Beware of side effects?
Spillover evidence from a hot water intervention

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Do economic interventions change untargeted behaviors?

Spillover literature in psychology

- Reviews: Truelove et al. (2014), Dolan and Galizzi (2015), Nilsson et al. (2017), Maki et al. (2019)

Mixed evidence from field experiments

- Spillover from water to electricity: Tiefenbeck et al. (2013), Carlsson et al. (2020), Jessoe et al. (2021)

Our contribution

- Natural field experiment on a hot water intervention
- Long-term effects (up to two years)
- Multiple spillover behaviors (cold water, electricity, heating)

Potential spillover mechanisms

A taxonomy of spillovers:

- Complementarities
- Direct spillovers
  Intervention $\Rightarrow$ non-targeted behavior
- Self-image
  Intervention $\Rightarrow$ target beh. $\Rightarrow$ self-image $\Rightarrow$ spillover behavior

Model

Field experiment

Setting

Collaboration with large Swiss real estate owner

- Implementation of a hot water saving intervention
- Field experiment in 782 buildings (4775 households)
  - 623 intervention buildings, 159 control buildings Randomization
  - Households informed about study after end of the intervention
  - Opt-out does not preclude anonymized data analysis

Intervention

- Email campaign from October 2019 to January 2020
  Timeline Email
- "Hot Water Challenge"
  1. Information on household's hot water consumption
  2. Social comparison
  3. Hot water conservation tips Screenshot
  4. 5% saving target
  5. Monthly lottery tied to attainment of the saving target
- Exclusive focus on hot water

Data and estimation

Hot and cold water data

- Household-level data (tap-level data for 30% sub-sample)
- Intervention period $t = 1$ (October 2019 to January 2020)
- Post-intervention periods $t = 2$ to $t = 7$ (until January 2022)
- Estimation according to pre-analysis plan Estimation

Balance dHW_b Balance dCW_b

Electricity data

- Data on the building-level
  - Data request to local electricity providers
  - 12 of 55 electricity providers provided data
  - 324 of 782 buildings (41%)
- Yearly data, 2018 as baseline year
- Estimation in line with water estimation

Heating energy data

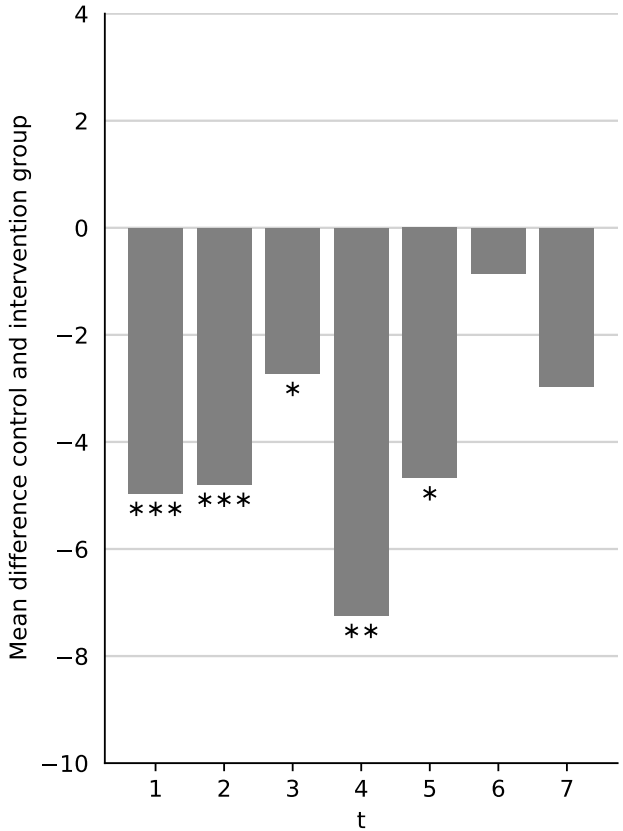
- Yearly data on the level of the cost-center
  - 300 of 333 cost-centers (20 with missing data, 13 with change in energy source)
  - Cost-centers may include multiple buildings
  - *Intervention* is the share of intervention households

$$dHE = \alpha + \beta Intervention + \gamma X + \epsilon$$

Note: We take the hot water effect into account Calculation of β_0

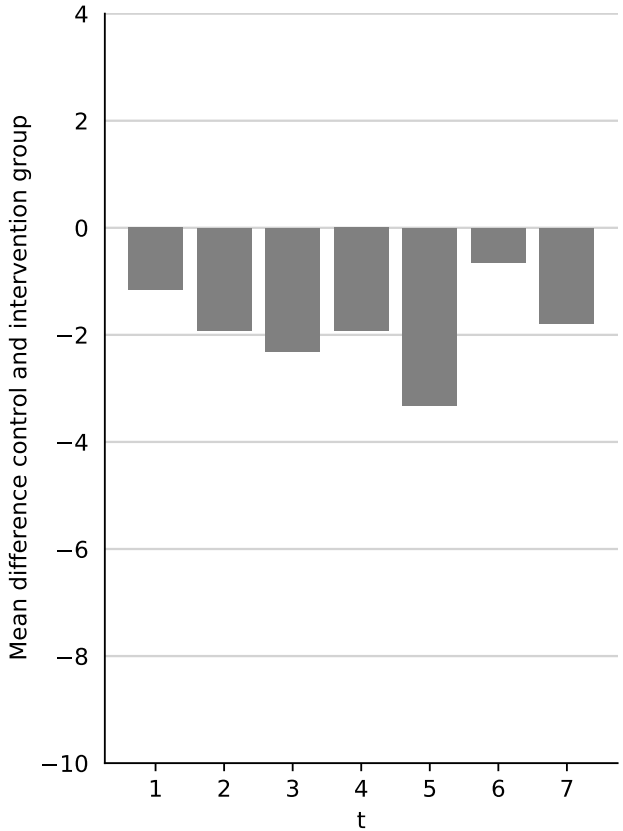
Results

Hot water results



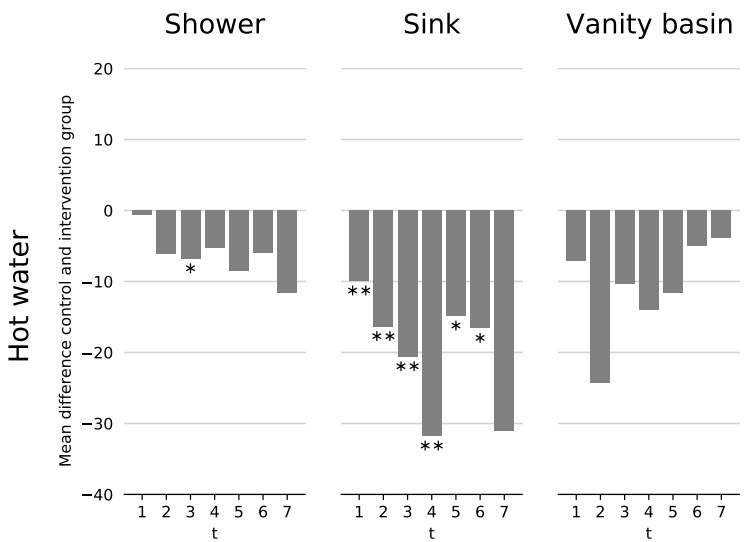
Table

Cold water results

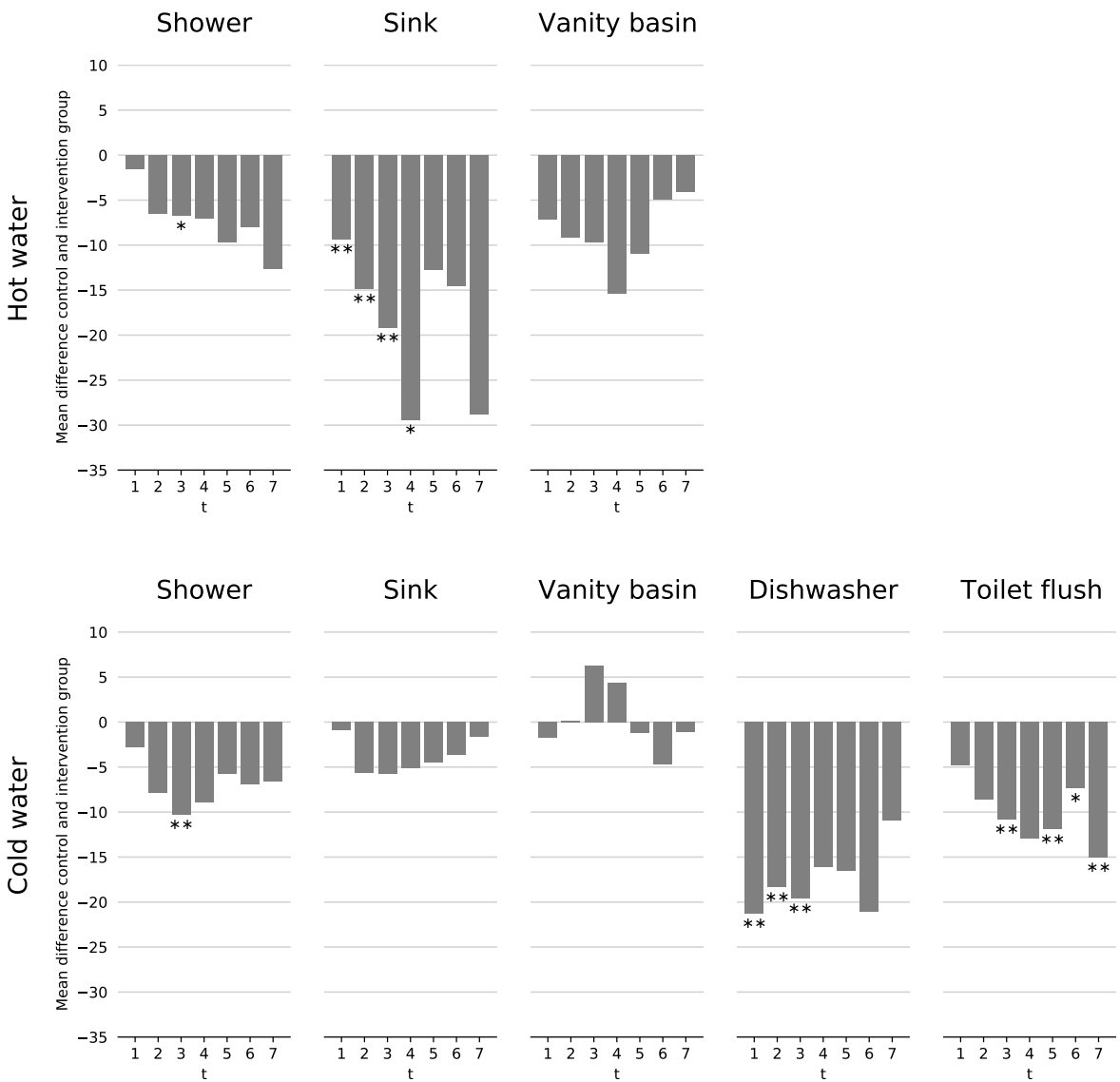


Table

Tap-level water results



Tap-level water results



Electricity results

	Control		Intervention		Difference		*p*-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Year	Mean	Median	Mean	Median	Mean	Median	
Year 2019	-1.37	-1.49	-1.38	-1.02	-0.00	0.47	0.923
Observations	58		241				
Year 2020	-12.64	-5.47	-11.14	-3.15	1.50	2.32	0.420
Observations	57		242				

Heating energy results

	Billing period 2020			Billing period 2021		
	(1)	(2)	(3)	(4)	(5)	(6)
Intervention	-5.96	-6.45	-9.61	-6.72	-6.84	-9.56
	(2.43)	(2.34)	(3.44)	(3.29)	(3.25)	(4.88)
	[0.021]	[0.009]	[0.007]	[0.063]	[0.055]	[0.067]
Billing period April		-2.45	-0.82		7.06	22.77
		(3.00)	(18.55)		(3.41)	(10.10)
Billing period May		-5.76	-11.30		0.89	-5.59
		(1.86)	(3.89)		(1.80)	(4.33)
Billing period June		-11.49	-12.61		2.02	-7.59
		(2.17)	(3.51)		(3.02)	(6.97)
Renewable heating		-3.17	-10.24		-7.58	-8.81
		(1.75)	(3.57)		(2.02)	(5.18)
April x Intervention			-1.48			-17.49
			(19.17)			(12.01)
May x Intervention			7.13			8.26
			(4.53)			(5.09)
June x Intervention			1.63			13.07
			(4.78)			(7.97)
Ren. heating x Intervention			8.97			1.72
			(3.93)			(5.93)
Constant	7.81	10.82	13.28	14.47	15.46	17.58
	(2.38)	(2.63)	(3.46)	(2.97)	(3.19)	(4.47)
Observations	300	300	300	297	297	297

Effect size

Discussion

Welfare implications

$$\Delta W = -\Delta x \times (p - \pi + \phi_l + \phi_g) - C + \Delta U$$

	(1) Hot water	(2) Heating	(3) Total
Utility bill ($-\Delta x \times p$)	12.95	104.69	117.64
Profits ($\Delta x \times \pi$)	−9.27	−73.62	−82.89
Local externalities ($-\Delta x \times \phi_l$)	0.20	2.25	2.45
Global externalities ($-\Delta x \times \phi_g$)	1.83	20.46	22.29
Intervention costs ($-C$)	−12.63		−12.63
Other (ΔU)	−2.10		−2.10
Total	−9.02	53.78	44.77

Conclusions

- Side effects can be a good thing!
- We find persistent spillovers of a hot water intervention
  - Consistent with cognitive dissonance
  - Room heating spillover has large welfare implications
- Many open research questions:
  - Other interventions, behaviors, settings (external validity)
  - Spillover mechanisms

Thank you

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Appendix

Model setup

- Building on Bénabou and Tirole (2011), Dolan and Galizzi (2015)
- Time period $t \in \{1, 2, \ldots, T\}$
- Income y_t, target behavior x_t^a, spillover behavior x_t^b
- Household cares about:
  - Consumption utility $u(x_t)$
  - Moral utility (moral prices μ_t^a and μ_t^b)
  - Self-image $I_t = I(x_{t-1}, I_{t-1})$

$$\max_{x_t} U_t = y_t - x_t \times p_t + u(x_t) + \left[(m - x_t \times \mu_t)^\rho + I(x_{t-1}, I_{t-1})^\rho \right]^{\frac{1}{\rho}}$$

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Intervention effect on the *target* behavior

- Intervention in period $t = 1$
- Environmental impact becomes more salient
  - Moral price μ_1^a increases
  - Target behavior x_1^a decreases

Spillover mechanisms

- Complementarities
  - $\frac{\partial^2 u}{\partial x_1^a \partial x_1^b} \neq 0$
- Direct spillover
  - μ_1^b increases (similar to μ_1^a)
- Self-image
  - Moral licensing ($\rho > 0$)
  - Cognitive dissonance ($\rho < 0$)

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Discussion of mechanisms behind our results

- Mixer taps suggest important role for complementarities
  - Hot and cold water are complementary in the shower (Tiefenbeck et al. 2018); substitutable in kitchen sink and vanity basin ("Cold start" feature)
- Spillover persistence suggests self-image
  - No complementarities between hot water and cold water for dishwasher, toilet flush, room heating $\Rightarrow$ persistent spillovers in line with self-image mechanism ($\rho < 0$)

Randomization

	Lottery type 1	*Lottery type 2*	
No Social Comparison	A	B	
Social Comparison	C	D	
			Control

- Treatment groups (A, B, C, D) and control group are each 20% of the sample.
- Stratified randomization in two steps
  1. Control group allocated on the building level.
  2. Other groups allocated on the household level.
- Treatment groups collapsed for this paper

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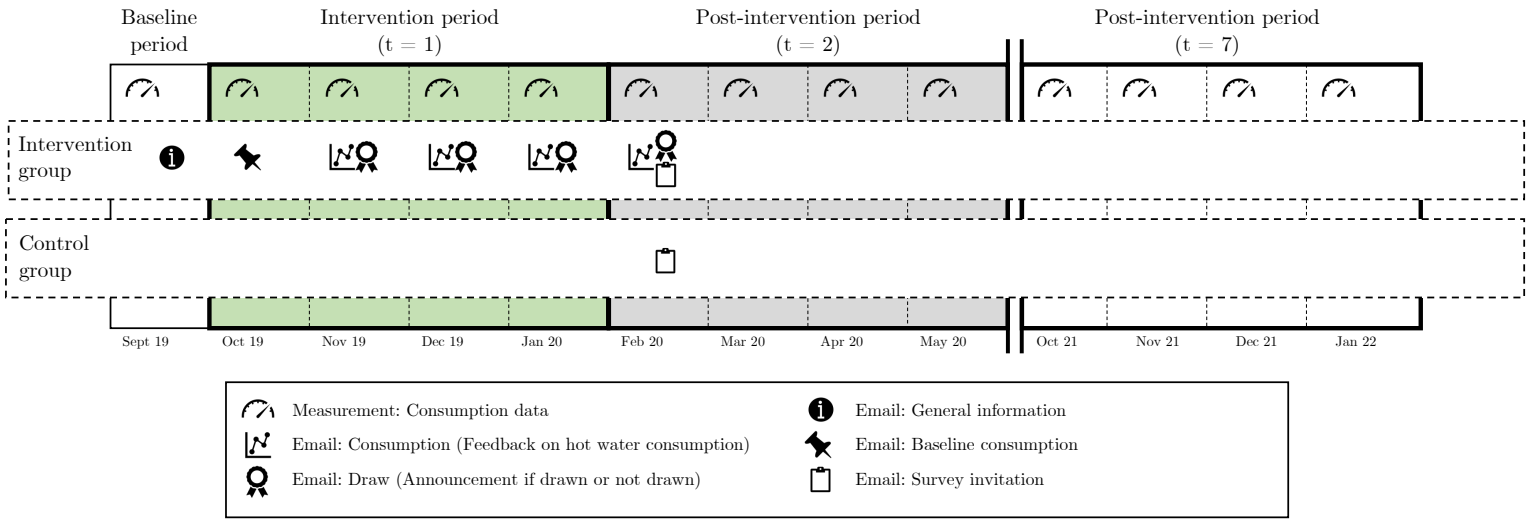
Timeline



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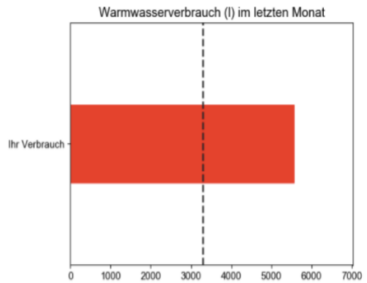
Email

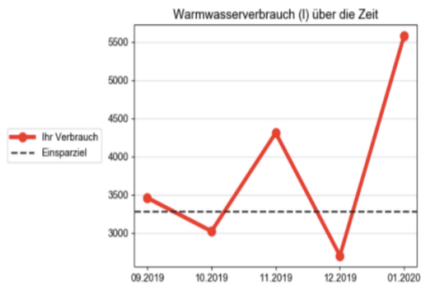
Sehr geehrter Herr [redacted]

Herzliche Gratulation, Sie haben es geschafft – Sie haben das Einsparziel von mind. 5 % erreicht! Gerne informieren wir Sie nachfolgend über die Entwicklung Ihres Warmwasser-Verbrauchs.

Bereits morgen werden wir Sie in einem separaten Mail informieren, ob Sie bei der Verlosung gezogen wurden oder nicht. Ausserdem erfahren Sie morgen, wie es mit der Warmwasser-Challenge weitergeht.

Nachfolgend finden Sie Ihre persönliche Auswertung.





Wir freuen uns sehr, gemeinsam mit Ihrem Engagement einen Beitrag zur Nachhaltigkeit leisten zu können.

Haben Sie Fragen? Wie immer stehen wir Ihnen im Customer Service online@livit.ch gerne zur Verfügung.

Freundliche Grüsse

Ihre Livit AG

Ihre persönlichen Warmwasser-Verbrauchsdaten werden ausschliesslich an Sie übermittelt. Für Auswertungszwecke werden sämtliche Daten vollständig anonymisiert, so dass keine Rückschlüsse auf einzelne Haushalte möglich sind. Einzelheiten zum Datenschutz finden Sie hier.

Wir gehen davon aus, dass Sie an Ihrem Warmwasser-Verbrauch interessiert sind und erlauben uns daher, Ihnen auch im nächsten Monat Ihre Auswertung zuzustellen. Falls Sie dies nicht mehr möchten, besteht die Möglichkeit, uns dies hier mitzuteilen. In diesem Fall respektieren wir Ihre Entscheidung und senden Ihnen keine weiteren Informationen zur Warmwasser-Challenge zu.

Falls Verbrauchswerte am Monatsbeginn auf Grund technischer Gegebenheiten nicht verfügbar sein sollten, werden Sie nicht automatisch über den monatlichen Verbrauch informiert und eine Teilnahme an der Challenge ist ausgeschlossen.

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Conservation tips

Warmwasser sparen

In der Schweiz verbraucht eine Person im Durchschnitt etwa 50 Liter Warmwasser pro Tag. Warmwasser wird in der Schweiz zu 61 Prozent mit fossilen Energieträgern aufgeheizt. Die Aufheizung macht knapp 15 Prozent unseres Energieverbrauchs im Haushalt aus. Mit einigen einfachen Tipps können Sie Warmwasser und damit auch Energie sparen.

TIPP 1

Duschen statt Baden
Für eine volle Badewanne werden 150 Liter Warmwasser benötigt, was wesentlich über dem Wasserverbrauch einer gewöhnlichen Dusche liegt. Das Vollbad erfordert ca. fünf Kilowattstunden Energie. Mit einem Elektrovelo fahren Sie damit von Basel nach Paris.

Zusatztipp: Nur warm, statt heiss duschen
So sparen Sie nicht nur Warmwasser, sondern auch gleich Geld. Denn schon 5° weniger spart 10% Energie. Wenn ein Dreipersonenhaushalt von heiss auf warm umstellt, so wird zirka ein jährlicher Stromverbrauch von Handy, Computer, Fernseher und sonstigen elektronischen Unterhaltungsgeräten zusammen gespart.

TIPP 2

Wassersparende Einsätze verwenden
Duschbrausen oder Wasserspareinsätze mit Energie-Etikette lassen erkennen, ob wenig Energie verbraucht wird. Mit wassersparenden Duschbrausen (mindestens Energieeffizienz-Klasse B) lässt sich gegenüber Brausen niedriger Klassen bis zu 50 Prozent Warmwasser sparen.

Zusatztipp: Einfach kürzer duschen
Bereits eine Minute weniger lang duschen ermöglicht eine Einsparung von fast einem Viertel der Energie, die für das warme Wasser benötigt wird.

TIPP 3

Fliessendes Warmwasser vermeiden
Warmwasser kann gespart werden, indem unnötig fliessendes Warmwasser reduziert wird. Beispielsweise kann beim Einseifen während einer Dusche das Wasser abgedreht werden. Weiter ist beim Händewaschen die Verwendung von Warmwasser nicht nötig, da herkömmliche Seife Keime und Bakterien auch mit Kaltwasser gänzlich entfernt.

TIPP 4

Verbrauchsmenge realisieren
Werden Sie sich bewusst, wieviel Wasser Sie verbrauchen. Im Rahmen der Warmwasser-Challenge werden Sie monatlich über Ihren Verbrauch informiert. So können Sie Ihren Verbrauch mit den Vormonatswerten vergleichen.

TIPP 5

Kalt reinigen
Ob Hände, Tisch oder Boden: Egal bei welcher Wassertemperatur, Seife und Reinigungsmittel töten 99.9% der Bakterien ab.
Beim Boden wischen hat es sogar Vorteile, denn warmes Wasser hinterlässt oft Streifen, weil es zu einer chemischen Reaktion mit dem Putzmittel kommt.

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Hot and cold water estimation

Estimation according to pre-analysis plan:

- Exclude households with missing data
- Exclude outliers in two steps:
  1. Households with lowest 5% baseline consumption
  2. Households with outcome variable in top or bottom 1%
- Calculate difference in means between intervention and control group
- Use Mann-Whitney U test

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Balance pre-intervention hot water consumption

	Control		Intervention		Difference		p-value
	(1) Mean	(2) Median	(3) Mean	(4) Median	(5) Mean	(6) Median	(7)
Household							
Jun 2019	2.53	2.34	2.54	2.31	0.01	-0.02	0.687
Jul 2019	2.09	1.98	2.22	1.98	0.12	-0.00	0.711
Aug 2019	2.28	2.11	2.32	2.18	0.03	0.07	0.840
Sep 2019	2.49	2.34	2.56	2.44	0.07	0.10	0.490
Observations	156		608				
Shower							
Jun 2019	1.51	1.42	1.34	1.25	-0.17	-0.17	0.097
Jul 2019	1.20	1.23	1.20	0.97	-0.00	-0.26	0.451
Aug 2019	1.28	1.18	1.28	1.11	-0.00	-0.07	0.559
Sep 2019	1.42	1.23	1.41	1.25	-0.01	0.02	0.839
Observations	46		183				
Sink							
Jun 2019	0.71	0.62	0.68	0.62	-0.02	0.01	0.831
Jul 2019	0.61	0.52	0.58	0.53	-0.03	0.01	0.751
Aug 2019	0.66	0.54	0.64	0.58	-0.02	0.04	0.818
Sep 2019	0.74	0.64	0.72	0.67	-0.03	0.03	0.957
Observations	47		182				
Vanity basin							
Jun 2019	0.46	0.35	0.42	0.37	-0.04	0.02	0.351
Jul 2019	0.38	0.29	0.36	0.32	-0.02	0.03	0.602
Aug 2019	0.41	0.29	0.40	0.35	-0.01	0.06	0.356
Sep 2019	0.43	0.35	0.42	0.36	-0.01	0.02	0.660
Observations	48		182				

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Balance pre-intervention cold water consumption

	Control		Intervention		Difference		p-value
	(1) Mean	(2) Median	(3) Mean	(4) Median	(5) Mean	(6) Median	(7)
Household							
Jun 2019	5.68	5.30	5.61	5.17	-0.06	-0.13	0.816
Jul 2019	5.47	5.16	5.37	4.96	-0.10	-0.20	0.409
Aug 2019	5.57	5.22	5.42	5.09	-0.15	-0.12	0.398
Sep 2019	5.40	5.15	5.48	5.13	0.07	-0.02	0.748
Observations	134		529				
Shower							
Jun 2019	1.42	1.25	1.28	1.14	-0.14	-0.10	0.122
Jul 2019	1.29	1.20	1.26	1.10	-0.02	-0.10	0.485
Aug 2019	1.29	1.08	1.24	1.11	-0.05	0.03	0.527
Sep 2019	1.28	1.10	1.25	1.10	-0.02	0.01	0.912
Observations	48		183				
Sink							
Jun 2019	0.82	0.73	0.86	0.76	0.04	0.03	0.598
Jul 2019	0.84	0.80	0.87	0.78	0.03	-0.01	0.958
Aug 2019	0.79	0.66	0.84	0.75	0.06	0.09	0.642
Sep 2019	0.76	0.66	0.81	0.72	0.05	0.06	0.773
Observations	48		183				
Vanity basin							
Jun 2019	0.58	0.39	0.54	0.47	-0.04	0.08	0.173
Jul 2019	0.60	0.39	0.56	0.49	-0.04	0.10	0.176
Aug 2019	0.60	0.40	0.54	0.46	-0.05	0.06	0.247
Sep 2019	0.58	0.37	0.54	0.45	-0.04	0.08	0.209
Observations	47		182				
Dishwasher							
Jun 2019	0.33	0.21	0.29	0.23	-0.04	0.02	0.975
Jul 2019	0.32	0.18	0.25	0.20	-0.07	0.02	0.933
Aug 2019	0.34	0.19	0.27	0.23	-0.07	0.03	0.915
Sep 2019	0.29	0.21	0.29	0.25	-0.00	0.05	0.328
Observations	34		128				
Toilet flush							
Jun 2019	2.93	2.41	3.25	2.78	0.32	0.37	0.482
Jul 2019	2.85	2.45	3.07	2.60	0.23	0.14	0.902
Aug 2019	2.93	2.46	3.25	2.65	0.32	0.19	0.846
Sep 2019	2.85	2.59	3.39	2.76	0.54	0.17	0.288
Observations	47		183				

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Hot water results (periods 1 to 4)

	Control		Intervention		Difference		p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean	Median	Mean	Median	Mean	Median	
Intervention ($t = 1$)	17.07	15.79	11.99	10.16	-5.09	-5.63	0.000
Oct 2019	10.49	8.10	5.52	5.06	-4.97	-3.04	0.000
Nov 2019	15.75	15.20	11.29	10.34	-4.46	-4.87	0.000
Dec 2019	19.24	17.07	13.65	12.65	-5.59	-4.42	0.001
Jan 2020	22.80	21.83	17.48	16.17	-5.32	-5.65	0.001
Observations	156		608				
Post-interv. ($t = 2$)	28.53	28.23	23.72	21.83	-4.81	-6.40	0.005
Feb 2020	15.56	13.78	10.35	9.48	-5.21	-4.30	0.004
Mar 2020	38.64	36.02	33.20	30.68	-5.44	-5.35	0.010
Apr 2020	32.81	31.71	27.68	26.97	-5.13	-4.74	0.016
May 2020	27.11	27.00	23.65	21.91	-3.46	-5.09	0.032
Observations	156		607				
Post-interv. ($t = 3$)	2.75	0.88	-0.00	-2.12	-2.75	-2.99	0.073
Jun 2020	13.31	9.13	10.69	8.30	-2.61	-0.83	0.156
Jul 2020	-2.98	-3.61	-3.90	-4.99	-0.92	-1.39	0.285
Aug 2020	-4.70	-7.31	-7.03	-8.27	-2.32	-0.96	0.429
Sep 2020	5.38	1.21	0.23	-1.05	-5.15	-2.25	0.050
Observations	156		607				
Post-interv. ($t = 4$)	29.54	24.58	22.31	20.96	-7.22	-3.62	0.010
Oct 2020	22.50	17.94	13.93	12.73	-8.57	-5.21	0.007
Nov 2020	27.72	24.18	19.70	17.81	-8.02	-6.38	0.002
Dec 2020	32.10	28.30	25.32	23.38	-6.79	-4.92	0.030
Jan 2021	35.81	32.22	30.30	27.95	-5.51	-4.27	0.128
Observations	156		607				

Hot water results (periods 5 to 7)

	Control		Intervention		Difference		p-value
	(1) Mean	(2) Median	(3) Mean	(4) Median	(5) Mean	(6) Median	(7)
Post-interv. ($t = 5$)	26.28	22.54	21.63	18.57	-4.65	-3.97	0.091
Feb 2021	21.51	16.76	17.18	14.13	-4.32	-2.62	0.127
Mar 2021	33.12	30.06	28.78	25.28	-4.34	-4.78	0.181
Apr 2021	25.26	21.17	19.31	17.11	-5.95	-4.06	0.059
May 2021	25.22	22.80	21.24	17.85	-3.98	-4.95	0.081
Observations	153		596				
Post-interv. ($t = 6$)	-3.11	-5.11	-3.95	-5.47	-0.84	-0.36	0.738
Jun 2021	3.81	1.13	1.22	-1.33	-2.59	-2.46	0.180
Jul 2021	-8.16	-8.78	-8.60	-11.28	-0.44	-2.50	0.760
Aug 2021	-5.91	-7.85	-6.47	-9.28	-0.56	-1.43	0.999
Sep 2021	-2.19	-2.28	-1.94	-3.13	0.25	-0.85	0.693
Observations	151		596				
Post-interv. ($t = 7$)	18.72	17.94	15.83	12.59	-2.90	-5.35	0.274
Oct 2021	11.11	9.12	9.82	7.15	-1.29	-1.97	0.563
Nov 2021	18.73	21.38	13.59	10.62	-5.14	-10.75	0.068
Dec 2021	20.51	20.08	18.44	14.24	-2.07	-5.83	0.368
Jan 2022	24.54	23.90	21.46	17.87	-3.09	-6.03	0.267
Observations	148		588				

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Cold water results (periods 1 to 4)

	Control		Intervention		Difference		p-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean	Median	Mean	Median	Mean	Median	
Intervention ($t = 1$)	-1.12	-1.06	-2.19	-2.94	-1.07	-1.89	0.223
Oct 2019	0.57	-1.01	0.44	-0.59	-0.14	0.42	0.728
Nov 2019	-2.88	-3.23	-2.59	-3.78	0.29	-0.55	0.950
Dec 2019	-1.80	-3.26	-3.39	-4.77	-1.58	-1.51	0.282
Jan 2020	-0.35	-0.90	-3.21	-3.54	-2.86	-2.64	0.055
Observations	134		529				
Post-interv. ($t = 2$)	9.54	6.95	7.74	5.80	-1.81	-1.15	0.245
Feb 2020	-6.49	-7.96	-7.67	-8.54	-1.18	-0.58	0.169
Mar 2020	12.05	8.93	10.75	6.64	-1.30	-2.29	0.224
Apr 2020	16.13	13.41	12.56	11.21	-3.57	-2.20	0.175
May 2020	16.48	16.96	15.31	12.97	-1.18	-4.00	0.286
Observations	134		530				
Post-interv. ($t = 3$)	8.99	5.86	6.78	5.36	-2.21	-0.51	0.586
Jun 2020	10.49	6.94	8.20	6.27	-2.29	-0.67	0.437
Jul 2020	5.94	5.67	5.43	4.47	-0.51	-1.20	0.948
Aug 2020	11.97	6.65	8.22	7.55	-3.75	0.89	0.617
Sep 2020	7.56	5.60	5.28	3.21	-2.28	-2.39	0.231
Observations	134		530				
Post-interv. ($t = 4$)	6.34	7.40	4.48	2.85	-1.86	-4.55	0.331
Oct 2020	5.83	5.47	4.20	3.49	-1.63	-1.98	0.501
Nov 2020	6.51	8.56	3.88	3.01	-2.64	-5.56	0.208
Dec 2020	4.74	3.92	4.22	1.77	-0.52	-2.15	0.473
Jan 2021	8.27	8.37	5.63	3.27	-2.64	-5.11	0.260
Observations	134		530				

Cold water results (periods 5 to 7)

	Control		Intervention		Difference		p-value
	(1) Mean	(2) Median	(3) Mean	(4) Median	(5) Mean	(6) Median	(7)
Post-interv. ($t = 5$)	6.76	5.26	3.46	1.70	-3.30	-3.56	0.167
Feb 2021	0.23	-3.64	-3.42	-4.15	-3.65	-0.51	0.387
Mar 2021	9.82	5.34	6.11	4.34	-3.71	-1.01	0.500
Apr 2021	6.21	3.46	3.84	2.44	-2.36	-1.02	0.447
May 2021	10.80	8.26	7.32	6.63	-3.49	-1.63	0.263
Observations	131		518				
Post-interv. ($t = 6$)	3.61	0.33	2.80	0.96	-0.82	0.63	0.877
Jun 2021	10.56	6.77	8.11	6.04	-2.45	-0.73	0.320
Jul 2021	-0.21	0.03	-1.91	-3.28	-1.70	-3.31	0.338
Aug 2021	2.37	-1.10	2.04	0.00	-0.33	1.10	0.867
Sep 2021	1.72	0.61	2.94	1.47	1.22	0.86	0.489
Observations	129		519				
Post-interv. ($t = 7$)	3.05	-0.07	1.32	0.00	-1.73	0.07	0.728
Oct 2021	3.67	0.00	3.34	0.87	-0.33	0.87	0.622
Nov 2021	2.80	-0.44	0.23	-1.34	-2.57	-0.90	0.502
Dec 2021	-0.06	-3.15	-0.16	0.00	-0.10	3.15	0.855
Jan 2022	5.80	1.94	1.87	-0.21	-3.93	-2.15	0.198
Observations	127		513				

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Mechanical linkages

- Cold water
  - Hot water comes with at least 50 degrees Celsius
  - Mixed with cold water for most purposes
  - Hot water can be saved in two ways:
    1. Lower temperature (e.g. shower at 34 instead of 40 degrees)
       $\rightarrow$ increases cold water consumption
    2. Less volume (e.g. shower for 4 instead of 5 minutes)
       $\rightarrow$ decreases cold water consumption
- Room heating
  - Hot water and heating are distributed via distinct systems
  - No mechanical effect of hot water savings on room heating

Calculation of β_0

$$dHE = \alpha + \beta Intervention + \gamma X + \epsilon$$

$\beta_0 = -0.36$ to account for effect on hot water

- $10,067$ m^3 of hot water in baseline month
- times 71 kWh/m^3 of hot water
- $= 714,772$ kWh energy consumption in baseline month
  - 5.09% for four intervention months
  - 2.5 post-intervention months until end of billing period: 5.21%, 5.44%, and $0.5 \times 5.13\%$
- $= 239,985$ kWh energy savings
- $\beta_0 = -0.33\%$ of total energy consumption ($71,817$ MWh)

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Why is the room heating spillover so strong?

- Consistent with $\rho < 0$
- Hot water and room heating are similar
  - Associated with warmth and comfort
  - Relevant for environmental self-image if households care about carbon footprint
- Easy change (turn down the thermostat once) with long-lasting impact?
- Fortunate timing with respect to the heating season?
- Small changes in room temperature save a lot of energy: 5.6% corresponds to less than one degree Celsius

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