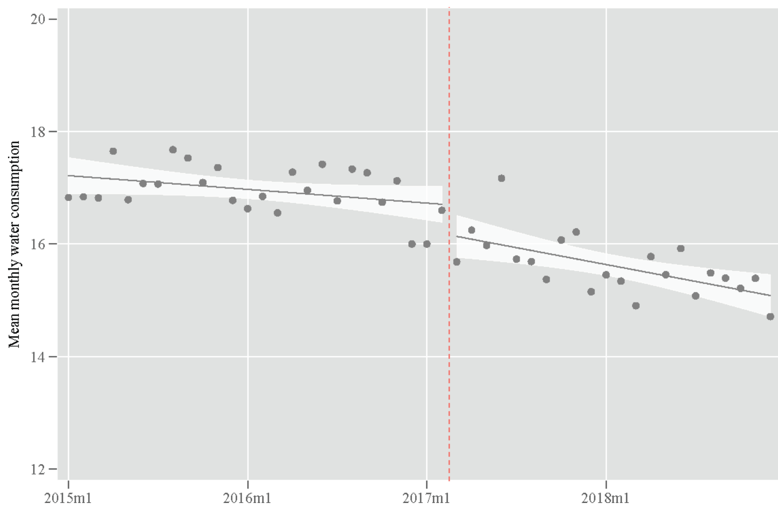
All authors contributed to the research design, implementation, data analysis and writing.

Conflicts of interests

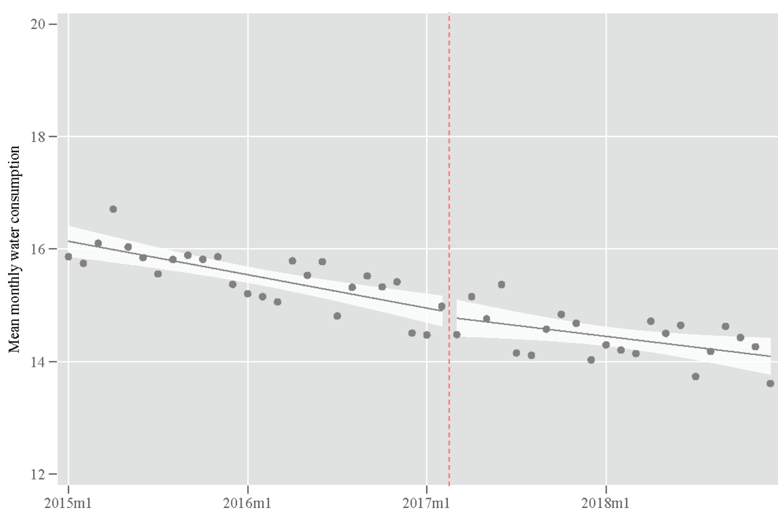
The authors declare no competing interests.

Figures and Tables

Figure 1: Graphical analysis of regression discontinuity



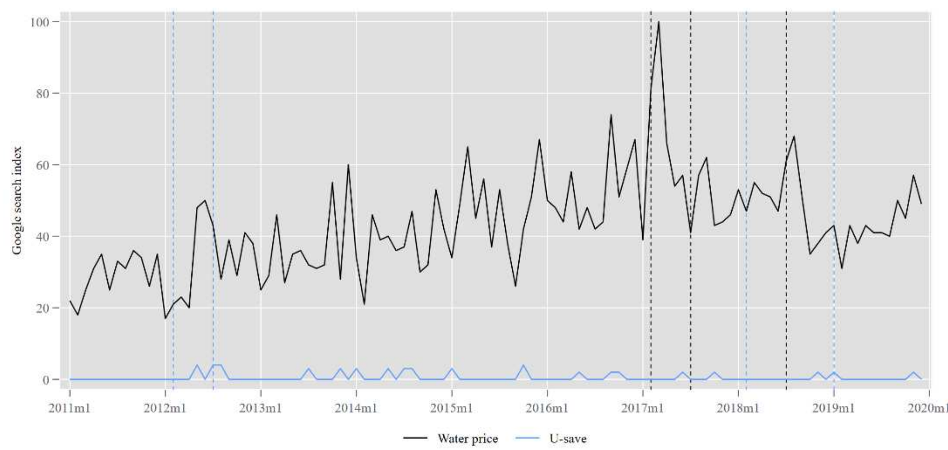
(a) HDB flats

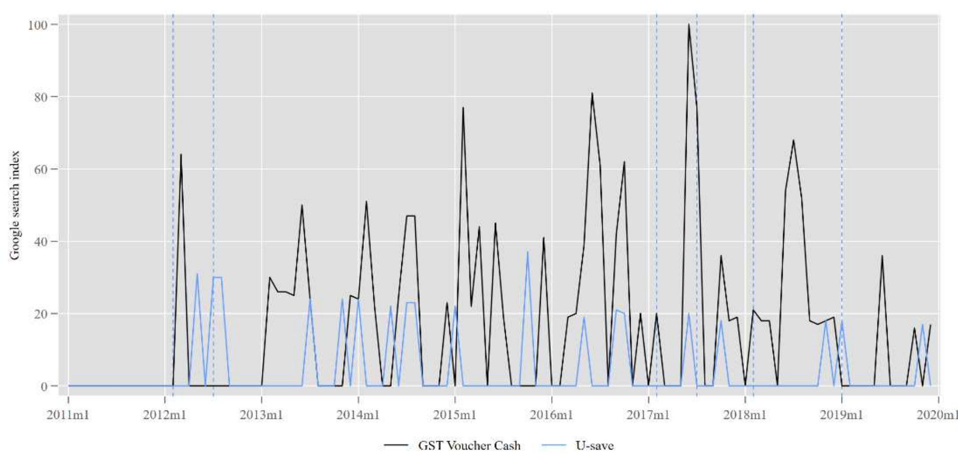


(b) Private apartments

Note: The figures show linear trends in monthly water consumption before and after the announcement of water price increase (February 2017 as indicated by vertical dotted lines) for HDB flats and private apartments respectively. The white areas represent the 95% confidence interval, and the dots show the monthly mean water consumption.

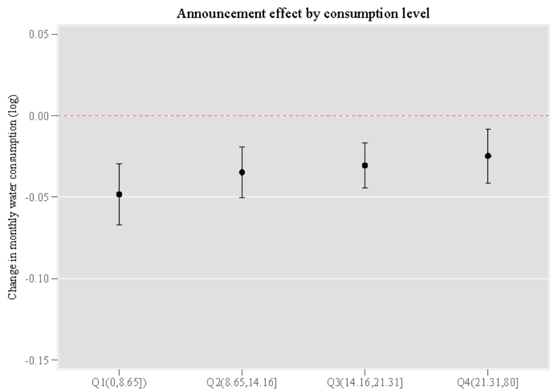
Figure 2: Google search on price and rebate change



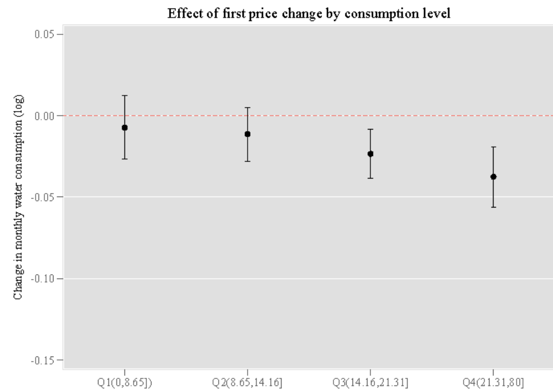


Note: The figures present the Google Search Index on water price, u-sav and GST Voucher Cash. In subfigure (a), the month with the highest number of searches on water price is indexed as 100; while in subfigure(b), the month with the highest number of searches on GST Voucher Cash is indexed as 100.

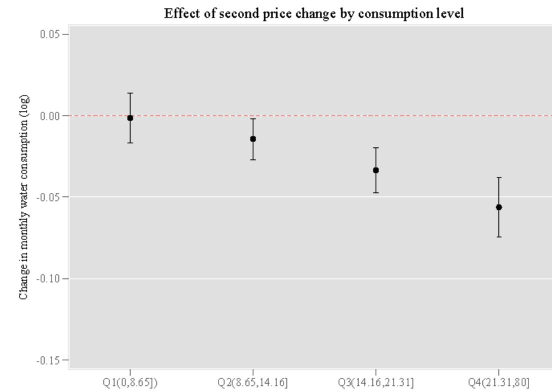
Figure 3: Heterogeneous responses to price change



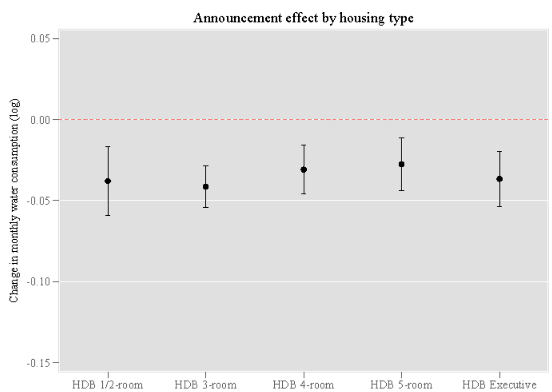
(a) Announcement effect by water demand



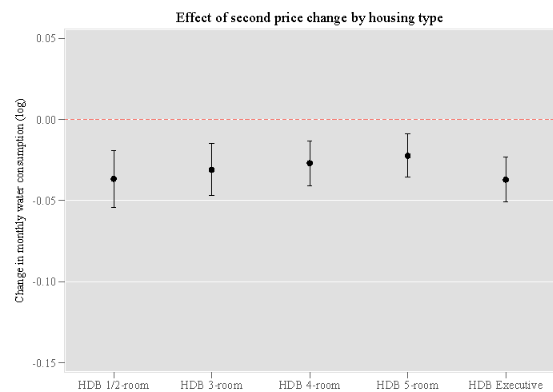
(b) Effect of first price increase by water demand



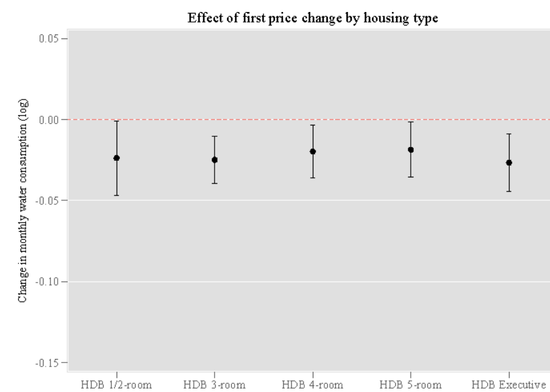
(c) Effect of second price increase by water demand



(d) Announcement effect by flat type

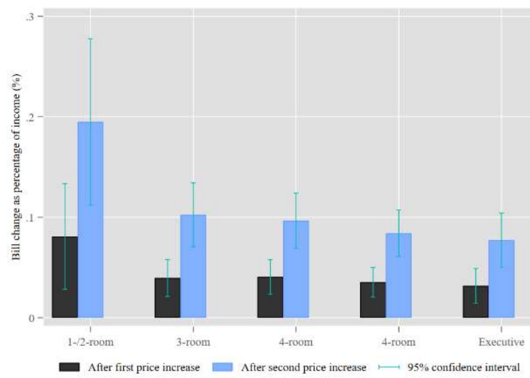


(e) Effect of first price increase by flat type

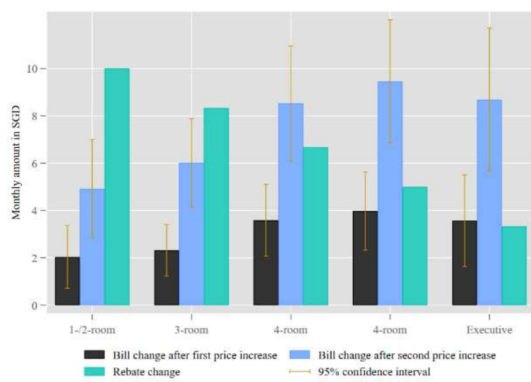


(f) Effect of second price increase by flat type

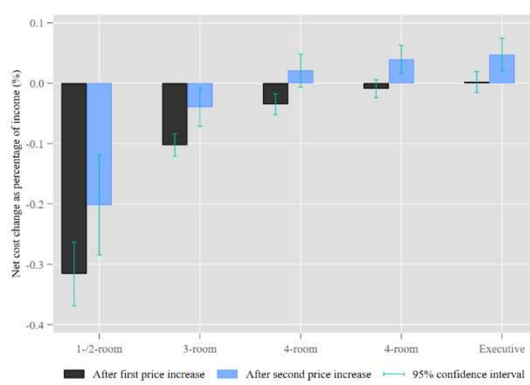
Figure 4: Distributional effect of price increase



(a) Bill change as percentage of income



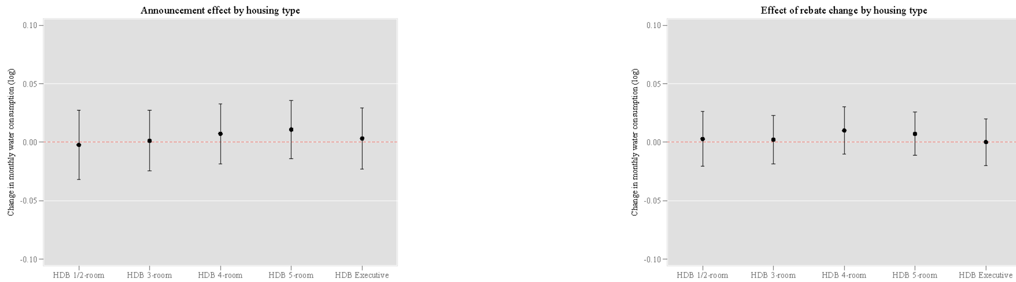
(b) Bill change and rebate change



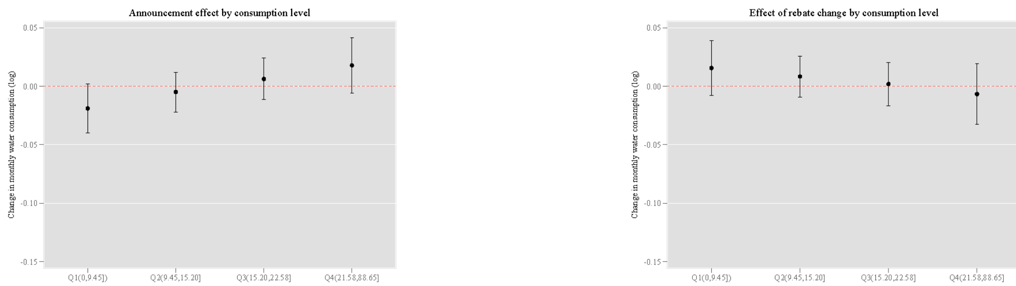
(c) Net cost of water as percentage of income

Note: The figures show the estimated changes in water bill (bars) and the corresponding 95% confidence intervals (error bars) after each price increase by HDB flat types. The changes in water consumption by flat type are estimated using equation (6). Subfigure (a) presents the change in water bill as a percentage in income, subfigure (b) compares the change in water bill to the change in subsidy, while subfigure (c) presents the change in the net cost of water as percentage of income.

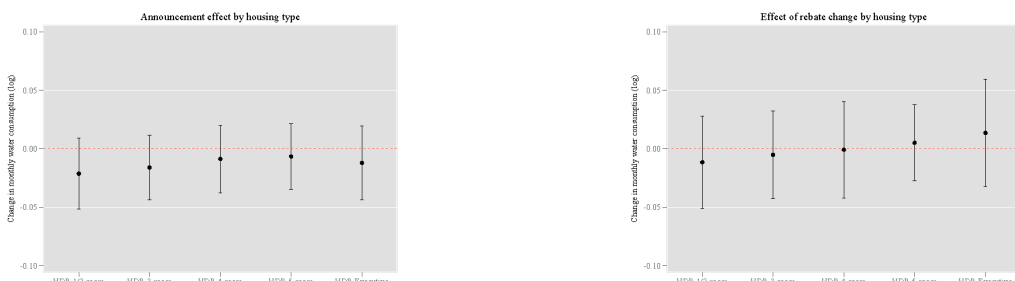
Figure 5: Heterogeneous responses to subsidy increase



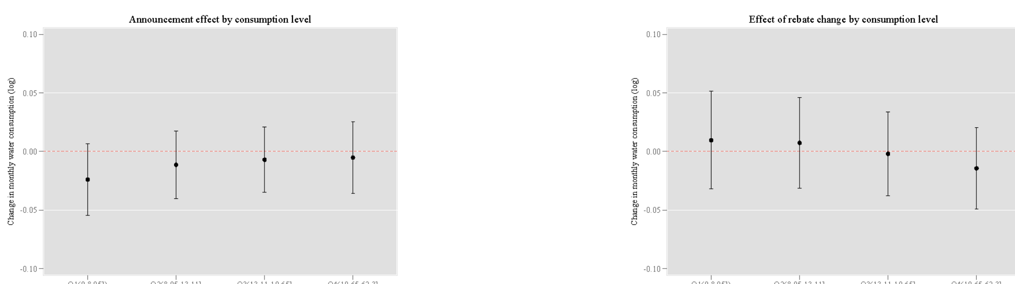
(a) 2012 subsidy increase: by HDB flat type



(b) 2012 subsidy increase: by water consumption quartile



(c) 2019 subsidy increase: by HDB flat type



(d) 2019 subsidy increase: by water consumption quartile

Note: The figures show the effects of announcement and subsidy increase in 2012 and 2019 by water consumption quartile and HDB flat type. The coefficients (dots) and corresponding 95% confidence intervals (error bars) are estimated using equation (6). Standard errors are clustered by block and year-month.

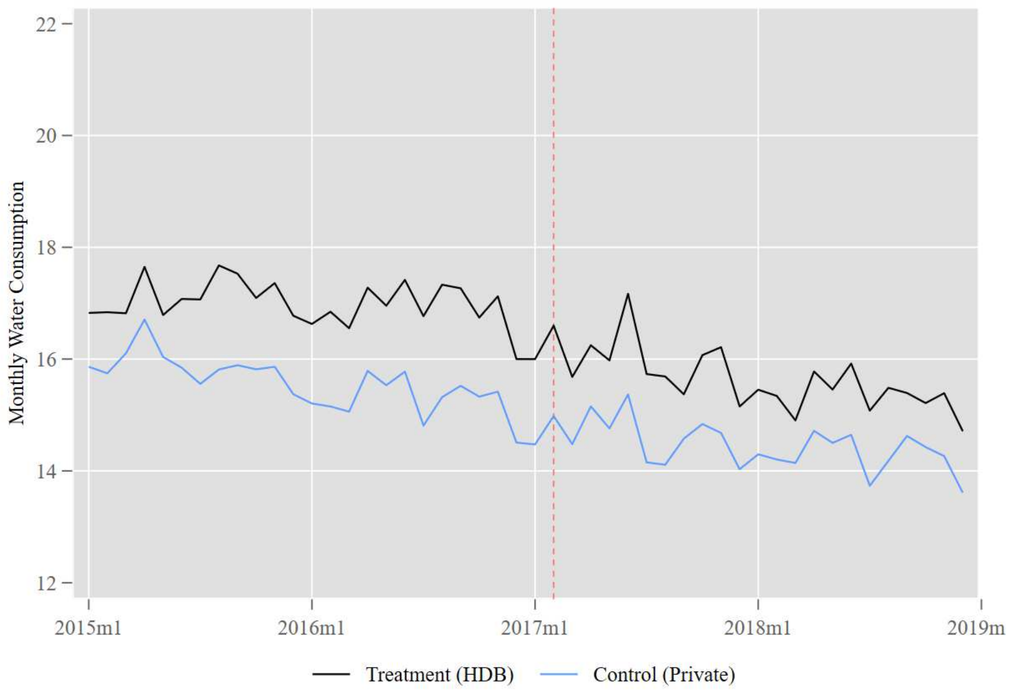
Table 1: Effect of price and subsidy increase on water consumption

Dependent variable: Log of water consumption	(1)	(2)	(3)	(4)	（5）	（6）	（7）
	Price increase		Subsidy increase				
			2012	2012	2019	2019	2019
Pre*HDB	-0.007	-0.007	0.004	0.006	-0.009	-0.001	-0.008
	(0.006)	(0.006)	(0.008)	(0.010)	(0.012)	(0.008)	(0.011)
Post announcement*HDB	-0.058***	-0.037***	0.005	0.006	-0.020		-0.019
	(0.006)	(0.008)	(0.012)	(0.013)	(0.020)		(0.014)
Post first price increase*HDB		-0.021***					
		(0.008)					
Post second price increase*HDB		-0.028***					-0.021**
		(0.007)					(0.008)
Post subsidy increase*HDB				0.006		-0.009	0.001
				(0.010)		(0.017)	(0.015)
Group time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Account FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	56,953,157	56,953,157	38,381,985	38,381,985	14,578,483	21,342,188	35,940,387
R^2	0.773	0.773	0.784	0.784	0.837	0.826	0.801

Note: This table presents the effect of price and subsidy increase on the water consumption for the HDB flats, relative to private apartments. The dependent variable is natural logarithms of 1 plus the monthly water consumption. Sample period is January 2015 to December 2018 for columns (1) and (2); January 2011 to December 2013 for columns (3) and (4); August 2017 to July 2018, Aug 2018 to December 2019 and August 2017 to December 2019 for columns (5) to (7) respectively. Columns (1) and (3) show the average effect of price change and 2012 subsidy change by estimating equation (3); Columns (2) and (4) shows the decomposed effects by estimating equation (4); Columns (5) and (6) estimate the effect of 2017 announcement and subsidy increase separately; while column (7) jointly estimates the announcement of 2019 subsidy change, the second price increase, and the subsidy increase. *HDB* is an indicator variable takes the value of 1 for HDB flats or treatment group. *Pre* is an indicator variable takes the value of 1 for the six months before the announcement of price and subsidy change. *Post announcement*, *Post first price increase*, *Post second price increase* and *Post subsidy increase* are indicator variables equal 1 for time periods after the corresponding event. All models include group-specific time trend, account fixed effects and year-month fixed effects. Standard errors in parentheses are two-way clustered by block and year-month. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

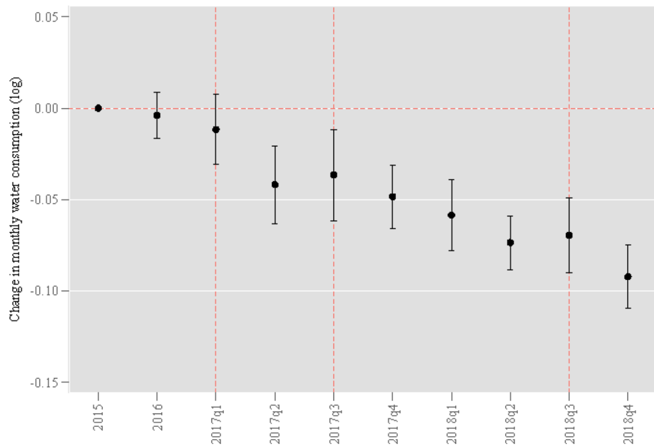
Supplementary Information

Supplementary Figure 1: Trends in water consumption for treatment and control group



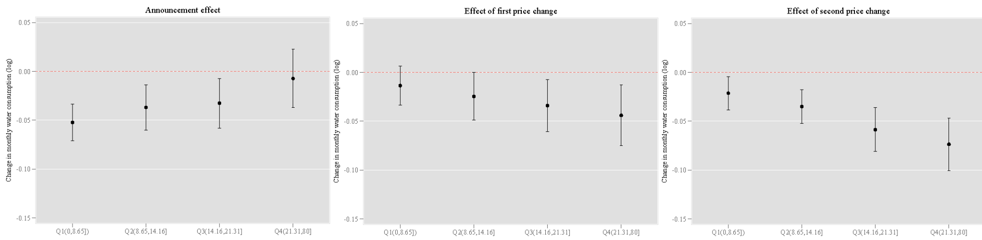
Note: The figure shows the average monthly water consumption for HDB flats and private apartments from January 2015 to December 2019. The red vertical line indicates the timing for the announcement of water price increase.

Supplementary Figure 2: Evolutionary effect of price increase

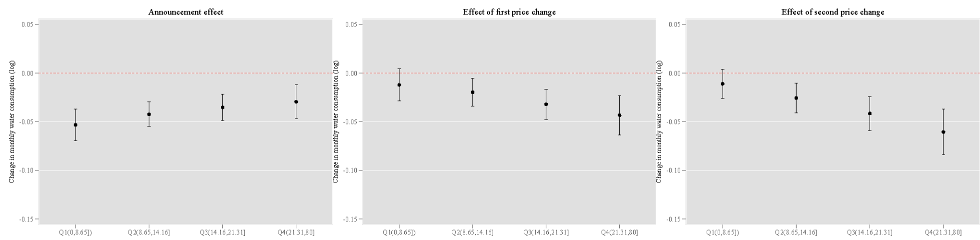


Note: The figure shows the coefficients (dots) and corresponding 95% confidence intervals (error bars) for the difference in water consumption between the control and treatment group each quarter after the announcement of price increase by estimating equation (5). Standard errors are clustered by block and year-month. The vertical lines from left to right indicate the timing for the announcement, first price increase and second price increase.

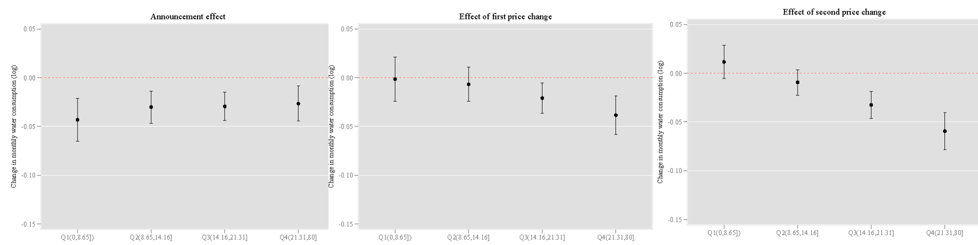
Supplementary Figure 3: Heterogeneous responses to price change by HDB type and water consumption quartile



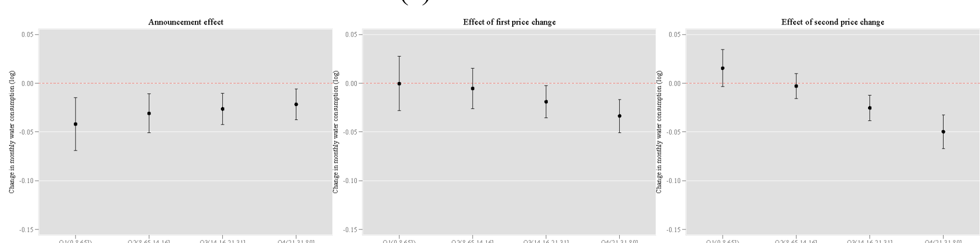
(a) HDB 1-/2-room



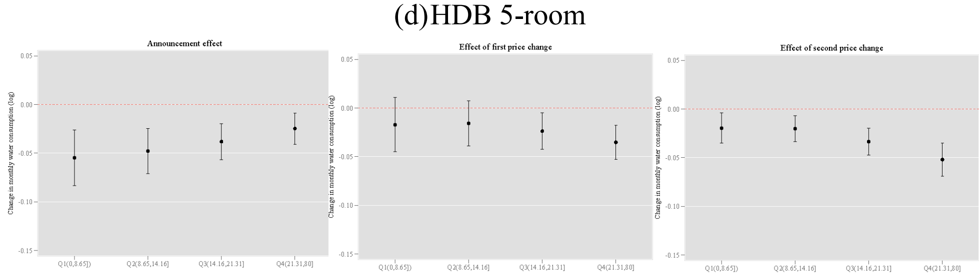
(b) HDB 3-room



(c) HDB 4-room



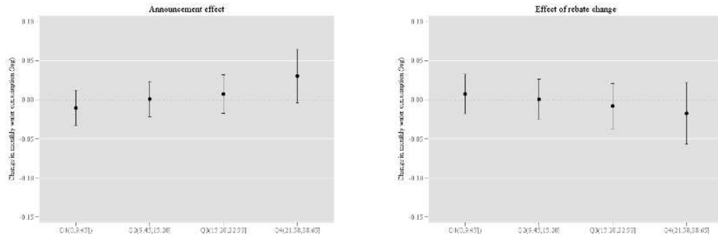
(d) HDB 5-room



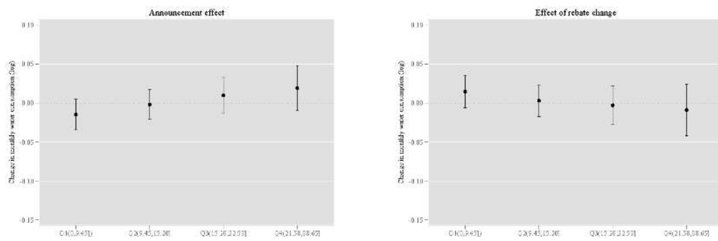
(e) HDB Executive

Note: The figures show the effects of announcement, first price increase, and second price increase by water consumption quartile for each HDB flat type. The coefficients (dots) and corresponding 95% confidence intervals (error bars) are estimated using equation (6). Standard errors are clustered by block and year-month.

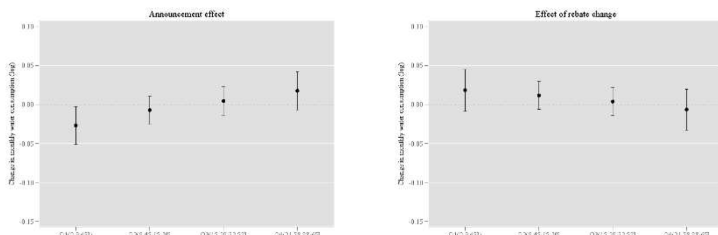
Supplementary Figure 4: Heterogeneous responses to 2012 subsidy increase by water consumption quartile for each flat type



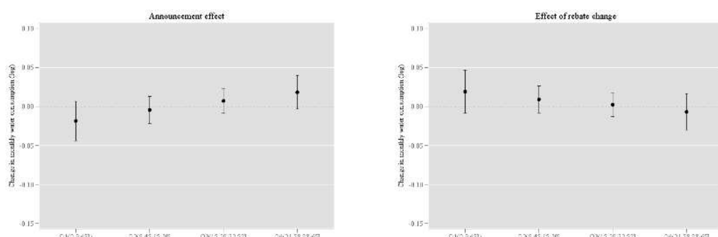
(a) HDB 1-/2-room



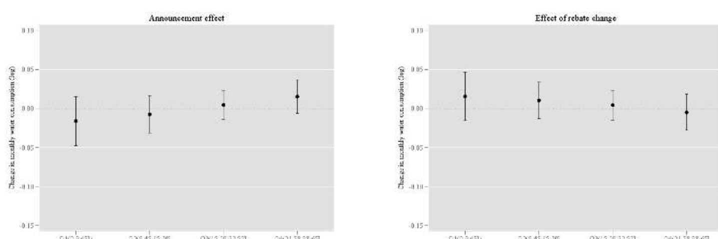
(b) HDB 3-room



(c) HDB 4-room



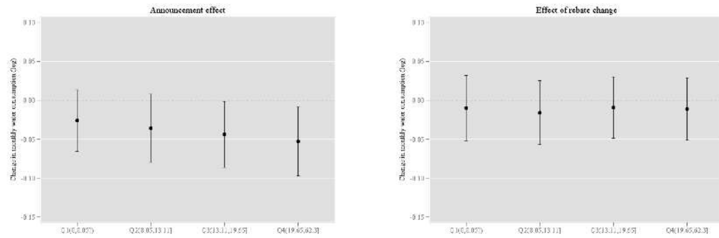
(d) HDB 5-room



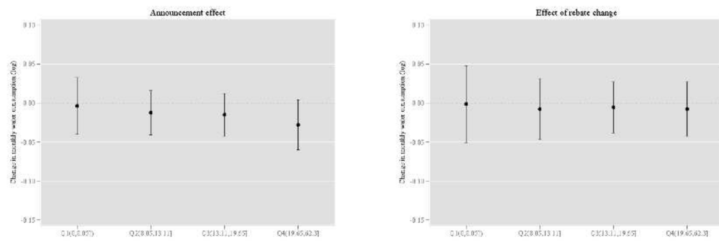
(e) HDB Executive

Note: The figures show the effects of announcement and 2012 subsidy increase by water consumption quartile for each HDB flat type. The coefficients (dots) and corresponding 95% confidence intervals (error bars) are estimated using equation (6). Standard errors are clustered by block and year-month.

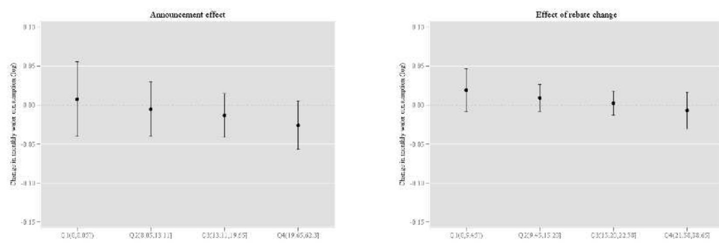
Supplementary Figure 5: Heterogeneous responses to 2019 subsidy by water consumption quartile for each flat type



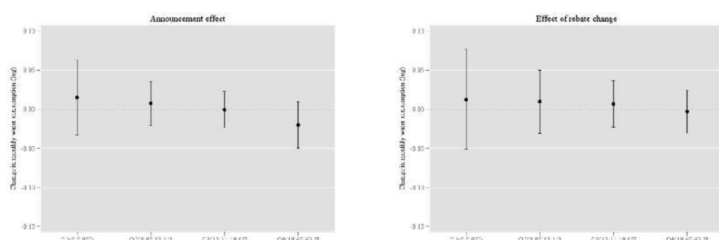
(a) HDB 1-/2-room



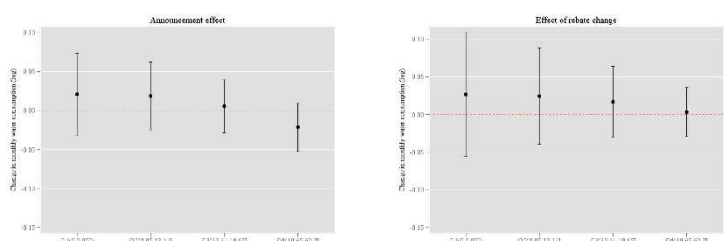
(b) HDB 3-room



(c) HDB 4-room



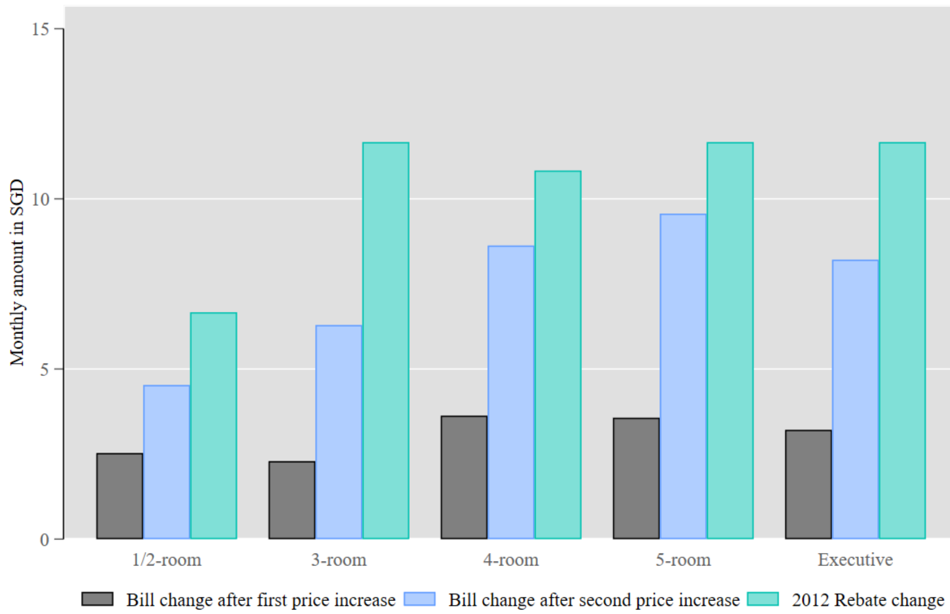
(d) HDB 5-room



(e) HDB Executive

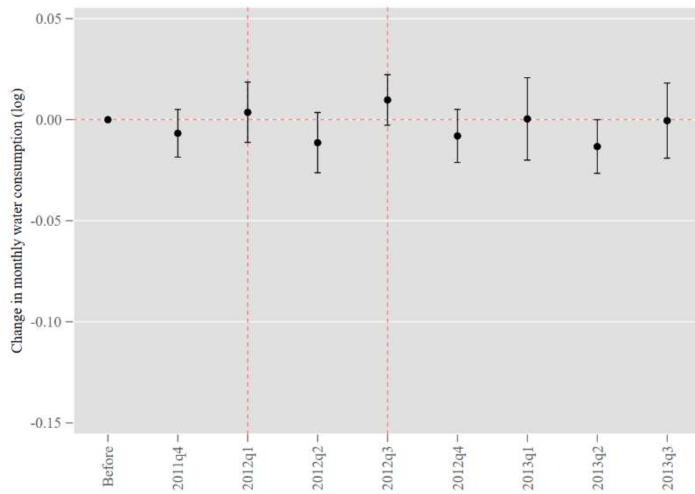
Note: The figures show the effects of announcement and 2019 subsidy increase by water consumption quartile for each HDB flat type. The coefficients (dots) and corresponding 95% confidence intervals (error bars) are estimated using equation (6). Standard errors are clustered by block and year-month.

Supplementary Figure 6: Amount of subsidy increase in 2012

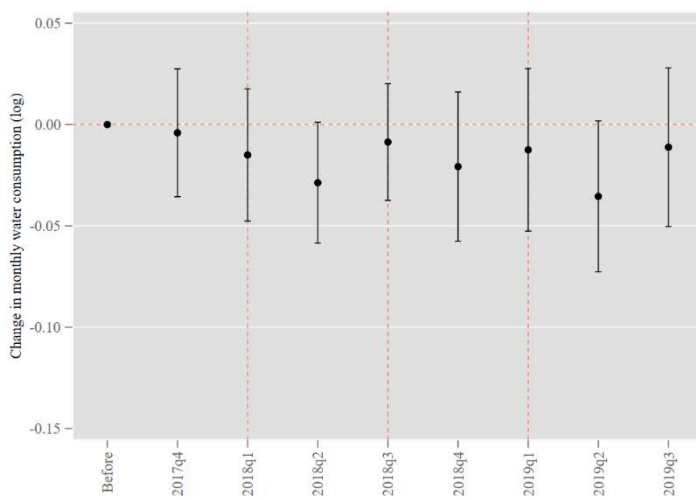


Note: The figure compares the estimated change in water bill after the price increases with the 2012 subsidy increase by HDB flat types.

Supplementary Figure 7: Evolutionary effect of subsidy increases



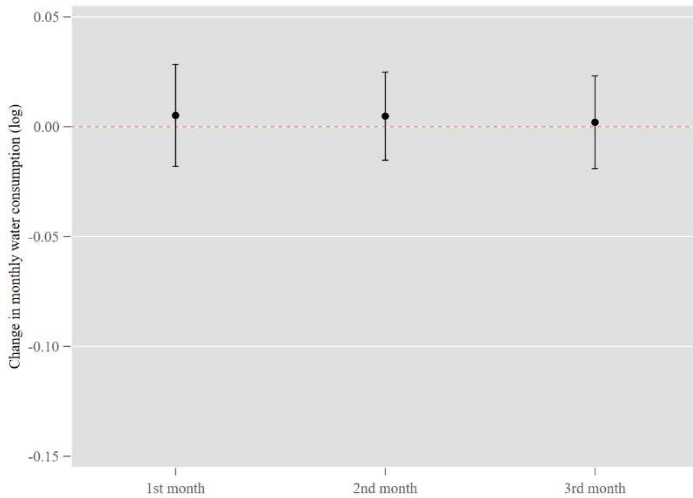
(a) 2012 subsidy increase



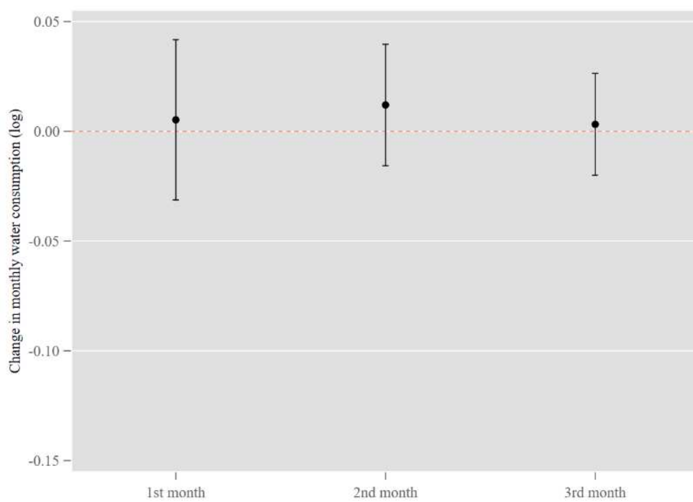
(b) 2019 subsidy increase

Note: The figure shows the coefficients (dots) and corresponding 95% confidence intervals (error bars) for the difference in water consumption between the control and treatment group each quarter after the announcement of 2012 (subfigure (a)) and 2019 (subfigure (b)) subsidy increase, by estimating equation (5). Standard errors are clustered by block and year-month. The vertical lines from left to right in subfigure (a) indicate the timing for the announcement and implementations of the subsidy increase; while the subfigure (b) indicate the timing for the announcement of subsidy increase, second price increase and the implementation of the subsidy increase.

Supplementary Figure 8: Effect of subsidy by distance in time to disbursement



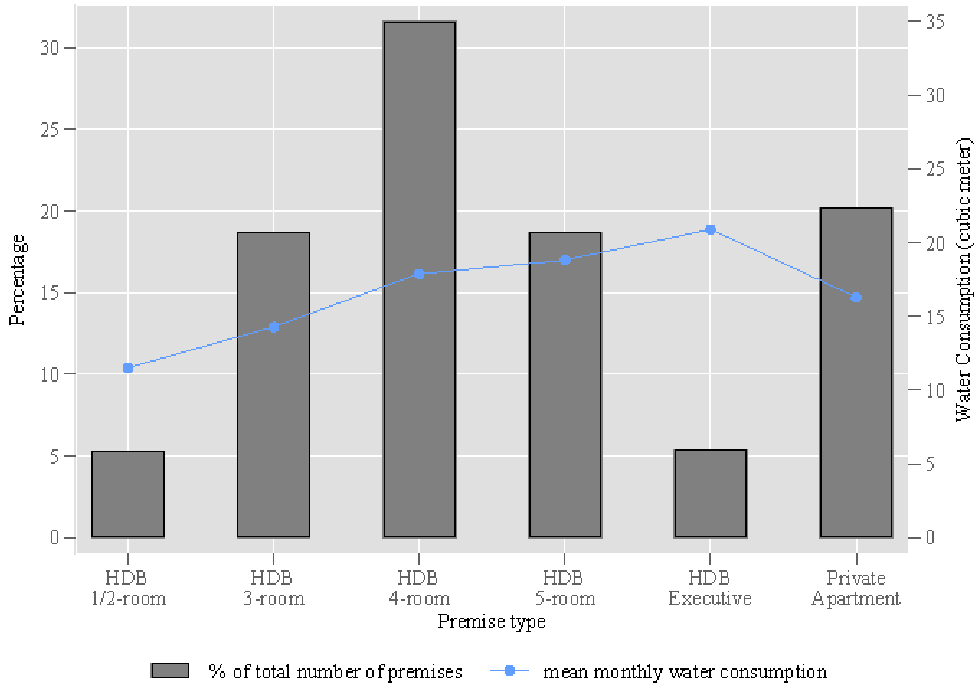
(a) 2012 subsidy increase



(b) 2019 subsidy increase

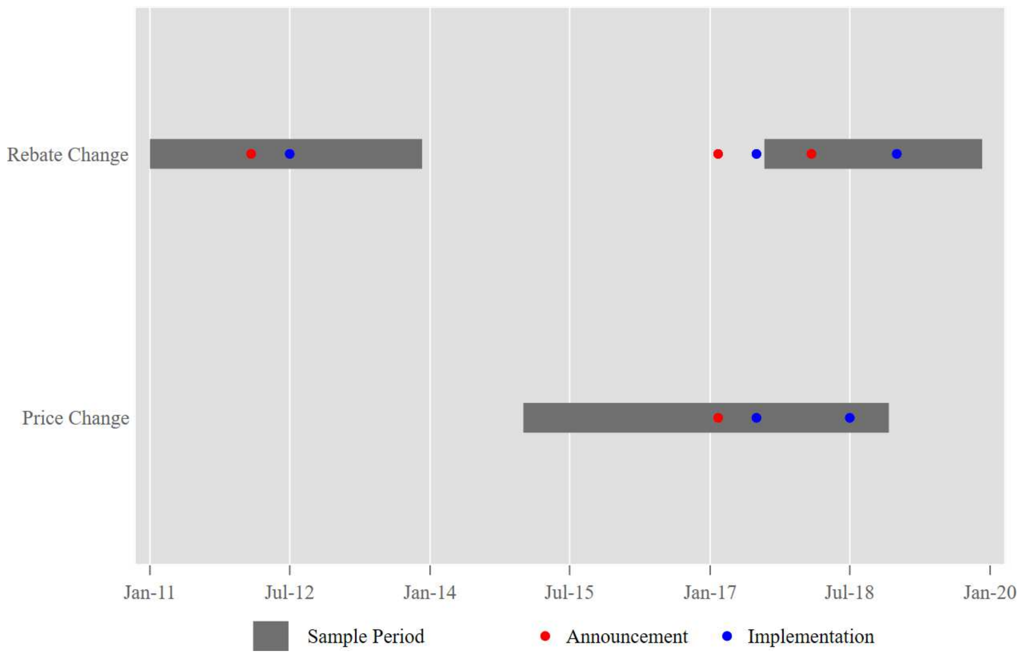
Note: The figures show the effects of subsidy increase by the distance in month to disbursement. The coefficients (dots) and corresponding 95% confidence intervals (error bars) are estimated using equation (6). Standard errors are clustered by block and year-month.

Supplementary Figure 9: Distribution of premises and mean monthly water consumption



Note: The figure shows the distribution of flat types and their corresponding mean monthly water consumption

Supplementary Figure 10: Sample period



Note: The figure shows the timeline for the announcement (red dots) and implementation (blue dots) of the price increase and 2012 and 2019 rebate increase. The horizontal bars indicate the baseline sample periods used to evaluate each of the policy change.

Supplementary Table 1: Potable water prices per cubic meter for domestic users

	Before July 1, 2017		From July 1, 2017		From July 1, 2018	
	0-40 m^3	>40 m^3	0-40 m^3	>40 m^3	0-40 m^3	>40 m^3
Tariff	S$1.17	S$1.40	S$1.19	S$1.46	S$1.21	S$1.52
Water Conservation Tax	S$0.35	S$0.63	S$0.42	S$0.73	S$0.61	S$0.99
Waterborne Fee	S$0.28	S$0.28	S$0.78	S$1.02	S$0.92	S$1.18
Sanitary Appliance Fee	S$2.80 per fitting		Combined into Waterborne Fee			
Water Price	**S$2.10**	**S$2.61**	**S$2.39**	**S$3.21**	**S$2.74**	**S$3.69**
% increase (step-wise)			13.8%	23.0%	14.6%	15.0%
% increase (total)					30.5%	41.4%

Note: The table shows the water price structure in Singapore over time, available at: https://www.pub.gov.sg/watersupply/waterprice (accessed on March 10, 2020).

Supplementary Table 2: Household income and monthly water bill

Type	Monthly income	Monthly water bill	Water bill as % of income
1-2-room	S$2,521	S$25	0.99
3-room	S$5,868	S$30	0.53
4-room	S$8,827	S$38	0.43
5-room	S$11,244	S$40	0.36
Executive		S$44	0.39
Private	S$21,830	S$33	0.15

Note: The table compares the average monthly household income and water bill across different flat types. Average monthly household income data is from the Report on Household Expenditure Survey 2017/18 by the Department of Statistics, available at: https://www.singstat.gov.sg/-/media/files/publications/households/hes201718.png (accessed on March 10, 2020). Average monthly water bill provided by HDB flat type provided by PUB at https://www.pub.gov.sg/watersupply/waterprice (accessed on March 10,2020).

Supplementary Table 3: Regression discontinuity in time

Dependent variable:	(1)	(2)	(3)	(4)
Log of water consumption	Private apartments		HDB flats	
Announcement	-0.014	-0.010	-0.047***	-0.031***
	(0.009)	(0.008)	(0.005)	(0.008)
First price increase		-0.007		-0.052***
		(0.010)		(0.005)
Second price increase		0.024		-0.051***
		(0.014)		(0.006)
First-degree polynomial	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Premise FE	Yes	Yes	Yes	Yes
N	12,021,085	12,021,085	44,932,072	44,932,072
R2	0.730	0.731	0.786	0.786

Note: This table presents the change in water consumption before and after the price change for private apartments and HDB flats. The dependent variable is natural logarithms of 1 plus the monthly water consumption. Sample period is January 2015 to December 2018. Columns (1) and (3) show the average effect of price by estimating equation (1). Columns (2) and (3) shows the decomposed effects by estimating equation (2). *Announcement*, *First price increase*, *Second price increase* and *Rebate increase* are indicator variables equal 1 for time periods after the corresponding event. All models include first-degree polynomial of the running variable (time), account fixed effects and month fixed effects. Standard errors in parentheses are two-way clustered by block and year-month. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Supplementary Table 4: Regression discontinuity in time: robustness checks

Dependent variable: Log of water consumption	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Alternative specification				Alternative sample		Alternative bandwidth	
Panel A: Private								
Announcement	-0.005	0.004	-0.016	-0.009	0.004	0.006	0.003	0.003
	(0.016)	(0.017)	(0.010)	(0.009)	(0.007)	(0.008)	(0.005)	(0.007)
First price increase		-0.000		-0.006		0.002		0.003
		(0.018)		(0.011)		(0.009)		(0.006)
Second price increase		0.031		0.025		0.000		0.002
		(0.023)		(0.015)		(0.012)		(0.010)
N	12,021,085	12,021,085	11,869,620	11,869,620	10,687,059	10,687,059	5,482,368	5,482,368
R^2	0.730	0.730	0.731	0.731	0.733	0.733	0.799	0.799
Panel B: HDB								
Announcement	-0.046***	-0.030**	-0.044***	-0.028***	-0.047***	-0.025***	-0.047***	-0.028***
	(0.008)	(0.014)	(0.006)	(0.009)	(0.005)	(0.008)	(0.004)	(0.007)
First price increase		-0.053***		-0.050***		-0.050***		-0.048***
		(0.008)		(0.006)		(0.005)		(0.003)
Second price increase		-0.047***		-0.048***		-0.065***		-0.064***
		(0.010)		(0.006)		(0.004)		(0.003)
N	44,932,072	44,932,072	44,522,850	44,522,850	43,433,638	43,433,638	22,026,661	22,026,661
R^2	0.785	0.785	0.786	0.786	0.790	0.790	0.830	0.830
First-degree polynomial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Premise FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weather control	No	No	Yes	Yes	No	Yes	No	No

Note: This table presents robustness checks on the change in water consumption before and after the price change for private apartments (Panel A) and HDB flats (Panel B). The dependent variable is natural logarithms of 1 plus the monthly water consumption. Sample period is January 2015 to December 2018. *Announcement*, *First price increase*, *Second price increase* and *Rebate increase* are indicator variables equal 1 for time periods after the corresponding event. Columns (1) to (4) show the estimates using alternative specification by exclusion month fix effects and including weather controls. Columns (5) and (6) show the estimates using a balanced sample including only accounts with at least two observations before the price increase was announced. Columns (7) and (8) uses alternative bandwidth, i.e., bi-monthly instead of monthly water consumption. Standard errors in parentheses are two-way clustered by block and year-month. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Supplementary Table 5: Effect of price change: robustness checks

Dependent variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log of water consumption	Alternative specification				Alternative sample			
Pre*HDB	-0.008	-0.007	-0.006	-0.011*	-0.008	-0.005	-0.005	-0.003
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)
Post announcement*HDB	-0.039***	-0.038***	-0.039***	-0.033***	-0.034***	-0.034***	-0.034***	-0.031***
	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)
Post first price change*HDB	-0.021***	-0.022***	-0.019**	-0.033***	-0.022**	-0.021***	-0.018**	-0.018**
	(0.008)	(0.008)	(0.008)	(0.010)	(0.008)	(0.008)	(0.008)	(0.008)
Post second price change*HDB	-0.028***	-0.029***	-0.021***	-0.009*	-0.027***	-0.028***	-0.027***	-0.027***
	(0.007)	(0.007)	(0.007)	(0.005)	(0.008)	(0.007)	(0.006)	(0.006)
Group time trend	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Account FE	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Year-month FE	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Weather controls	No	Yes	No	No	No	No	No	No
Block FE	No	No	Yes	No	No	No	No	No
Year FE	No	No	No	Yes	No	No	No	No
Month FE	No	No	No	Yes	No	No	No	No
N	56,953,157	56,392,470	56,969,644	56,953,157	57,809,131	108,517,299	72,077,527	123,641,600
R^2	0.773	0.773	0.142	0.772	0.756	0.737	0.762	0.731

Note: This table presents robust checks on the effect of price change on the water consumption for the HDB flats, relative to private apartments by estimating equation (4). The dependent variable is natural logarithms of 1 plus the monthly water consumption. *HDB* is an indicator variable takes the value of 1 for HDB flats or treatment group. *Pre* is an indicator variable takes the value of 1 for the six months before the announcement of price and rebate change. *Post announcement*, *Post first price increase*, and *Post second price increase* are indicator variables equal 1 for time periods after the corresponding event. Columns (1) to (4) show the estimates using alternative model specifications, such as excluding group specific time trend, including weather controls, replacing account fixed effects with block fixed effects, and replacing year-month fixed effects with year and month fixed effects. Sample period is January 2015 to December 2018 for columns (1) to (5), with column (5) inclusive of the top and bottom 1% observations in monthly water consumption. Column (6) extends the base sample period to start from January 2011, column (7) extends it to end in December 2019 while column (8) includes the full sample from 2011 to 2019. Standard errors in parentheses are two-way clustered by block and year-month. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Supplementary Table 6: Quarterly utility subsidy

Type	Before 2012/6	2012/7-2017/6	2017/7-2018/12	After 2019/1
1/2-room	S$45	S$65	S$95	S$100
3-room	S$25	S$60	S$85	S$90
4-room	S$22.50	S$55	S$75	S$80
5-room	S$15	S$50	S$65	S$70
Executive	S$10	S$45	S$55	S$60

Note: The table shows the amount of quarterly utility rebates over time across different flat types. The data is from the annual press release by the Ministry of Finance, available at: https://www.mof.gov.sg/newsroom/press-releases (accessed on March 10,2020).

Supplementary Table 7: Effect of 2012 subsidy increase: robustness checks

Dependent variable:	(1)	(2)	(3)	(4)	(5)	(6)
Log of water consumption	Alternative specification				Alternative sample	
Pre*HDB	-0.000	0.007	0.004	-0.008	-0.002	0.002
	(0.007)	(0.009)	(0.010)	(0.006)	(0.007)	(0.007)
Post announcement*HDB	-0.006	0.006	0.002	-0.015*	-0.010	-0.002
	(0.008)	(0.012)	(0.013)	(0.009)	(0.008)	(0.008)
Post subsidy increase*HDB	-0.004	0.006	0.002	-0.003	-0.005	-0.000
	(0.007)	(0.009)	(0.010)	(0.005)	(0.007)	(0.006)
Group time trend	No	Yes	Yes	Yes	Yes	Yes
Account FE	Yes	Yes	No	Yes	Yes	Yes
Year-month FE	Yes	Yes	Yes	No	Yes	Yes
Weather controls	No	Yes	No	No	No	No
Block FE	No	No	Yes	No	No	No
Year FE	No	No	No	Yes	No	No
Month FE	No	No	No	Yes	No	No
N	38,381,985	38,381,983	38,394,208	38,381,985	25,420,629	81,720,645
R^2	0.784	0.784	0.132	0.784	0.802	0.748

Note: This table presents robust checks on the effect of 2012 rebate change on the water consumption for the HDB flats, relative to private apartments by estimating equation (4). The dependent variable is natural logarithms of 1 plus the monthly water consumption. *HDB* is an indicator variable takes the value of 1 for HDB flats or treatment group. *Pre* is an indicator variable takes the value of 1 for the six months before the announcement of price and rebate change. *Post announcement* and *Post subsidy increase* are indicator variables equal 1 for time periods after the corresponding event. Columns (1) to (4) show the estimates using alternative model specifications, such as excluding group specific time trend, including weather controls, replacing account fixed effects with block fixed effects, and replacing year-month fixed effects with year and month fixed effects. Sample period is January 2011 to December 2013 for columns (1) to (4). Column (5) restricts the sample period to December 2012 while column (7) extends it to December 2016. Standard errors in parentheses are two-way clustered by block and year-month. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Supplementary Table 8: Effect of 2019 subsidy increase: robustness checks

Dependent variable: Log of water consumption	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pre*HDB	-0.014	-0.009	-0.012	-0.009	-0.001	-0.000	0.002	-0.001
	(0.010)	(0.012)	(0.011)	(0.012)	(0.009)	(0.009)	(0.008)	(0.009)
Post announcement*HDB	-0.032***	-0.021	-0.024	-0.020				
	(0.009)	(0.020)	(0.020)	(0.020)				
Post subsidy increase*HDB					-0.009	-0.010	-0.002	-0.009
					(0.011)	(0.011)	(0.010)	(0.011)
Group time trend	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Account FE	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Year-month FE	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Weather controls	No	Yes	No	No	No	Yes	No	No
Block FE	No	No	Yes	No	No	No	Yes	No
Year FE	No	No	No	Yes	No	No	No	Yes
Month FE	No	No	No	Yes	No	No	No	Yes
N	14,578,483	14,559,490	14,597,597	14,578,483	21,342,188	21,340,658	21,346,281	21,342,188
R^2	0.837	0.837	0.144	0.837	0.826	0.826	0.140	0.826

Note: This table presents robust checks on the effect of 2018/19 rebate change on the water consumption for the HDB flats, relative to private apartments by estimating equation (4). The dependent variable is natural logarithms of 1 plus the monthly water consumption. *HDB* is an indicator variable takes the value of 1 for HDB flats or treatment group. *Pre* is an indicator variable takes the value of 1 for the six months before the announcement of price and rebate change. *Post announcement* and *Post subsidy increase* are indicator variables equal 1 for time periods after the corresponding event. Columns (1) to (4) and (5) to (8) show the estimates on the effect of announcement and rebate increase respectively, using alternative model specifications, such as excluding group specific time trend, including weather controls, replacing account fixed effects with block fixed effects, and replacing year-month fixed effects with year and month fixed effects. Sample period is August 2017 to July 2018 for columns (1) to (4) and August 2018 to December 2019 for columns (5) to (8). Standard errors in parentheses are two-way clustered by block and year-month. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Supplementary Table 9: Effect of subsidy increase
on electricity consumption and household expenditure

	(1)	(2)	(3)	(4)
Dependent Variable:	Log of electricity consumption			Log of expenditure
Time of rebate increase:	2012	2017	2019	2017
Post announcement*HDB	-0.013	0.018	0.001	-0.045
	(0.008)	(0.013)	(0.014)	(0.036)
Post subsidy increase*HDB	0.005	-0.014	-0.002	0.022
	(0.009)	(0.012)	(0.015)	(0.041)
Group trend	Yes	Yes	Yes	Yes
Household FE				Yes
Flat-type FE	Yes	Yes	Yes	
Year-month FE	Yes	Yes	Yes	Yes
N	180	240	145	19,082
R^2	0.999	0.999	0.999	0.524

Note: This table presents the effect of subsidy increases on the electricity consumption and expenses on grocery for the HDB flats, relative to private apartments. The dependent variable is natural logarithms of 1 plus the monthly electricity consumption by HDB flat types for columns (1) to (3) and natural logarithms of 1 plus the monthly household expenses on grocery for column (4). Sample period is January 2011 to December 2013 for column (1); January 2015 to December 2018 for columns (2); July 2017 to December 2019 for column (3); and January 2016 to December 2017 for column (4). *HDB* is an indicator variable takes the value of 1 for HDB flats or treatment group. *Post announcement* and *Post subsidy increase* are indicator variables equal 1 for time periods after the corresponding event. All models include group-specific time trend and year-month fixed effects. Models on electricity consumption (columns (1)-(3)) control for flat type fixed effects while model on household expenses (column (4)) controls for household fixed effects. Standard errors in parentheses for columns (1)-(3) are clustered by year-month and for column (4) are two-way clustered by household and year-month. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Supplementary Table 10: Descriptive statistics

	(1) Control		(2) Treatment		(3) Normalized
	Mean	SD	Mean	SD	Difference
Mean before price change (m^3)	16.34	12.24	17.32	10.58	-0.08
Mean after price change (m^3)	14.29	10.16	15.44	9.52	-0.116
Observations	24,951,023		98,702,231		

Note: Table provides the mean and standard deviation of monthly water consumption for the control group or private apartments (column (1)), treatment group or HDB flats (column (2)), and the normalized differences in the mean water consumption between the two groups (column (3)).