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Informal Risk Sharing to Mitigate Local Environmental Risks

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Motivation

- Informal risk-sharing plays an important role in developing countries, where social safety net is weak and market failures are common.
- Within village informal risk-sharing can help insure against idiosyncratic financial and health risks – neighbors informally insure each other.
- Many environmental shocks or their impact are idiosyncratic.
- In this paper, we evaluate an intervention facilitating informal insurance to mitigate environmental risk in rural Bangladesh.

Environmental shock: Arsenic Contamination in Bangladesh

- Poisonous level of arsenic in groundwater known since 1993.
- Fifty million people of Bangladesh are estimated to be at risk through the consumption of water from contaminated tubewells.
- Chronic exposure to arsenic causes multi-organ pathologies such as cardiovascular diseases, and cancer, impairs children's cognitive abilities, and reduces productivity and wages.
- Still a large proportion of households drink water above 50 ppb (national standard).and 10 ppb (WHO standard).
- Private markets for well testing are mostly absent – consistent with low preventive health investment and willingness to pay for environmental quality in developing countries (Dupas and Miguel 2017; Kremer and Glennerster 2011; Jack and Greenstone 2015)
- Cost-effectiveness of mitigation options (Jamil et al. 2019)
  – **Switching** to a nearby lower-arsenic well (USD 1 per person)
  – Installing a deeper well or costly filters (USD 30 per person)
  – Public deep wells, piped water (USD 150 per person)

Arsenic in wells – Spatially variable

Figure: Arsenic distribution in three selected villages

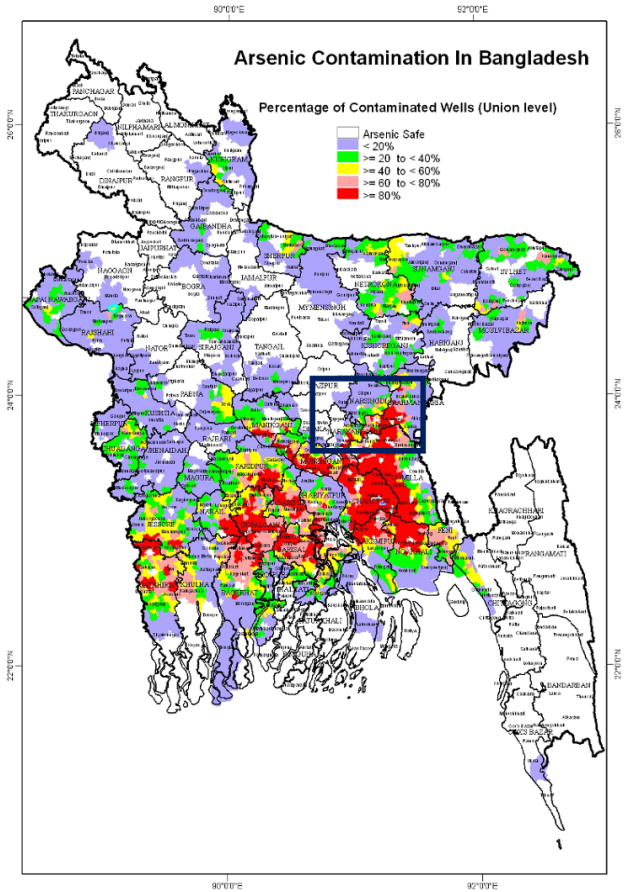
Red – $>$ 50 ppb, **Green** – $\geq$ 50 ppb

Arsenic is temporally quite stable ⏩ Backup Slide

Private groundwater wells

- Wells are replaced at a rate of about 10% per year.
- Some maintenance required over time, but marginal cost is low.
- The spatial distribution of safe wells is close to random, conditional on the village-level average. Spatial distribution
- Very few households could predict at baseline that their own private well or their neighbor's wells were unsafe.

Public program to test wells



– 5 million wells tested in early 2000 similarly (BAMWSP)
– However, almost all of the wells stand untested at baseline (2020) because of the natural well replacement.
– Arsenic Risk Reduction Project tests about 8 million wells in 2021-23.

Business-as-usual arsenic mitigation

- Well testing may lead to mitigation through **switching**, i.e., households switch from unsafe wells to safer wells nearby once they have the information on arsenic levels. Switching costs:
  - household with unsafe well- time, effort, and other factors
  - household with safe well - Privacy, more regular maintenance of wells may be required
- Switching levels as documented in prior research are highly variable – 20% to 70% (Madajewicz et al. 2007; Barnwal et al. 2017; Tarozzi et al. 2021; Pfaff et al. 2017)
- Not all households own a private well. The switching cost may depend on the well ownership – 'curse of convenience'.
- In the perfect risk-sharing world, over 90% of unsafe well owners will be able to switch to a safe well shared by their neighbors within 50 meters.

Experiment on enhancing commitment between households

- In our context, households receive a one-time shock that varies locally, namely information on **arsenic contamination in their private wells**.
- Mitigation entails affected households (high arsenic) switching to wells of households with low-arsenic wells.
- In the business-as-usual scenario, households can discuss with others regarding an arrangement to share water ex-ante. They may also resort to bargaining ex-post.
- Prior studies document large variations in well sharing/switching (20-70%).
- We experimentally study if facilitating ex-ante commitments between households to share water ex-post increases mitigation.
- Experiment mounted on the ongoing public arsenic testing program– 16,000 households in 135 village communities (whole village or one para of a large village) from Narsingdi and Brahmanbaria.

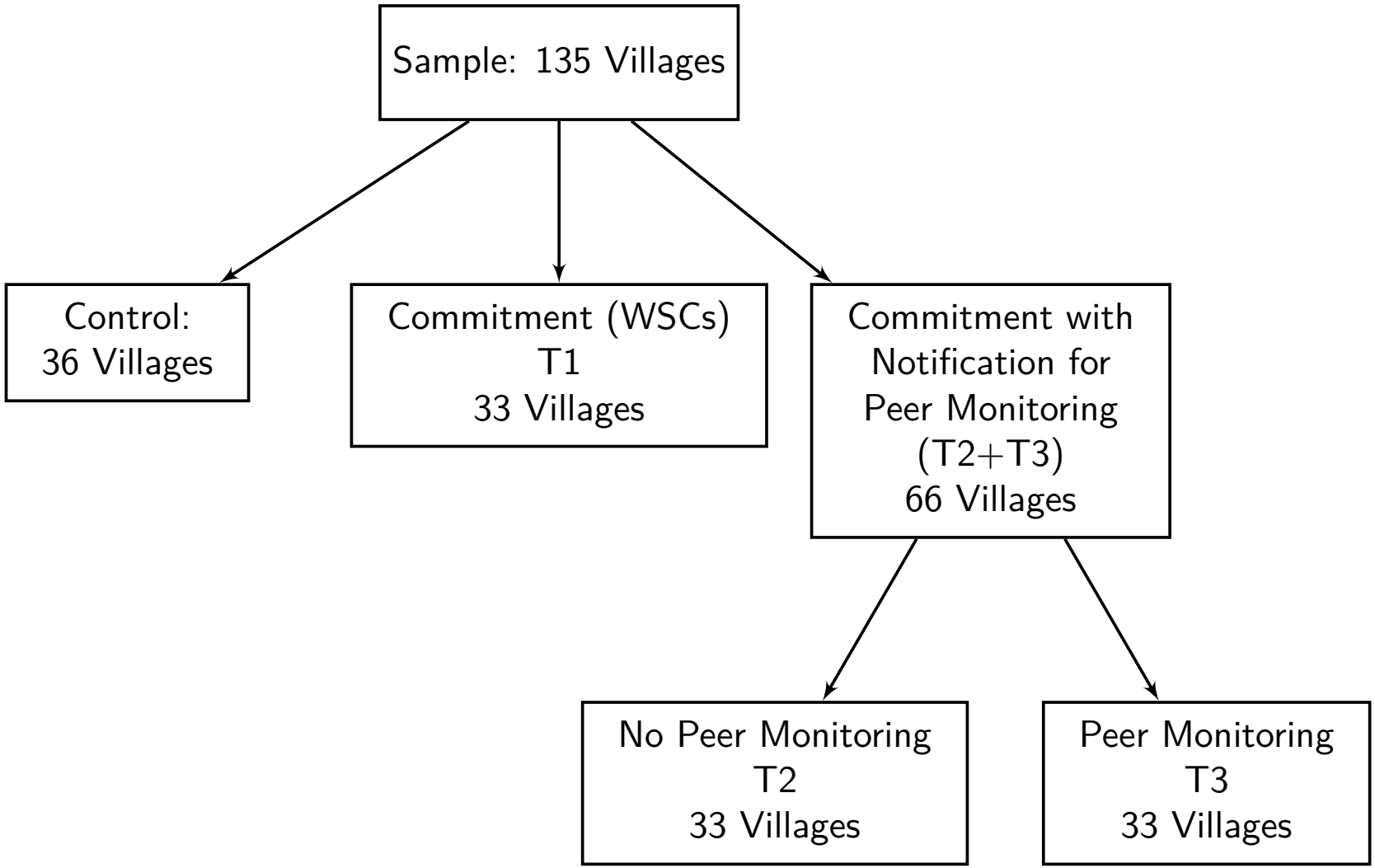
WSC – Bilateral exchange between two households

- **"If your tube well has high arsenic then I give you consent to use my tube well. You can collect water from my tube well for drinking and cooking".**
- Ex-ante WSCs reduce the cost of making commitments. Ex-post they increase the cost of reneging.
- They make the ex-ante informal mutual insurance aspect more salient.
- WSCs may also increase coordination and may encourage households to make commitments without using WSCs.

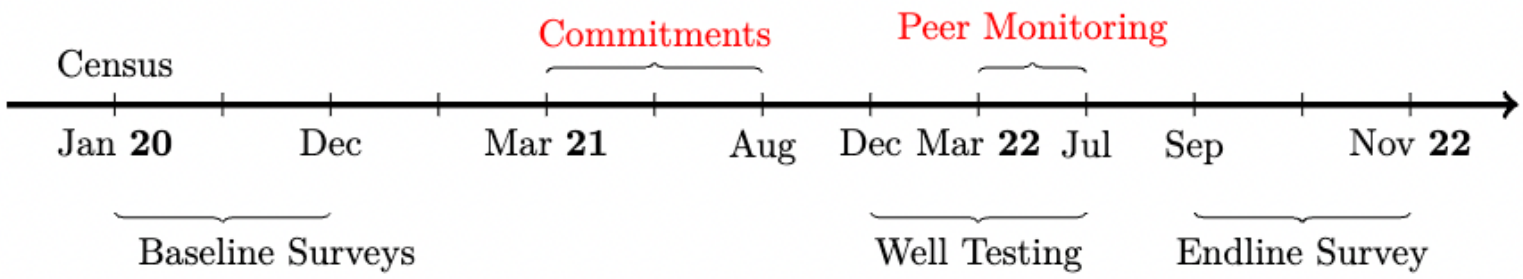
Peer-monitoring treatment and sorting

- Households may agree to mutually insure each other before testing but refuse later, in the absence of any enforcement.
- We implement a light-touch peer monitoring treatment to study this.
- We inform households about the peer-monitoring in advance (before they make contracts).
- To address sorting – risk-sharing bonds may evolve differently when under the shadow of future peer monitoring – we implement a two stage design.
  - Treatment 2: **Notification** of peer monitoring
  - Treatment 3: **Notification and facilitation** of peer-monitoring
- For each household, two randomly selected households (the first- and second-order WSC-network neighbors) were designated as monitors. (Monitor and Receipt messages)

Experiment Design



Timeline


Census
Commitments
Peer Monitoring
Jan 20
Dec
Mar 21
Aug
Dec
Mar 22
Jul
Sep
Nov 22
Baseline Surveys
Well Testing
Endline Survey

Data collection

- Census of 16k households and more than 10k wells in 135 villages
- Baseline surveys: Demographics and assets, references and Norms; Arsenic knowledge, Social networks
- Multiple rounds of surveys including phone surveys during COVID
- Data on wells' arsenic level as captured during testing
- Key outcome variables: Discussion about water sharing with other households, Arsenic level in HH's primary well at endline; Switching to other wells,
- Concerns about self-reporting bias
  - We only ask households about the primary well they use (and not about its arsenic level). We match it with the admin data on arsenic test results using a unique well ID.
  - Audit test for a small sample – asked for a glass of water from the kitchen and tested in the endline survey.

Summary statistics

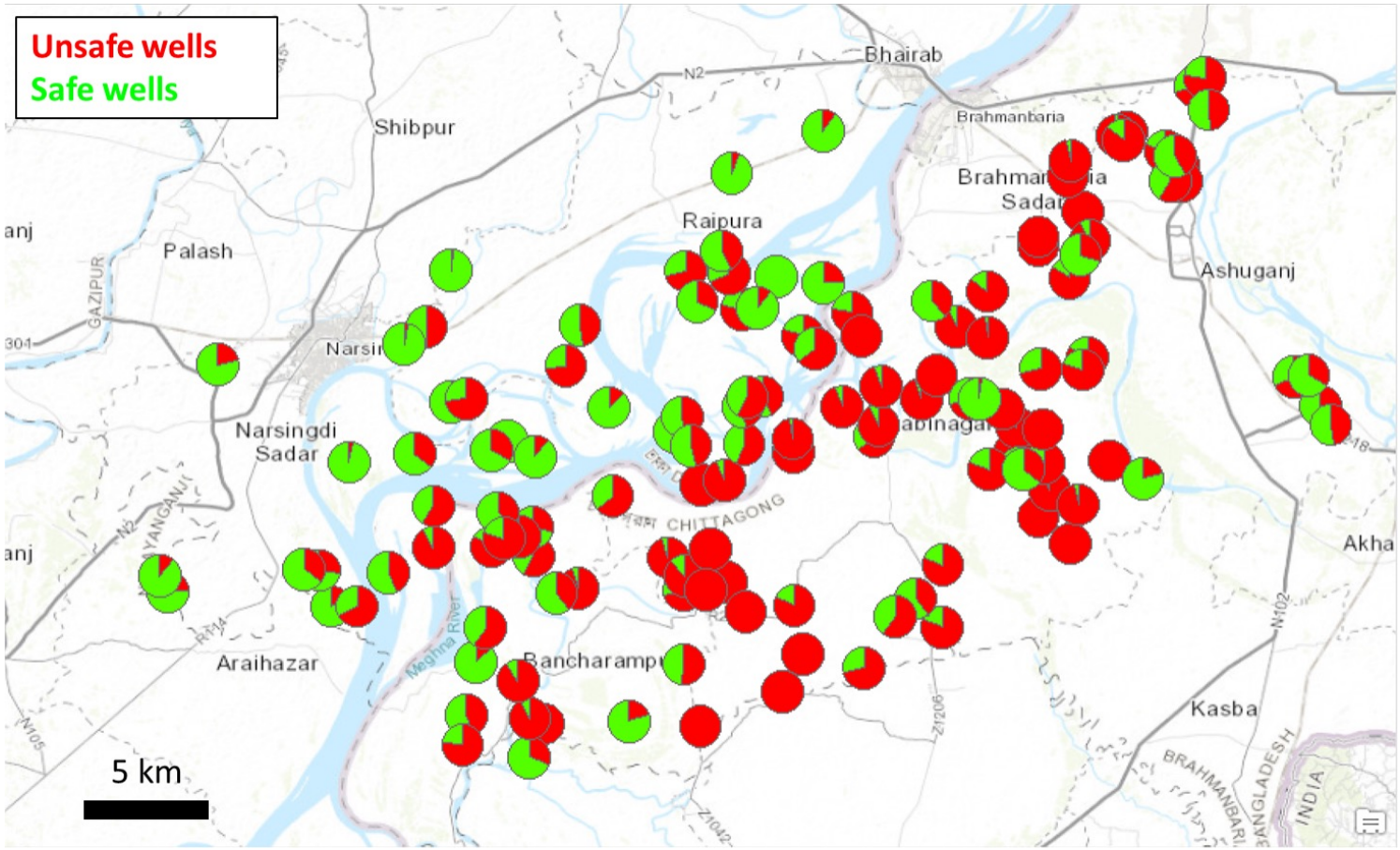
Summary Statistics: Household and well characteristics

	count	mean	sd	min	max
Household size	16054	5.10	2.05	1	21
Average age	16054	27.07	10.74	6	100
Male ratio	16054	0.48	.18	0	1
Child ratio	16054	0.39	0.21	0	1
Primary edu ratio	16054	0.29	0.26	0	1
Risk tolerance	14039	1.86	1.16	1	5
Asset PCA Index	13294	0.00	1.00	-2.64	9.99
Number of wells	16054	0.80	0.52	0	4
Well depth	7716	131.43	91.99	1	1000
Well age	9732	9.90	7.41	1	81
Well tested for arsenic	10032	0.07	0.263	0	1

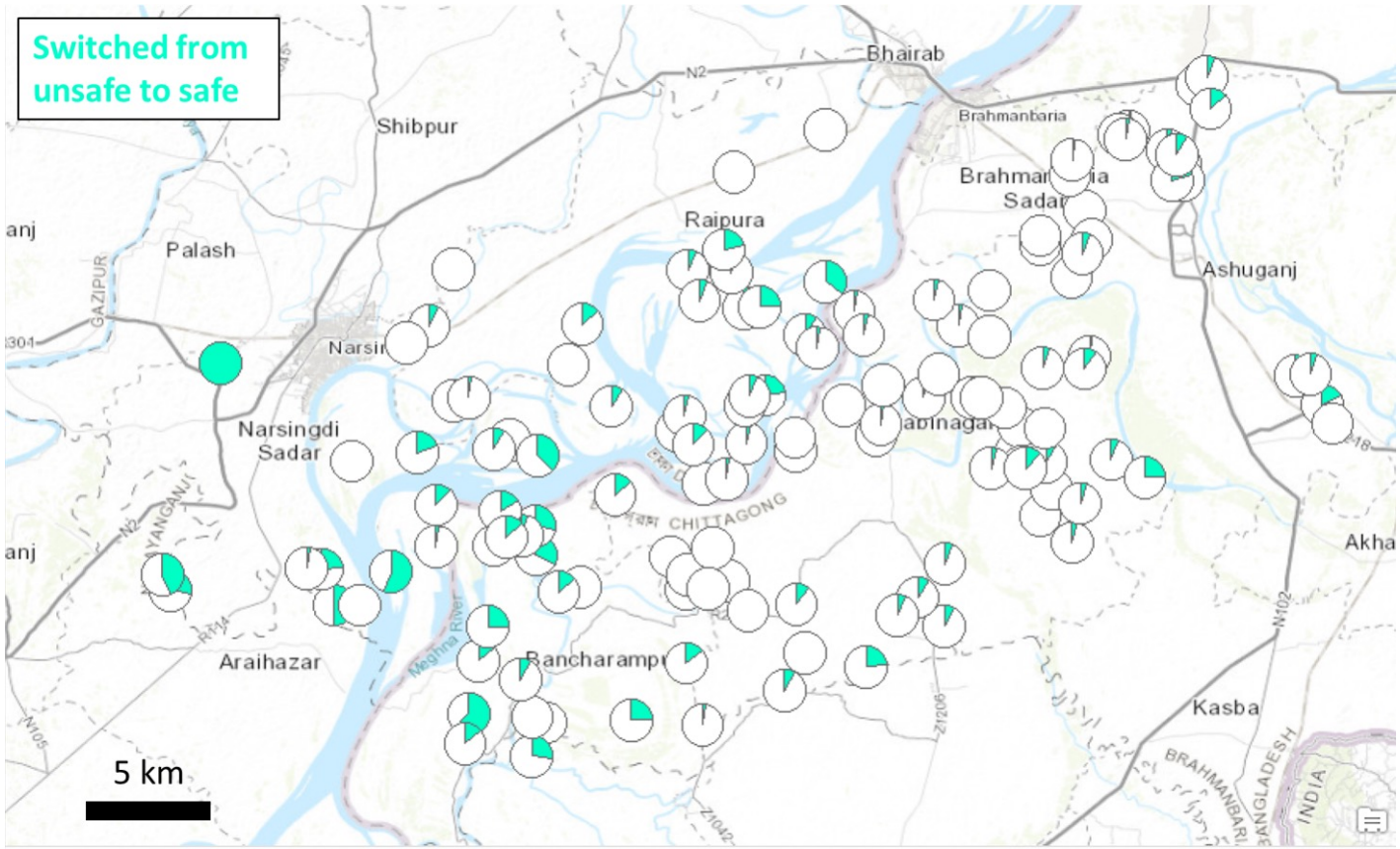
Only 7% households claim that their wells are tested for arsenic (baseline)
9k households fully own private well, another 2k households joint owners.

▶▶ Randomization Balance

Arsenic Testing – 60% of 9,839 private wells tested are unsafe

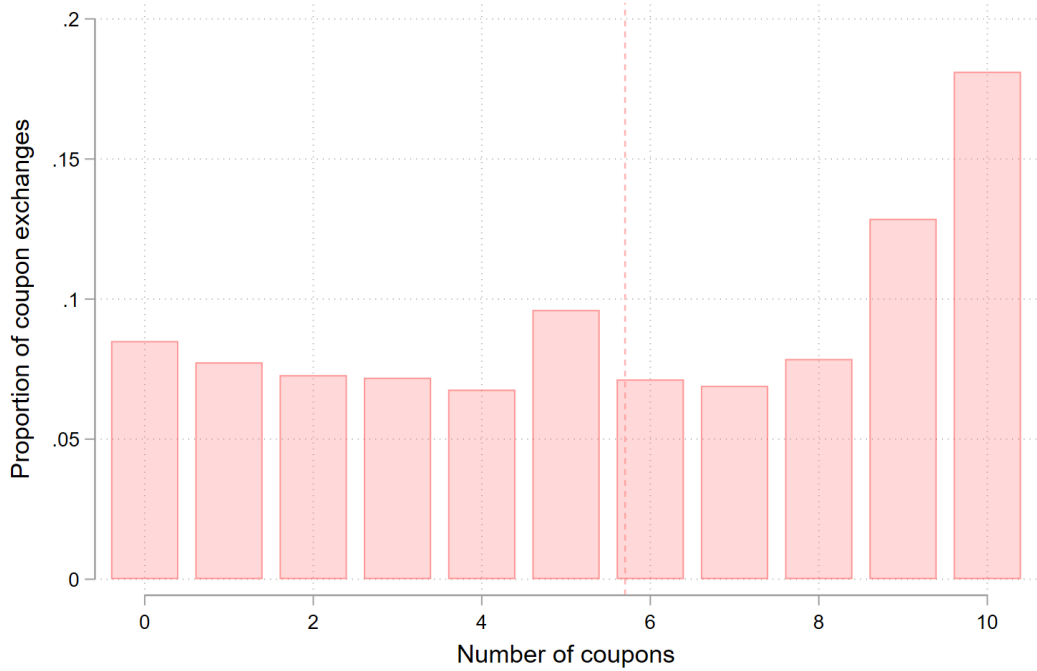


Switching from unsafe to safe well– 7.5% switching



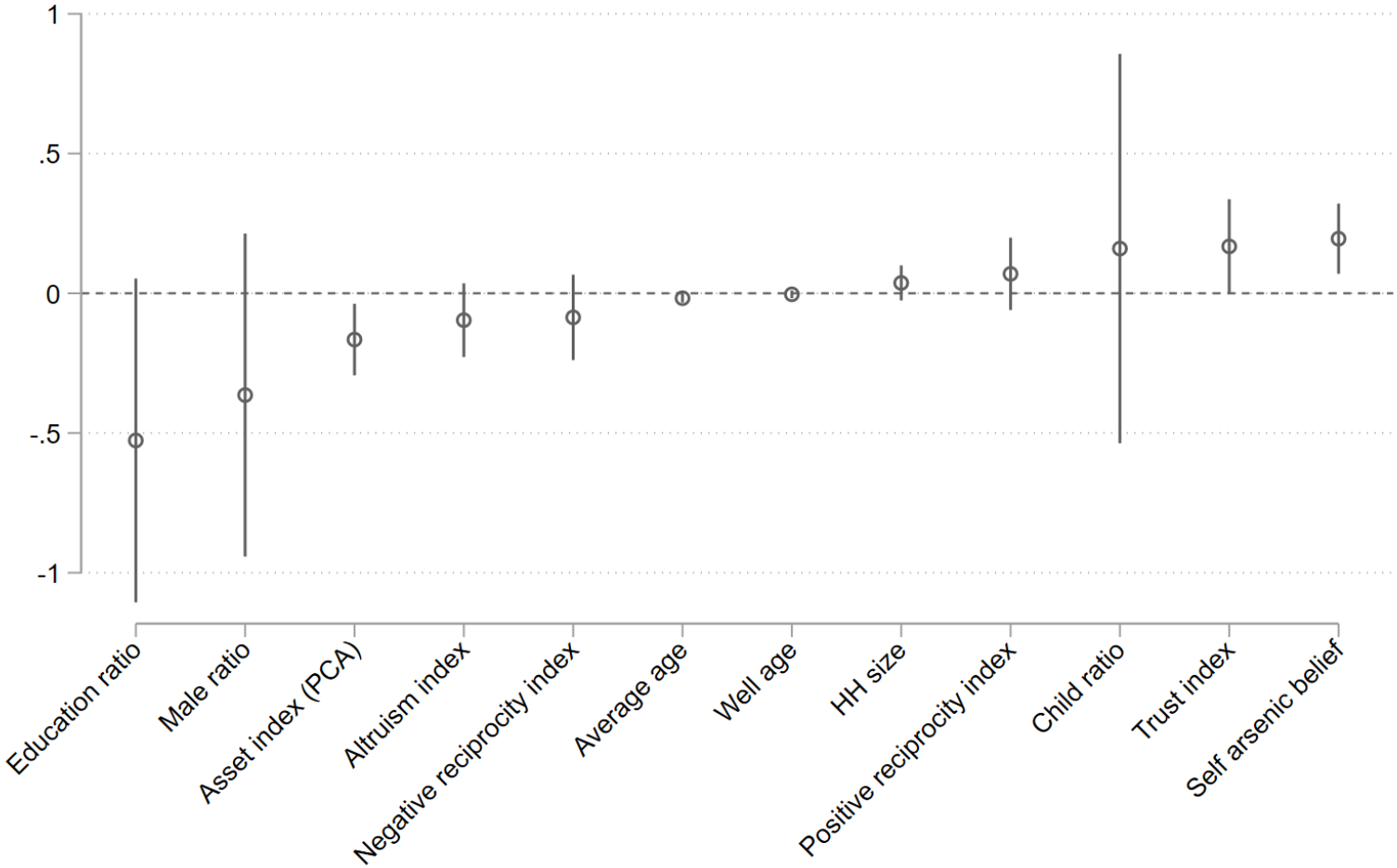
– Among well owners, 4.5% switched from unsafe to safe wells.
– Among households who do not own a well, about 12% switched.
– Not all households switch to lower arsenic wells.

Household broadly take up the opportunity to make explicit commitments



- 92% qualified HHs exchanged at least one coupon with other households, with on average 5.7 coupons exchanged per household.
- We further confirm some of the prior findings on how social networks and preferences shape risk-sharing between households in this context (Fafchamps and Gubert, 2007; Attanasio et al., 2012).

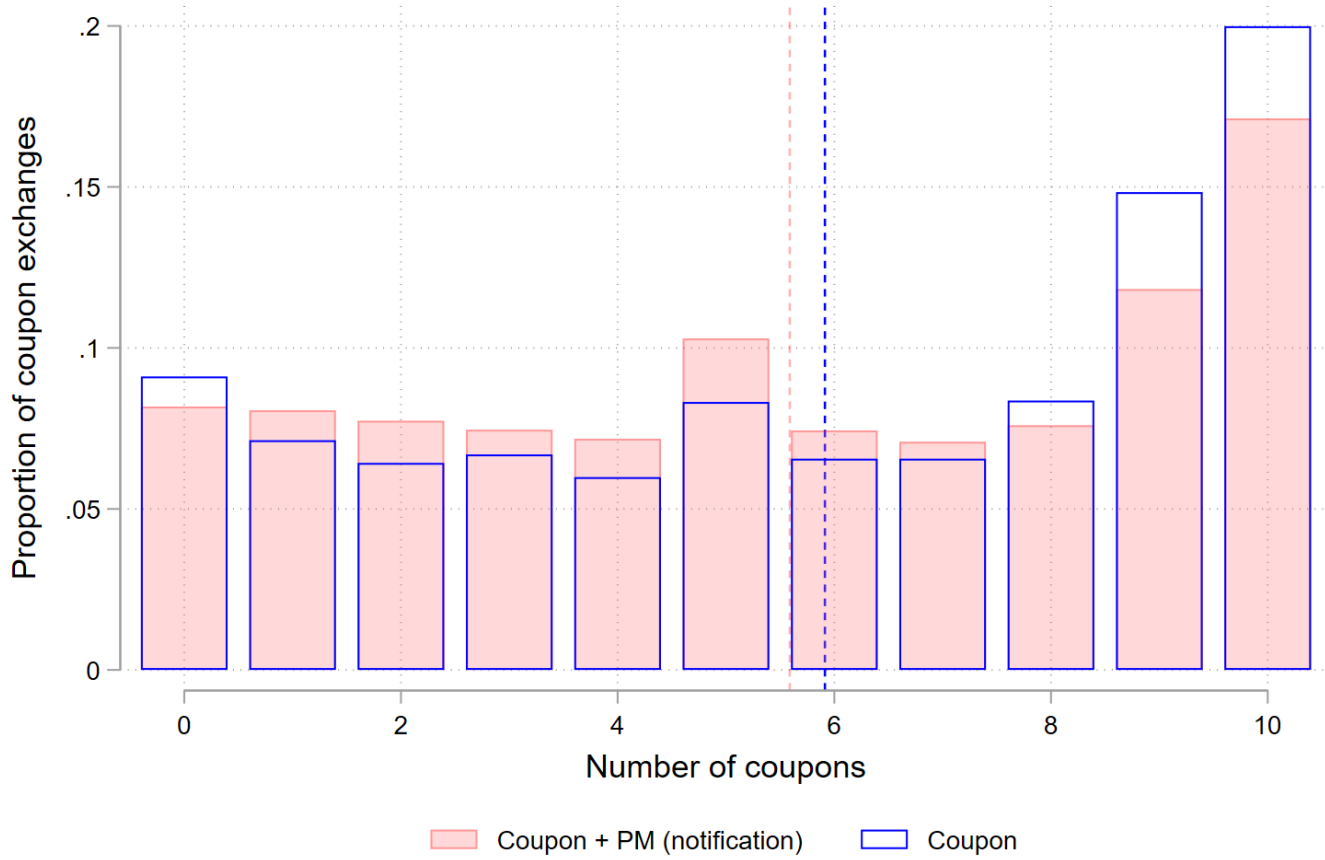
Household characteristics and number of contracts



Do risk-sharing agreements evolve differently under higher stake commitments?

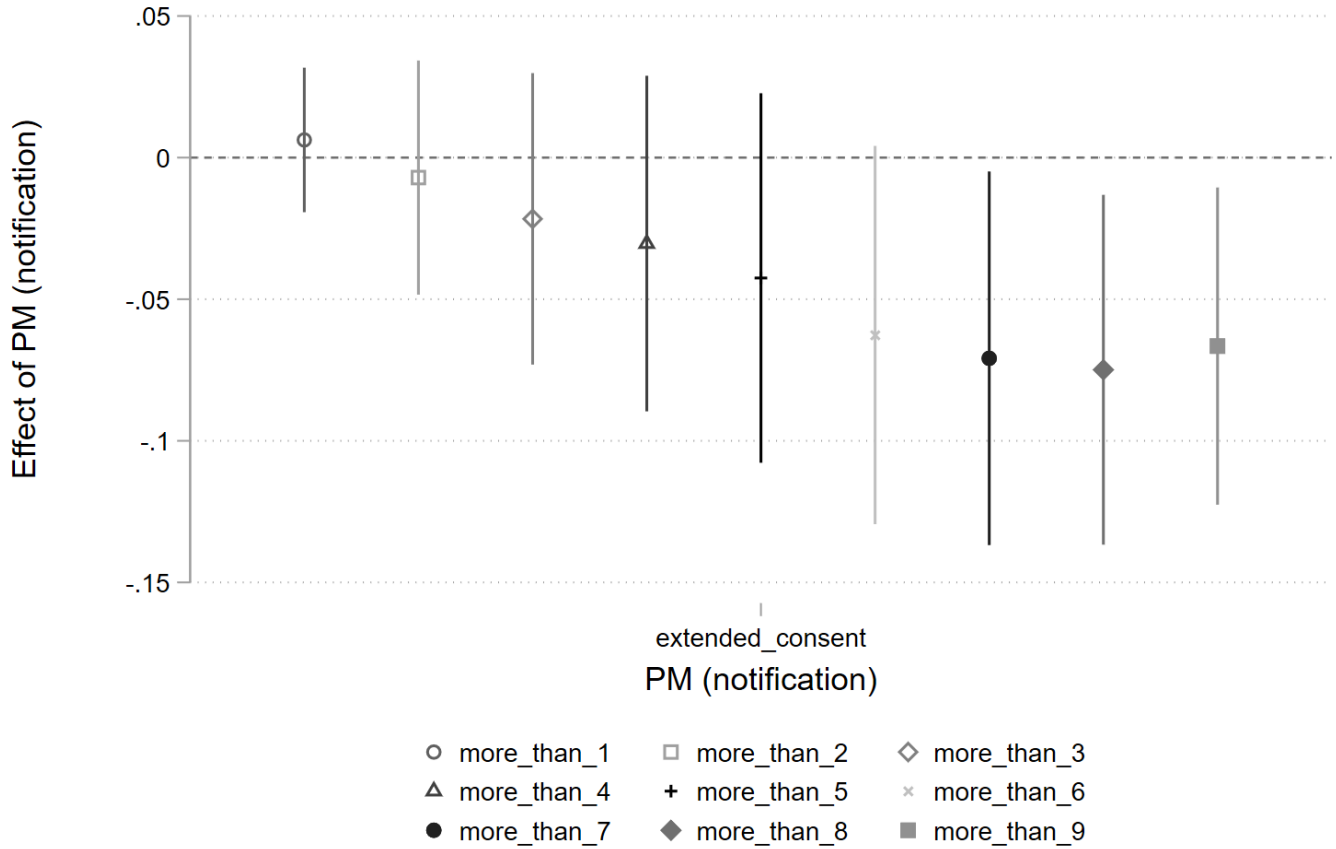
On average, households in T1 villages exchanged 5.9 coupons, while in T2+T3 villages households exchanged 5.6 coupons.

Figure: The Proportion of Number of Coupons Exchanged in Two Arms



Households expecting peer monitoring are likely more strategic

Outcome variables: whether household exchanges more than n coupons



Summary: risk sharing formation

- Households in the presence of stronger enforcement of commitments, become more strategic when choosing whom to share risk.
- Some evidence on heterogeneity in Assortative matching (especially, in distance and assets)
- Rich HH may strategically avoid making commitments to poor households – the higher expected cost of breaking the commitment.
- Households at a far distance may seem to weigh the cost of switching against the benefit
- Matching in the observable traits signals a higher trust between two households (Attanasio et al. 2012).
- Higher punishment to deviation make the risk-sharing more sustainable between HHs with stronger connections (Ambrus et al. 2014). In this case, geography may also proxy for stronger connections.

Specification

$$y_{iv} = \beta_0 + \beta_1 T1_v + \beta_2 T2_v + \beta_3 T3_v + X_{iv}\gamma + S_v\delta + \eta_u + \epsilon_{iv} \qquad (1)$$

Outcome variable y_{iv}: (1) Discussion about water sharing, (2) arsenic concentration of primary well households used at the endline, and (3) Switching to a new well at endline w.r.t. the baseline.

$T1$ is the binary variable that indicates whether village v received the WSC intervention only, $T2$ indicates that households in village v received the WSC intervention + the notification for peer-monitoring, $T3$ indicates that households in the village v received WSCs, notification and the peer-monitoring treatment.

X_{iv}: household-level characteristics (assets, educ, hh size, male ratio, child ratio). S_v: Village level proportion of safe wells. η_u: sub-district dummies.
The βs capture the estimated effect of the corresponding treatment.

Impact on the likelihood that households ex-ante discuss sharing water

	Discussed well-sharing with neighbors before testing		
	(1)	(2)	(3)
Coupon w/o Peer Monitoring	0.158***	0.0616*	0.133***
	(0.0265)	(0.0318)	(0.0232)
Coupon + PM Notification	0.170***	0.0579*	0.143***
	(0.0248)	(0.0330)	(0.0231)
Coupon + PM	0.164***	0.0412	0.139***
	(0.0264)	(0.0312)	(0.0241)
Observations	9,498	3,192	12,781
R-squared	0.060	0.080	0.062
Control Mean	0.29	0.28	0.29
Controls	YES	YES	YES
Sample	Owner	Non-owner	Full

Arsenic in households' primary well post-intervention – Coupons are effective but peer-monitoring is not

	Endline Arsenic (ppb)		
	(1)	(2)	(3)
Coupon w/o Peer Monitoring	-21.06	-24.01*	-28.84**
	(16.68)	(14.46)	(13.87)
Coupon + PM Notification	-34.30**	-29.00**	-29.02**
	(16.27)	(12.21)	(12.13)
Coupon + PM	5.007	-3.802	-7.287
	(16.34)	(12.21)	(11.93)
Observations	5,343	8,349	10,650
R-squared	0.262	0.405	0.387
Control Mean	321.97	210.88	211.13
Controls	YES	YES	YES
Sample	High As + Owner	Owner	Full
T1 vs T2	0.475	0.737	0.990
T1 vs T3	0.146	0.183	0.140
T2 vs T3	0.041	0.054	0.092

Impact on Switching wells

Switched	To lower	Unsafe to safe	To higher	Safe to Unsafe
	(1)	(2)	(3)	(4)
Coupon w/o Peer Monitoring	0.00627	0.00135	-0.0113**	-0.00554
	(0.00988)	(0.00908)	(0.00444)	(0.00688)
Coupon + PM Notification	0.0104	0.0249**	-0.00886*	-0.00207
	(0.00880)	(0.0121)	(0.00521)	(0.00585)
Coupon + PM	-0.000220	-0.00356	-0.0109**	-0.000599
	(0.00876)	(0.0108)	(0.00483)	(0.00521)
Observations	7,869	4,863	7,869	3,006
R-squared	0.008	0.057	0.003	0.011
Control Mean	0.04	0.04	0.02	0.01
Controls	YES	YES	YES	YES
Sample	High As + Own	High As + Own	High As + Own	High As + Own

Commitments more effective when households are socially and spatially closer

	Currently using a well owned by the neighbor			
	(1)	(2)	(3)	(4)
Exchanged coupon	0.00616***		0.00526***	0.00769***
	(0.00112)		(0.00103)	(0.00144)
Geo Dist (50m)		-0.000224***	-0.000136***	-0.000121***
		(4.33e-05)	(3.21e-05)	(3.07e-05)
Socially connected		0.00477***	0.00375***	0.00238***
		(0.000825)	(0.000728)	(0.000616)
Social Connection X Exchanged Coupon				0.00446*
				(0.00236)
Geo Dist X Exchanged Coupon				-0.00291***
				(0.000678)
Observations	314,221	314,221	314,221	314,221
R-squared	0.003	0.002	0.004	0.006
Mean	0.0006	0.0006	0.0006	0.0006
Sample	T1+T2+T3	T1+T2+T3	T1+T2+T3	T1+T2+T3

Policy problem: overall switching rate is surprisingly low

- Switching rates in this study are much lower than what previous studies have shown.
- Potential Reasons:
  - Curse of convenience: more households own a private well in recent years.
  - Media campaign and awareness about are much lower that the first time. ⏩ Arsenic in media.
  - Households plan for private investment in deeper wells that are likely to be lower in arsenic. ⏩ New Wells.
- Unfortunately, millions of households continue to drink high arsenic water despite the recent well-testing.

Higher switching among households not owning private well

VARIABLES	(1) Endline arsenic	(2) Endline arsenic
WSC (T1+T2+T3)	-4.465	-5.013*
	(2.707)	(2.741)
No ownership	-17.94**	-18.08**
	(7.834)	(7.761)
No ownership X WSC	2.657	-1.298
	(8.731)	(8.885)
Observations	7,083	6,085
R-squared	0.785	0.786
Control mean	336.54	334.15
Baseline arsenic	YES	YES
Controls	NO	YES

*** p<0.01, ** p<0.05, * p<0.1

Proposed solution and future directions

- A geological data- and evidence-driven multi-pronged approach
- Installation of safe private wells (300 ft vs. 100 ft.)
  - Information - Nolkup App pilot with support from USAID.
  - Accelerating private installations of wells at the right depth.
- Deep public-funded community wells– existing deep wells are targeted inefficiently. Incentivising better spatial targeting.
- Piped water – costly but may be the only option in certain areas.

Conclusion

- We test how enhancing commitment and enforcement can shape risk-sharing.
- While making ex-ante and explicit contracts increased the likelihood of risk-sharing discussions between households significantly, the gains in actual transfers are rather modest.
- Increasing peer monitoring counteracts the impact of enhanced commitment, in line with the evidence on extrinsic incentives crowding out intrinsic motivations.
- To sum up, enhancing the strength of commitments can improve efficiency in informal risk-sharing but only to a small extent. At the same time, even mild enforcement of these commitments may backfire.
- Could this be a reason why communities fail to develop stronger ways to address the limited commitment problem in informal risk-sharing?

Backup slides

Arsenic in wells – temporally relatively stable

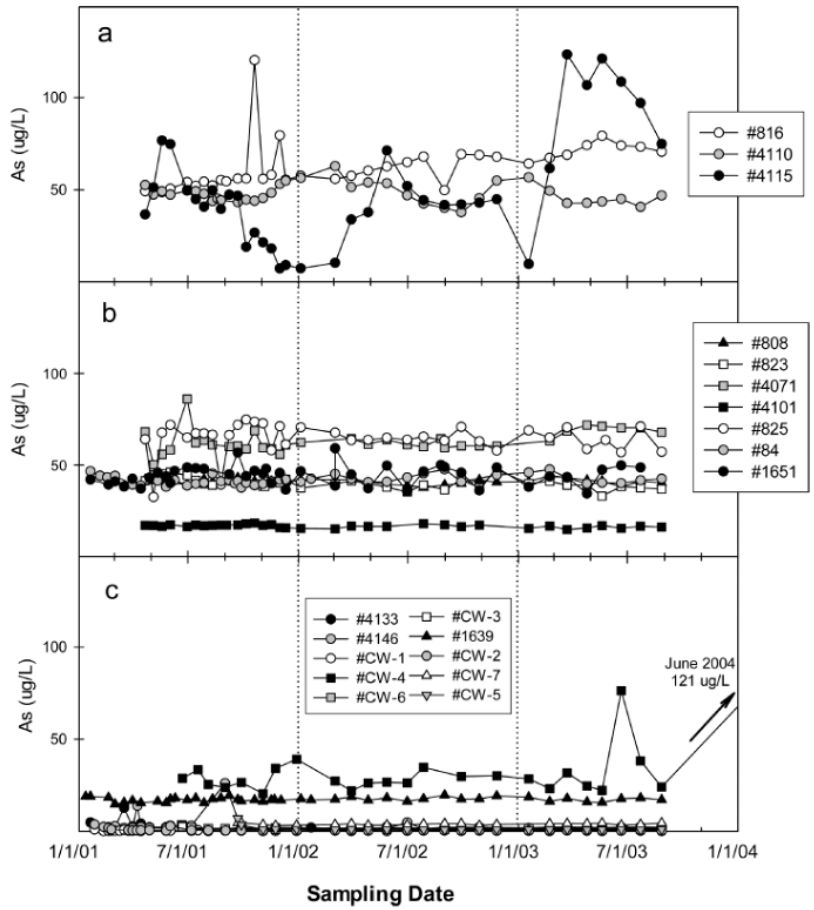


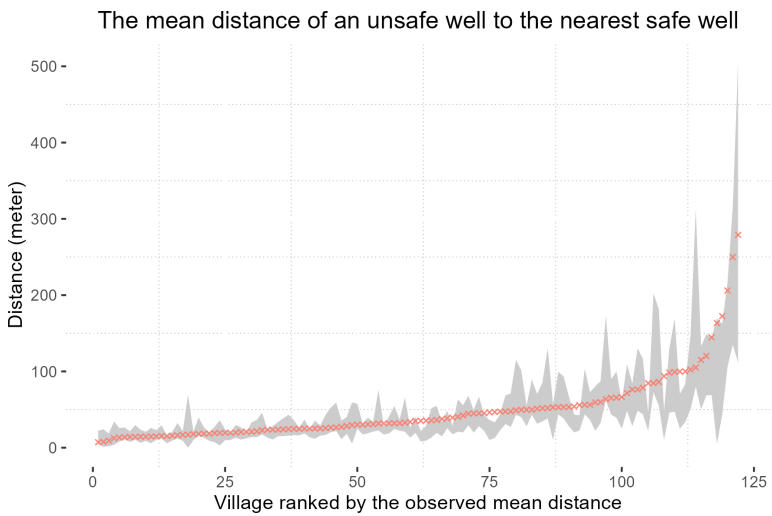
FIGURE 2. Arsenic levels in time series groundwater samples collected from 20 wells around Araiharzar, Bangladesh, between 2001 and 2003: (a) well depths 8–20 m, with apparent seasonal patterns or long-term trends; (b) well depths 8–20 m, without seasonal patterns or long-term trends; (c) well depths 30 m or more.

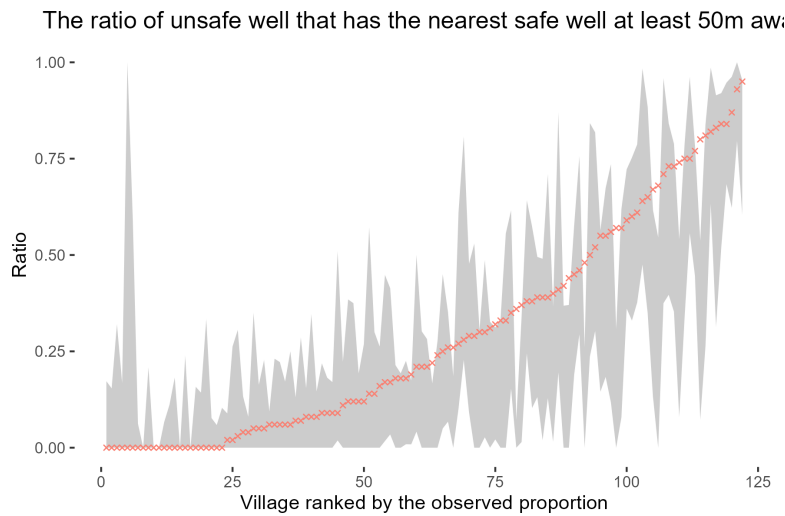
⏩ Back to spatial variation in arsenic

"Even though the majority of wells that were initially safe remained so for 3 years, our results indicate that tube wells should be tested periodically." (Cheng et al. 2005)

Is arsenic randomly distributed in space?

- Simulations– randomly reassigned high arsenic wells randomly within village





⏩ Back to Arsenic Prediction at baseline

Balance

	WSC only (T1- 33 villages)			WSC+PM Notification (T2+T3- 66 villages)			
	n	mean	sd	n	mean	sd	Diff
HH size	2274	5.37	2.20	4308	5.40	2.09	0.026
Average age	2274	28.49	9.86	4308	27.94	9.87	-0.558
Male ratio	2274	0.40	0.20	4308	0.42	0.20	0.017***
Child ratio	2274	0.37	0.21	4308	0.39	0.20	0.012
Education level	2274	0.32	0.26	4308	0.31	0.25	-0.007
Health risk tolerance	1781	1.66	1.04	3257	1.69	1.07	0.023
Asset index (PCA)	2110	0.17	1.03	3960	0.11	1.02	-0.055
Asset index (STD)	2110	0.16	1.00	3960	0.10	1.00	-0.058
Self arsenic perception	1492	2.75	1.25	2826	2.70	1.22	-0.055
Neighbor arsenic perception	1147	0.59	0.49	1760	0.56	0.50	-0.032

Back

Expected peer monitoring and assortative matching

VARIABLES	(1) Exchanged coupon	(2) Exchanged coupon	(3) Exchanged coupon	(4) Exchanged coupon	(5) Exchanged coupon
Monitoring Notification	-0.0155*	-0.0117	-0.0187**	-0.0126	-0.0142*
	(0.00799)	(0.00829)	(0.00822)	(0.00819)	(0.00776)
Diff	-0.000676	0.000253	-0.0148	0.00211	-0.0214***
	(0.000635)	(0.000231)	(0.00978)	(0.00649)	(0.00653)
Monitor Notification X Diff	-0.000254	-0.000431*	0.0132	-0.0151*	-0.00707
	(0.000880)	(0.000248)	(0.0116)	(0.00855)	(0.00849)
Observations	171,711	171,711	171,711	171,711	171,711
R-squared	0.094	0.094	0.094	0.094	0.094
Diff =	HH size	Average age	Male ratio	Child ratio	Education ratio

⏩ Back to Assortative Matching

Expected peer monitoring and assortative matching

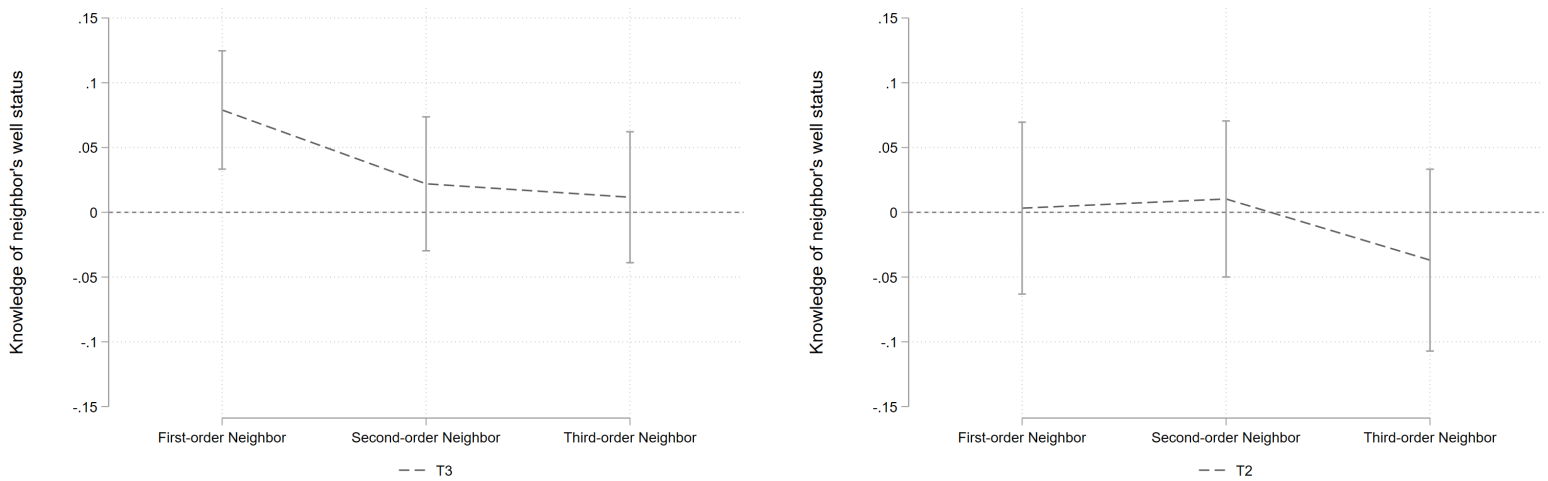
VARIABLES	(1) Exchanged coupon	(2) Exchanged coupon	(3) Exchanged coupon	(4) Exchanged coupon
Monitoring Notification	-0.0150*	-0.0173**	-0.0138*	-0.0132
	(0.00806)	(0.00813)	(0.00817)	(0.00808)
Diff	-0.00912**	-0.0151***	-0.0124***	-0.00811**
	(0.00351)	(0.00298)	(0.00364)	(0.00317)
Monitor Notification X Diff	-0.000397	0.00199	-0.00158	-0.00214
	(0.00418)	(0.00337)	(0.00427)	(0.00386)
Observations	171,711	171,711	171,711	171,711
R-squared	0.127	0.128	0.128	0.128
Diff =	Altruism index	Trust index	Positive reciprocity index	Negative reciprocity index

⏩ Back to Assortative Matching

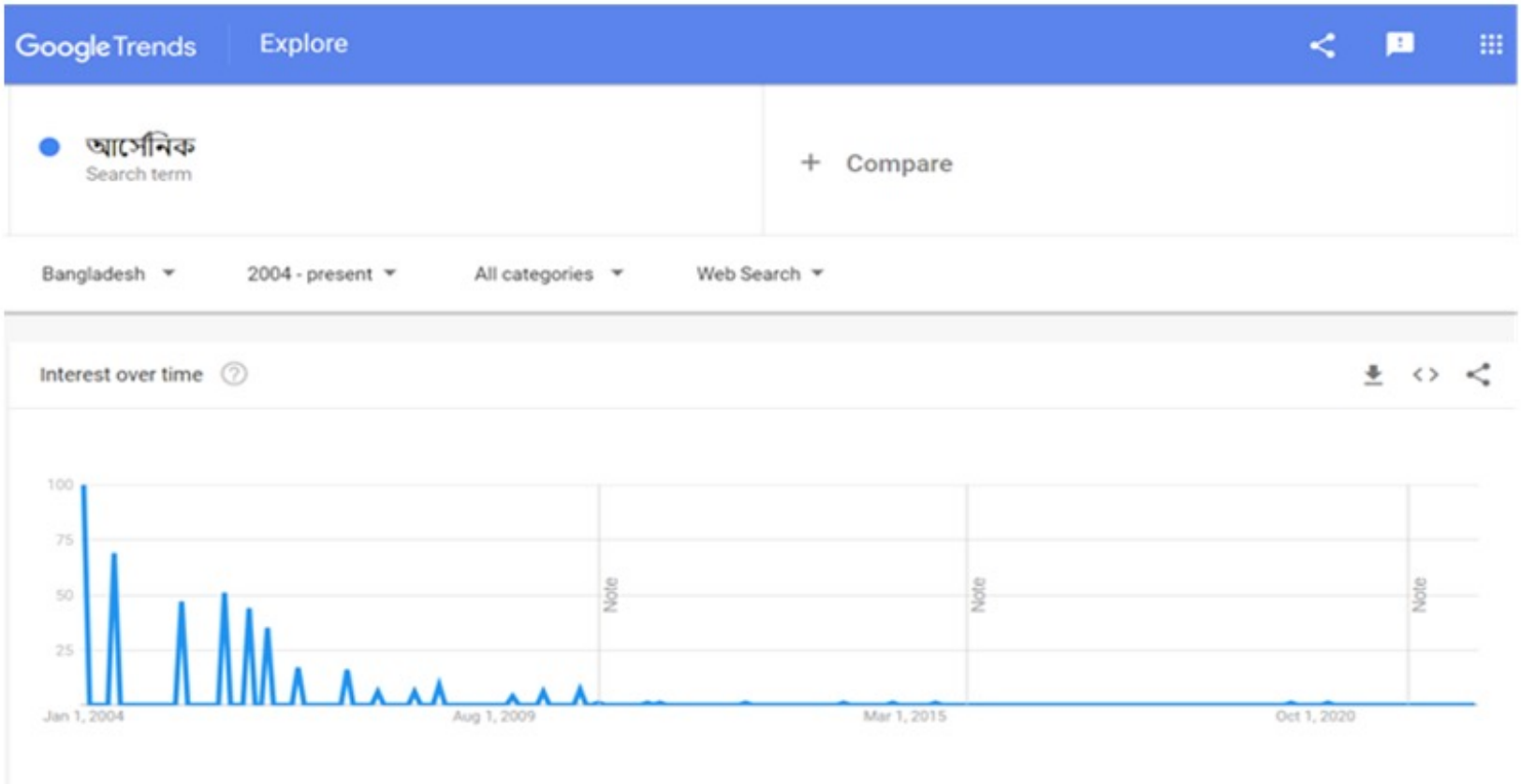
Did text messages actually increase peer monitoring?

Text messages incentivized households to find out the arsenic status of monitored households' wells in T3 villages

Figure: Whether households know the As status of other households well

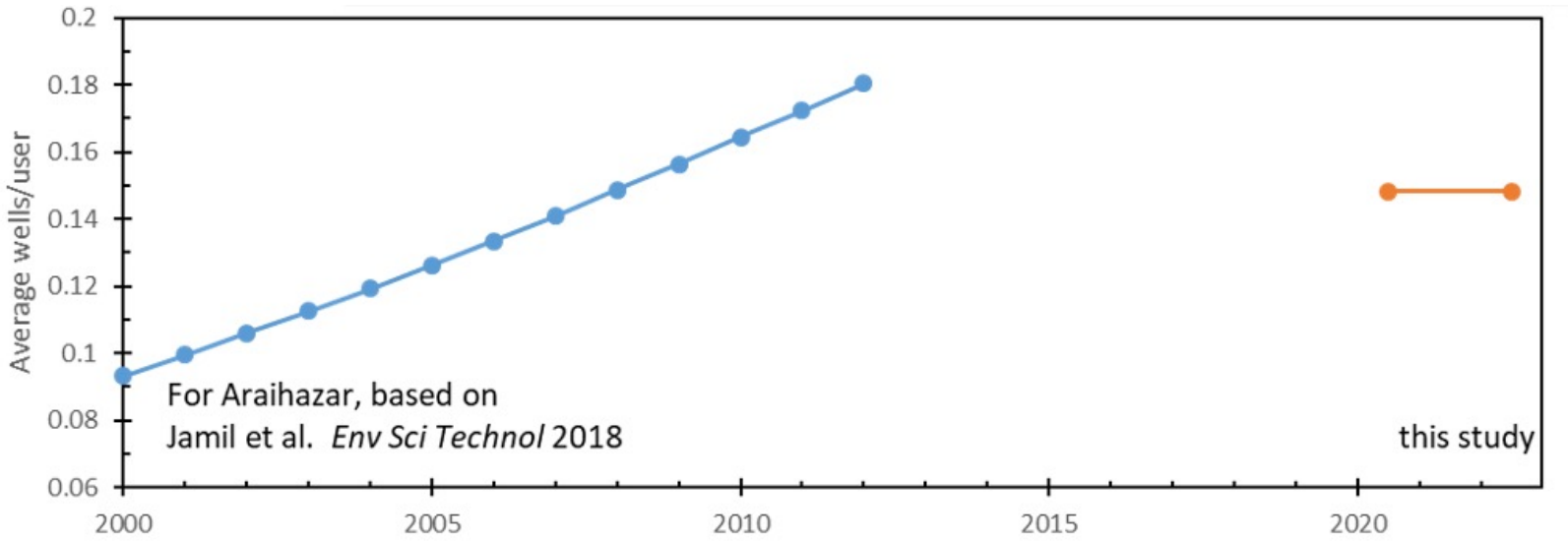


Low media coverage of arsenic problem



Back

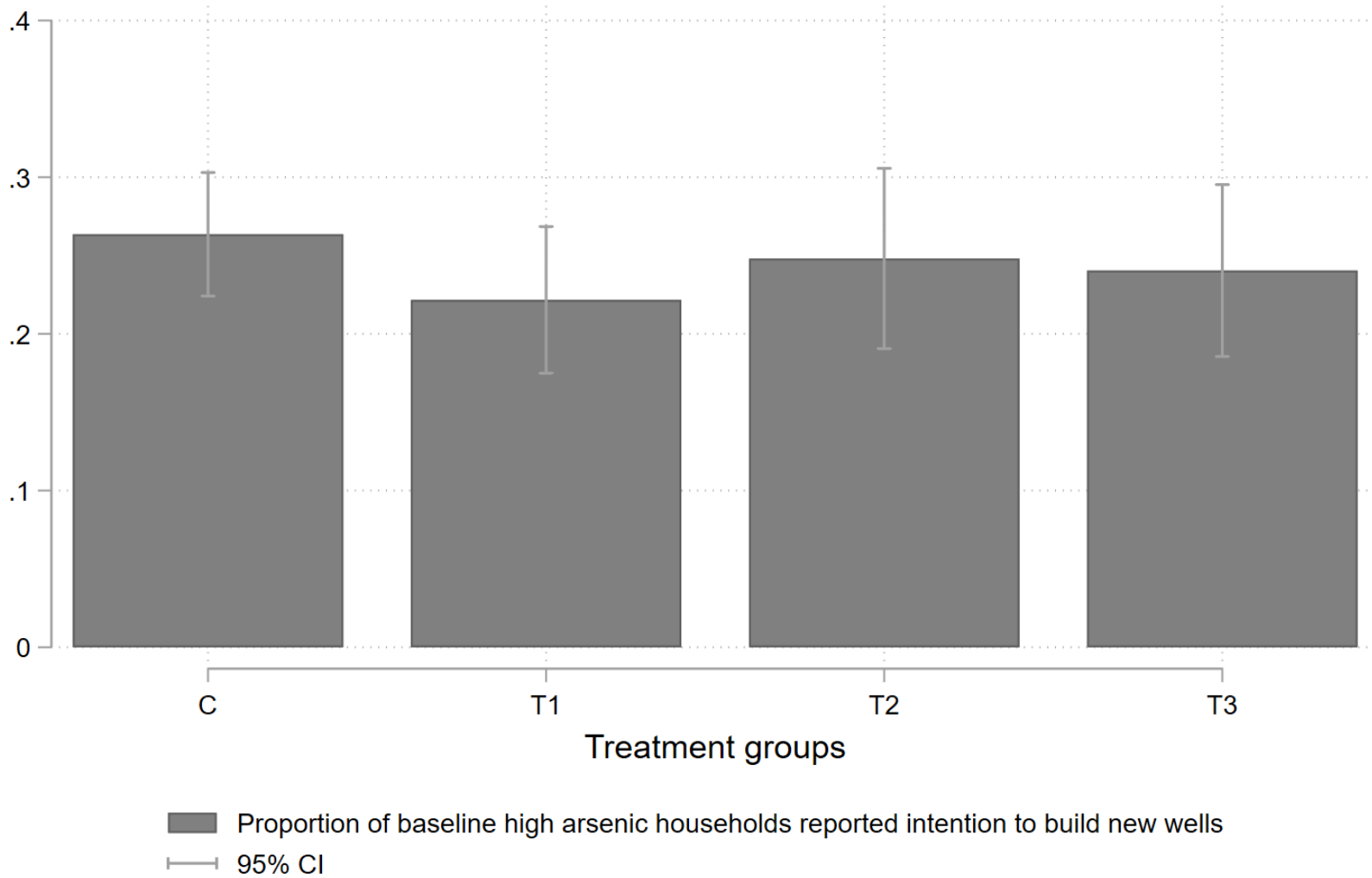
Well-ownership has been increasing over time



Back

Are households who can't switch planning to install deeper (safer) wells?

Among households whose baseline primary wells have high arsenic, at what proportion do they want to build new wells:



Are households more likely to install new wells

	(1)	(2)	(3)	(4)
	Installed a new well after testing			
T1	0.00248	0.00317	0.00230	0.00847
	(0.00444)	(0.00509)	(0.00514)	(0.0276)
T2	0.00313	0.00976	0.00894	0.0172
	(0.00461)	(0.00613)	(0.00606)	(0.0355)
T3	0.00828*	0.00655	0.00586	-0.0257
	(0.00486)	(0.00553)	(0.00578)	(0.0291)
Observations	8,441	5,476	5,206	216
R-squared	0.005	0.006	0.006	0.082
Control Mean	0.02	0.02	0.02	0.02
Controls	YES	YES	YES	YES
Sample	Full	High As	High As + Well owner	High As + Non well-owner