Social Learning among Urban Manufacturing Firms: Energy-Efficient Motors in Bangladesh

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  - Industrial policy
    - Hausmann and Rodrik (2003), Harrison and Rodríguez-Clare (2010), Juhász et al. (2023)

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  2. Learning is hard to measure.
     - Common approach is to use residual-based measures like Total Factor Productivity, which have issues.
  3. Saturation design unlikely to be feasible for industrial firms.
     - Few industries have enough clusters using similar technology.
     - Information is likely to flow across clusters.

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- Borusyak-Hull (2023) "re-centering" approach to address SUTVA violations and estimate spillovers.
- The research design allows us to addresses the three challenges:
  1. Clearly exogenous exposure to technology.
  2. Direct observation of adoption decisions.
  3. Implemented in single connected set of firms.

Preview of Results

- Direct effects:
  - Info + installation (T2): adoption ↑, beliefs about servo electricity usage ↓, willingness-to-pay ↑.
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- Little evidence of spillovers through communication network, common suppliers, common mosque.
- MVPF calculation: subsidies for servomotors attractive, especially once learning spillovers are taken into account.

Related Literature

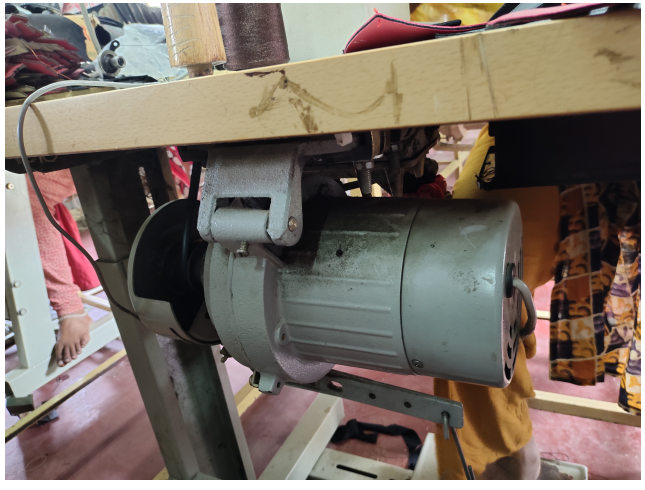
- Urban agglomeration effects:
  - Arzaghi and Henderson (2008), Atkin et al. (2022), Rosenthal and Strange (2020).
  - Distinctive aspect of our study: experimental variation.
- Experiments on knowledge spillovers among firms.
  - Fafchamps and Quinn (2018), Cai and Szeidl (2018), Hardy and McCasland (2021), Houeix (2025).
  - Distinctive aspects: naturally occurring production technology, existing network, spatial dimension.
- Social learning in agriculture, other contexts:
  - Foster and Rosenzweig (1995), Conley and Udry (2010), Miguel and Kremer (2004), Duflo and Saez (2003), Bloom et al. (2013), Banerjee et al. (2013), Beaman et al. (2021), Duflo et al. (2023), Tang (2024).
  - Distinctive aspects: market structure, inference problem more straightforward.
- Adoption of energy-efficient technologies:
  - Anderson and Newell (2004), Allcott and Greenstone (2012), Allcott and Rogers (2014), Allcott and Taubinsky (2015), Berkouwer and Dean (2022), Newell and Siikamäki (2014, 2015), Ryan (2018).
  - Distinctive aspects: firms, not households; learning.

Leather Goods Industry in Dhaka, Bangladesh

- Many SMEs. Median employment in our sample: 6.
- Main products: shoes, bags, belts

Servo vs. Clutch Motors

Servo motor



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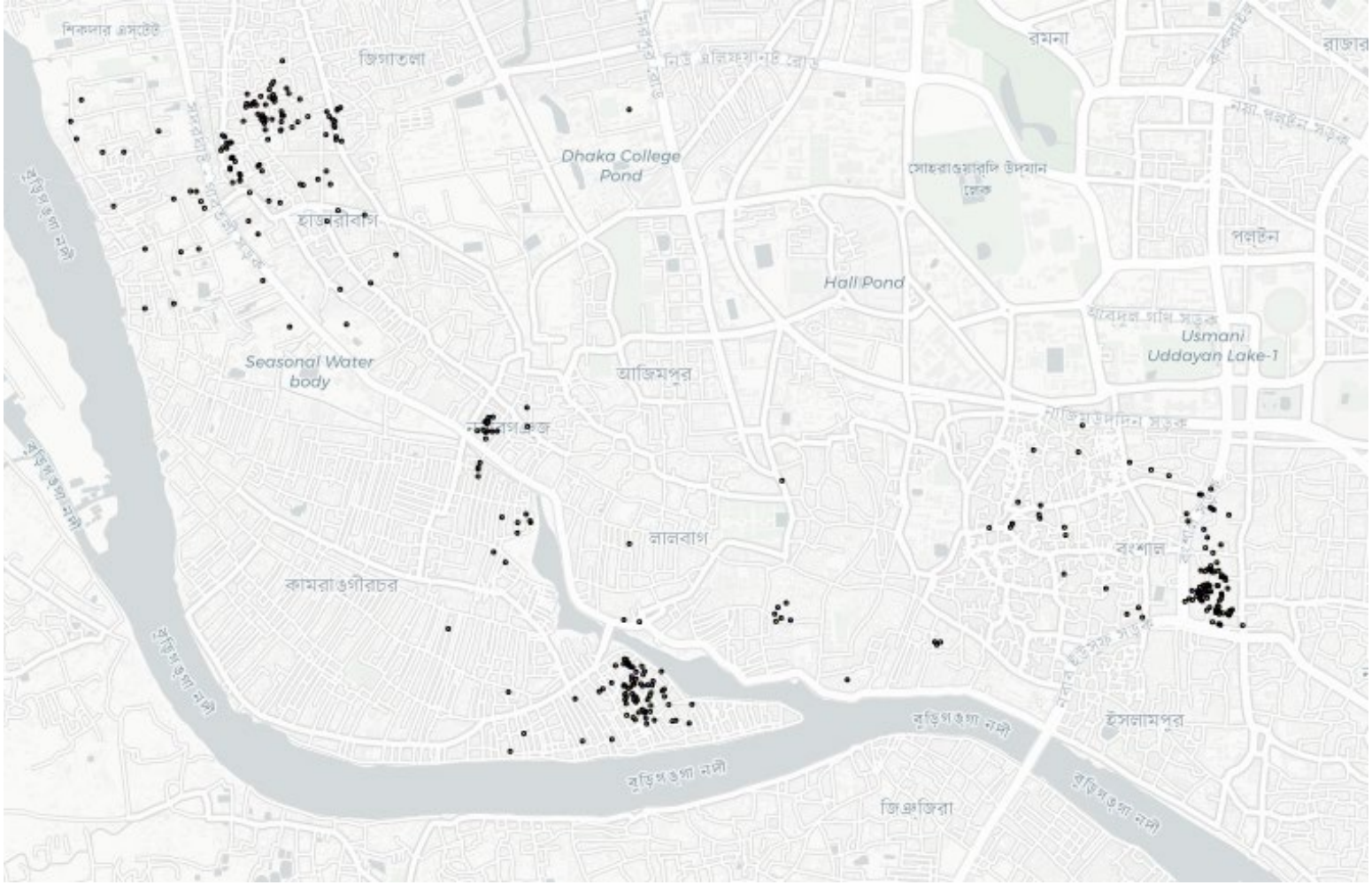
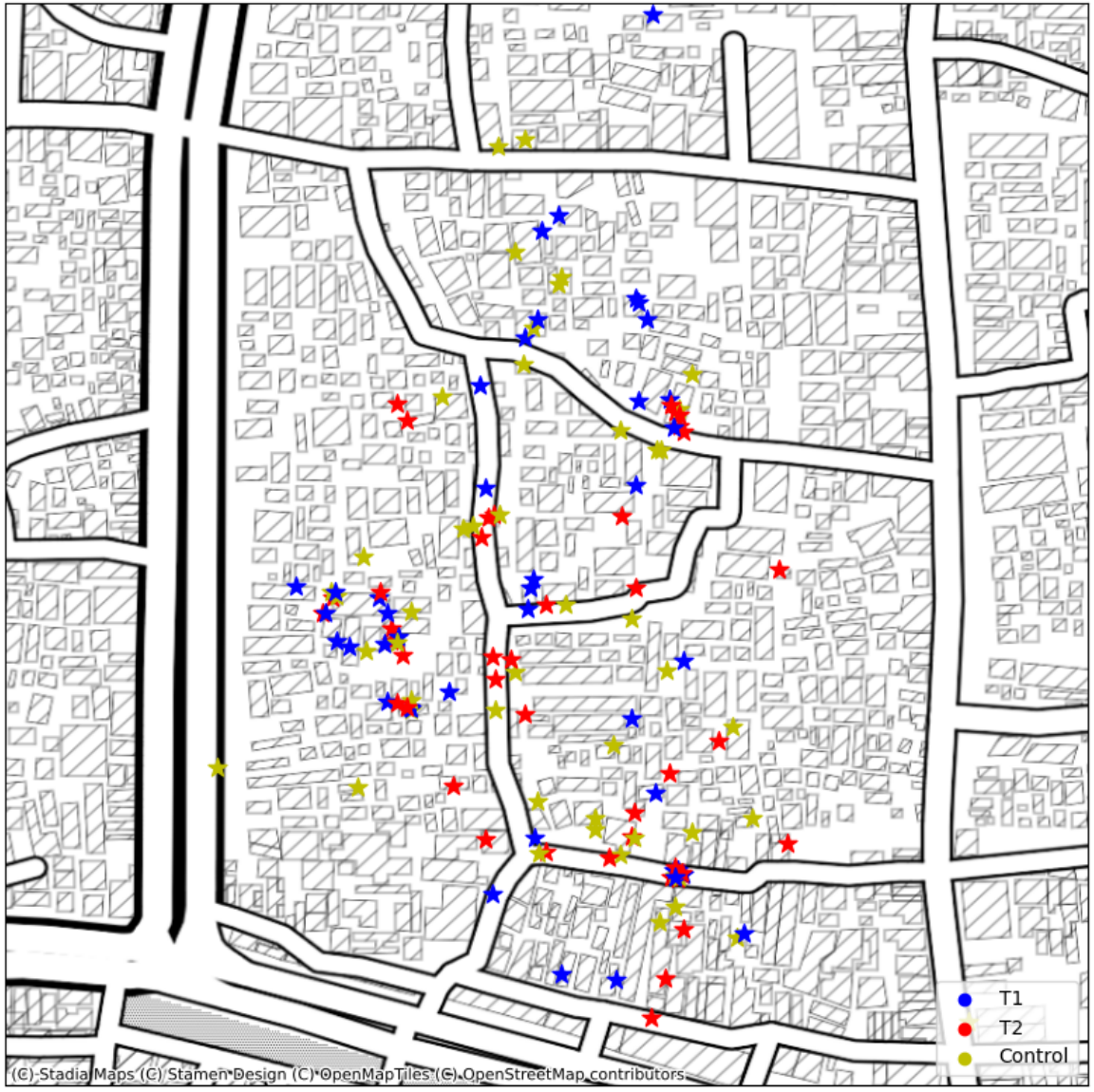
- Cost of new servo motor ∼$46 USD (cheaper if used; high-end motors can cost more).
- Electricity cost savings per machine: about $0.90/month.

Payback period opinions electricity sector

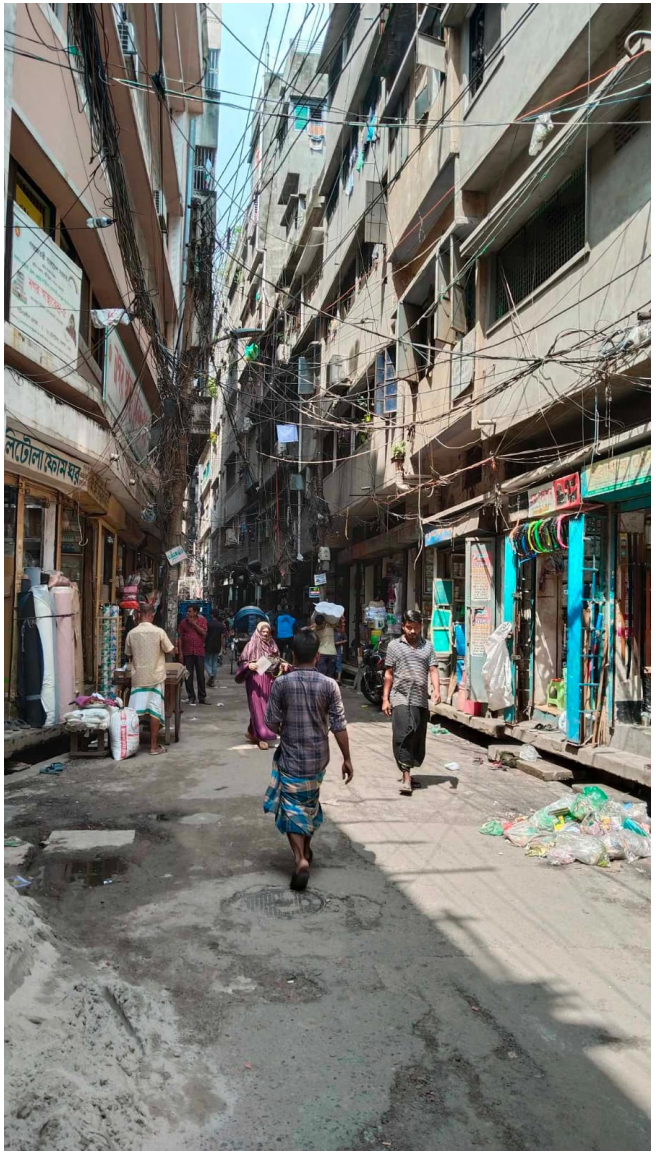
Map of Dhaka


Dhaka College Pond
Hall Pond
Seasonal Water body
Usmani Uddayan Lake-1
আজিমপুর
লালবাগ
কামরাঙ্গীরচর
বংশাল
ইসলামপুর
জিঞ্জিরা
বুড়িগঙ্গা নদী

Map of Bangshal (Old Dhaka)



Hazi Moin Uddin Road in Bangshal



Experimental Design

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  - T1: Information only.
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    - Installation of one servo motor.
    - Meter on clutch motor + meter on servo motor + report from meters.

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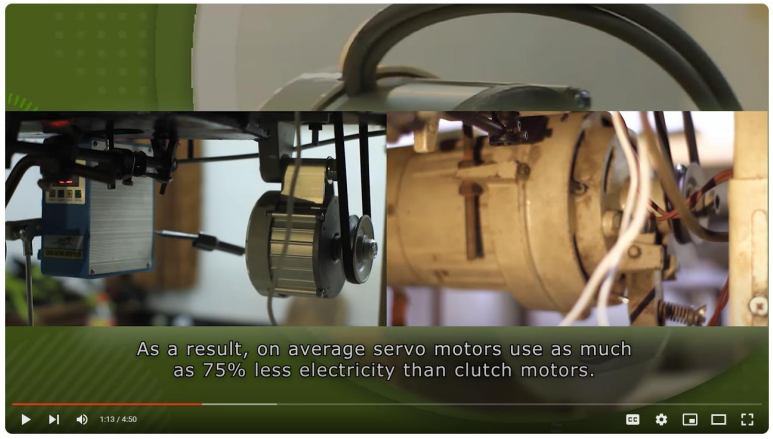
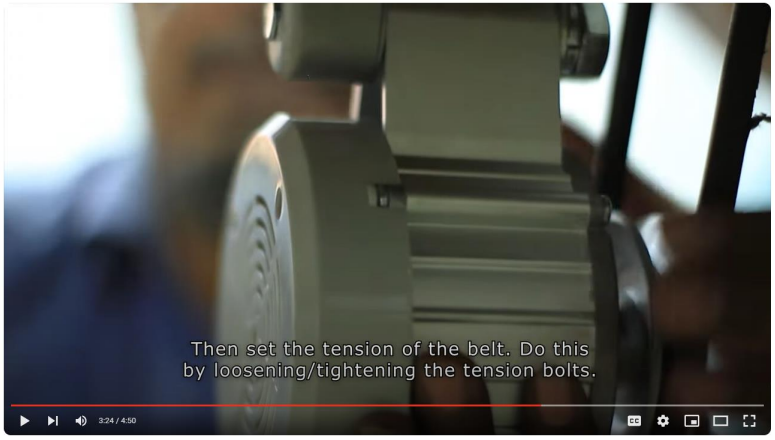
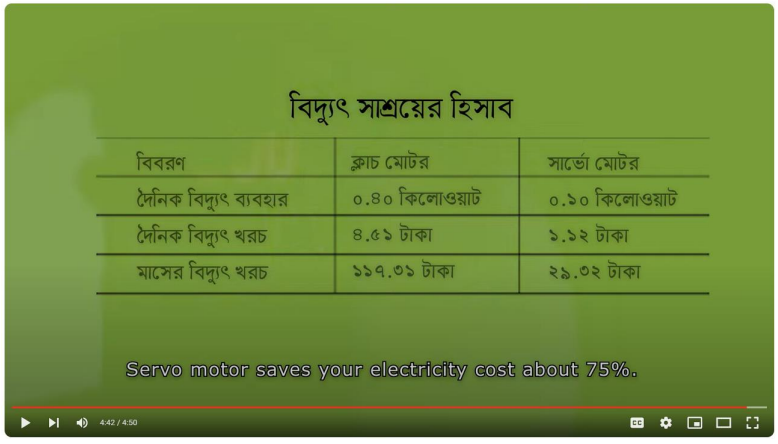
    - Installation of one servo motor.
    - Meter on clutch motor + meter on servo motor + report from meters.
- Randomization embedded in baseline WTP elicitation, to minimize Hawthorne/experimenter effects.
  - T2: almost all very low prices.
  - T1, C: almost all very high prices.

balance details on WTP beliefs

Informational Video







- Explains cost savings and installation. Running time: 4:50.

Meter Reports

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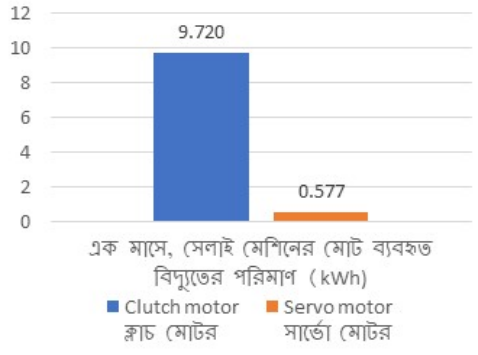
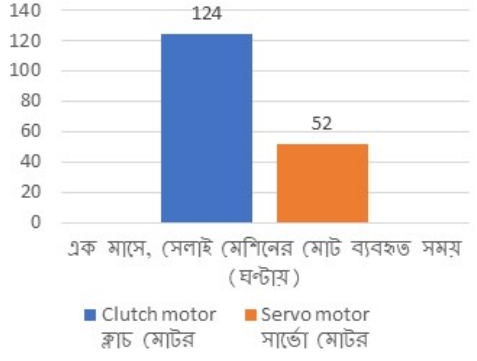
JOHNS HOPKINS
SCHOOL of ADVANCED INTERNATIONAL STUDIES

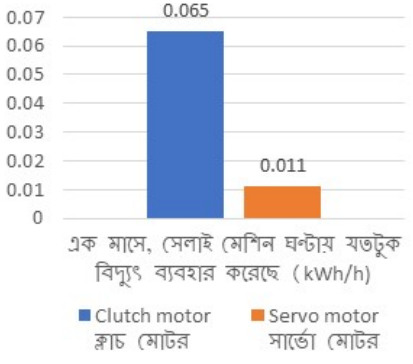
Electricity Consumption - Monthly Report (বিদ্যুৎ ব্যবহার – মাসিক রিপোর্ট)

Date: 22/05/2023 – 21/06/2023
ID: T-157 Firm: [redacted]

	Clutch motor ক্লাচ মোটর	Servo motor সার্ভো মোটর
Total electricity consumption for sewing machine with meter per month এক মাসে, সেলাই মেশিনের মোট ব্যবহৃত বিদ্যুতের পরিমাণ (kWh)	9.720	0.577
Total number of one-hour intervals for that machine in the month এক মাসে, সেলাই মেশিনের মোট ব্যবহৃত সময় (ঘণ্টায়)	124	52
Average energy consumption per one hour interval for that machine in the month এক মাসে, সেলাই মেশিন ঘণ্টায় যতটুক বিদ্যুৎ ব্যবহার করেছে (kWh/h)	0.065	0.011







দ্রষ্টব্য: মেশিনটি প্রতি ঘন্টায় যতটুকু সময়ের জন্য ব্যবহৃত হোক না কেন, তাকে আমরা এক ঘন্টা ব্যবহারের হিসাবে বিবেচনা করছি

Identification with Spillovers

- Estimating equation:

$$\begin{aligned} y_{ijs}^{endline} &= \beta_0 + \beta_1 T1_i + \beta_2 T2_i + \beta_3 \text{exposure}_i \\ &\quad + \beta_4 \mathbb{E}_i[\text{exposure}] + \lambda_j + \upsilon_s + y_{ijs}^{baseline} + \epsilon_{ijs} \end{aligned}$$

  - i, j, s index firm, stratum, sub-district (upazila).

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- exposure_i can be calculated in different ways:
  - Baseline: indicator for having any T2 firm within X meters.
  - Indicators for intensity of exposure (numbers of T2 firms within X meters, or bins thereof)
  - Indicator for having any T2 firm in communication network.
  - Indicators for sharing supplier/mosque with T2 firm.

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- Results similar if we instrument exposure_i by re-centered exposure (exposure_i-$\mathbb{E}_i[\text{exposure}]$), dropping $\mathbb{E}_i[\text{exposure}]$ as covariate.

approaches

Treatment and Local Spillover Effects on Adoption

	Including T2		Excluding T2	
	Purchased 1+ servo motors	Purchased 2+ servo motors	Purchased 1+ servo motors	Purchased 2+ servo motors
	(1)	(2)	(3)	(4)
T1	0.090	0.057	0.099	0.048
	(0.035)**	(0.018)***	(0.033)***	(0.018)***
	[0.041]**	[0.034]*	[0.042]**	[0.034]
T2	0.809	0.091		
	(0.079)***	(0.025)***		
	[0.032]***	[0.039]**		
Exposure (500m)	0.158	0.105	0.193	0.102
	(0.049)***	(0.049)**	(0.071)***	(0.057)*
	[0.062]**	[0.062]*	[0.078]**	[0.066]
Exp. Exposure (500m)	-0.010	0.029	0.001	0.016
	(0.088)	(0.093)	(0.118)	(0.093)
	[0.098]	[0.090]	[0.133]	[0.102]
Observations	473	473	325	325
Upazila FE	Y	Y	Y	Y
Strata FE	Y	Y	Y	Y
Rand. Inf. p-value (Exposure)	[0.018]	[0.090]	[0.024]	[0.066]

Notes: Dependent variables are 0/1 indicators for having purchased or received (from us) 1+ or 2+ servo motors between baseline and endline. Exposure (500m) is 0/1 indicator for having a T2 firm within a walking distance of 500m. Expected Exposure (500m) is average of Exposure (500m) over 1,000 counterfactual treatment assignments. The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p <0.10; **p <0.05; ***p <0.01. The randomization inference p-values for the coefficient on the realized exposure term are based on the test statistic recommended by Borusyak and Hull (2023).

Adoption, by Intensity of Exposure

	Including T2		Excluding T2	
	Purchased 1+ servo motors (1)	Purchased 2+ servo motors (2)	Purchased 1+ servo motors (3)	Purchased 2+ servo motors (4)
T1	0.092 (0.032)*** [0.041]**	0.062 (0.017)*** [0.034]*	0.102 (0.031)*** [0.041]**	0.050 (0.018)*** [0.034]
T2	0.811 (0.076)*** [0.032]***	0.088 (0.024)*** [0.038]**		
Exposure, 1-2 neighbors (500m) (0/1)	0.152 (0.059)** [0.066]**	0.102 (0.052)* [0.065]	0.158 (0.085)* [0.088]*	0.080 (0.057) [0.071]
Exposure, 3-5 neighbors (500m) (0/1)	0.186 (0.100)* [0.109]*	-0.038 (0.107) [0.122]	0.246 (0.125)** [0.145]*	0.191 (0.092)** [0.121]
Exposure, 6-8 neighbors (500m) (0/1)	0.295 (0.116)** [0.173]*	0.038 (0.135) [0.147]	0.416 (0.174)** [0.251]*	0.271 (0.102)*** [0.153]*
Exposure, 9+ neighbors (500m) (0/1)	0.576 (0.104)*** [0.239]**	0.433 (0.271) [0.264]	0.824 (0.167)*** [0.349]**	0.584 (0.087)*** [0.274]**
Observations	473	473	325	325
Exp. Exposure Controls	Y	Y	Y	Y
Upazila FE	Y	Y	Y	Y
Strata FE	Y	Y	Y	Y

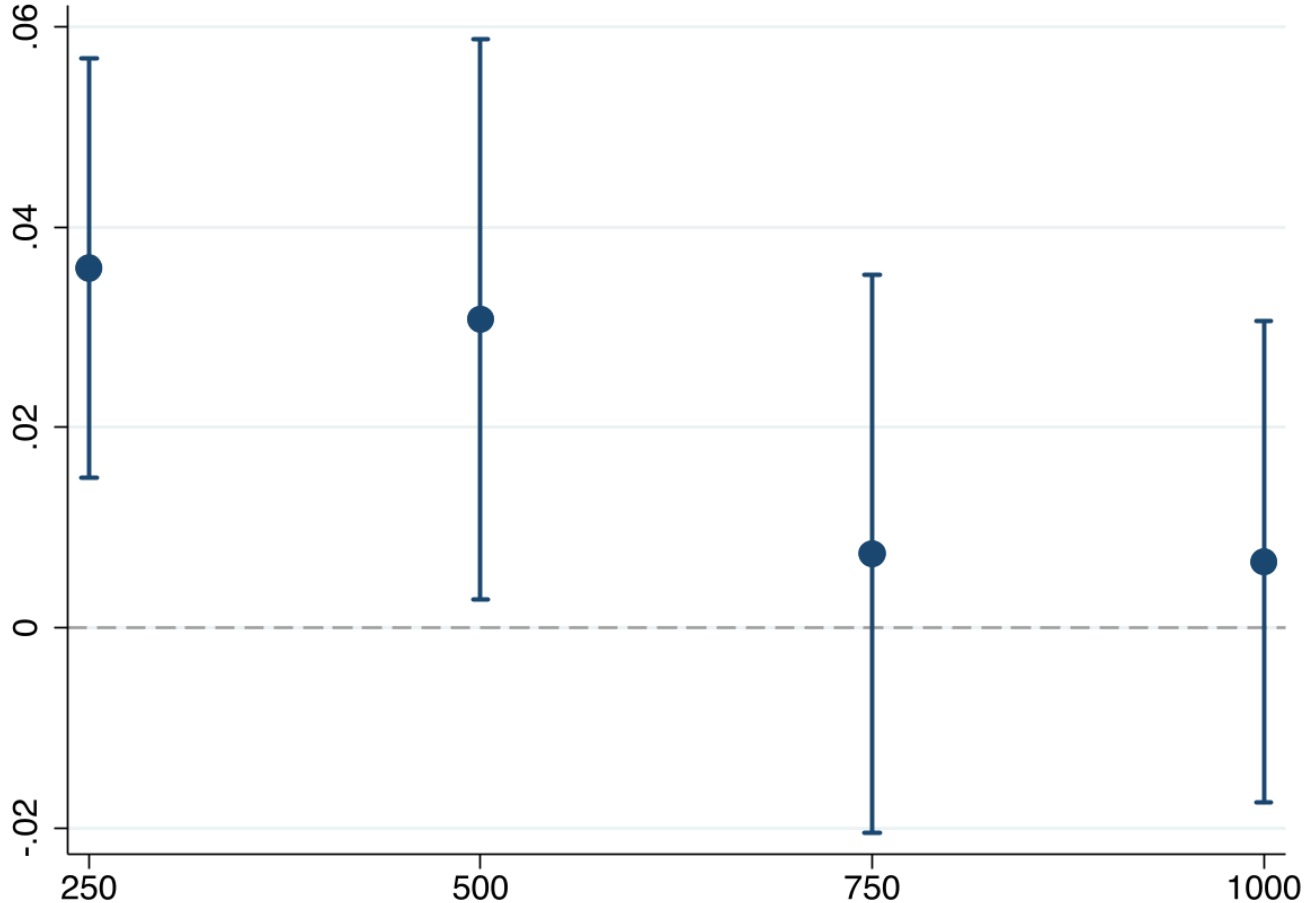
Notes: Dependent variables are 0/1 indicators for having purchased or received (from us) 1+ or 2+ servo motors between baseline and endline. Exposure, *a-b* ngh. (500m) is a 0/1 indicator for whether the firm has between *a* and *b* (included) T2 firm(s) within a walking distance of 500m. Expected Exposure, *a-b* ngh. (500m) is average of Exposure, *a-b* ngh. (500m) over 1,000 counterfactual treatment assignments. The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p <0.10; **p <0.05; ***p <0.01.

Adoption, by Intensity of Exposure (# T2 firms)

	Excluding T2			
	Purchased 1+ servo motors			
	250m	500m	750m	1000m
	(1)	(2)	(3)	(4)
T1	0.090***	0.099***	0.098***	0.100***
	(0.033)	(0.035)	(0.035)	(0.034)
	[0.042]	[0.042]	[0.042]	[0.042]
Exposure [N(T2, Xm)]	0.036***	0.031**	0.007	0.007
	(0.011)	(0.014)	(0.014)	(0.012)
	[0.016]	[0.014]	[0.016]	[0.014]
Exp. Exposure [N(T2, Xm)]	-0.033***	-0.027*	-0.003	-0.001
	(0.012)	(0.015)	(0.015)	(0.013)
	[0.017]	[0.015]	[0.017]	[0.014]
Observations	325	325	325	325
Strata FE	Yes	Yes	Yes	Yes
Upazila FE	Yes	Yes	Yes	Yes

Notes: Dependent variable is a 0/1 indicator for having purchased or received (from us) 1+ servo motors between baseline and endline. Exposure [N(T2, Xm)] is the number of T2 firms within a walking distance of Xm. Exposure [N(T2, Xm)] is the average of Exposure [N(T2, Xm)] over 1,000 counterfactual treatment assignments. The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p <0.10; **p <0.05; ***p <0.01.

Spillovers in Adoption, by Distance



Notes: Figure plots estimates of coefficient on Exposure term in specifications similar to previous table, but with Exposure defined as number of T2 firm within a walking distance of Xm. T2 firms excluded from estimation sample; regressions are similar to the previous table.

any T2 neighbor

Effect of Exposure to Producers of Common Products

	Including T2		Excluding T2	
	purchased 1+ servo motors			
	(1)	(2)	(3)	(4)
T1	0.192 (0.054)*** [0.074]**	0.054 (0.033)* [0.055]	0.166 (0.067)** [0.076]**	0.066 (0.033)** [0.055]
T2	0.859 (0.069)*** [0.054]***	0.744 (0.101)*** [0.044]***		
Exposure common prod. (500m)	0.175 (0.067)*** [0.077]**	0.189 (0.055)*** [0.095]**	0.258 (0.084)*** [0.101]**	0.185 (0.071)*** [0.119]
Exposure no common prod. (500m)	0.063 (0.158) [0.198]	-0.023 (0.110) [0.100]	0.141 (0.208) [0.235]	-0.065 (0.140) [0.130]
Exp. Exposure common (500m)	-0.168 (0.131) [0.160]	-0.110 (0.139) [0.139]	-0.213 (0.166) [0.219]	-0.043 (0.184) [0.180]
Exp. Exposure no common (500m)	0.100 (0.224) [0.215]	0.112 (0.066)* [0.080]	0.129 (0.289) [0.269]	0.203 (0.091)** [0.111]*
Observations	140	322	95	217
Products	Shoes	Bags	Shoes	Bags
Upazila FE	Y	Y	Y	Y
Strata FE	Y	Y	Y	Y

Notes: In columns 1 and 3, the sample includes respondents who report at least one product in the "shoes" category. In columns 2 and 4, the sample includes respondents who report at least one product in the "bags" category. Firms may produce both shoes and bags and these subsamples are not mutually exclusive. "Exposure, common prod. (500 m)" is a 0/1 indicator for having one or more T2 firms within walking distance of 500 m that reported at least one product in the same category as the respondent. "Exposure, no common prod. (500 m)" is a 0/1 indicator for having one or more T2 firms within a walking distance of 500 m that reported no product in the same category as the respondent. Exp. Exposure is mean of Exposure from 1,000 counterfactual treatment assignment draws. Dependent variables are 0/1 indicators for having purchased or received (from us) 1+ or 2+ servo motors between baseline and endline. (Means of the dependent variables at baseline are zero.) The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p <0.10; **p <0.05; ***p <0.01.

Effects on Information Flows

	Including T2		Excluding T2	
	Shown report by T2 firm (1)	Discussed servos w/ T2 firm (2)	Shown report by T2 firm (3)	Discussed servos w/ T2 firm (4)
T1	-0.007	0.017	-0.010	0.024
	(0.017)	(0.034)	(0.016)	(0.029)
	[0.018]	[0.046]	[0.018]	[0.046]
T2	0.007	0.056		
	(0.022)	(0.044)		
	[0.020]	[0.050]		
Exposure (500m)	0.029	0.155	0.019	0.224
	(0.013)**	(0.072)**	(0.008)**	(0.063)***
	[0.013]**	[0.058]***	[0.010]**	[0.060]***
Exp. Exposure (500m)	-0.002	-0.018	0.011	-0.141
	(0.013)	(0.115)	(0.012)	(0.094)
	[0.021]	[0.106]	[0.011]	[0.121]
Observations	473	473	325	325
Upazila FE	Y	Y	Y	Y
Strata FE	Y	Y	Y	Y
Rand. Inf. p-value (Exposure)	[0.014]	[0.030]	[0.020]	[0.000]

Notes: Outcome in columns 1 and 3 is a (0/1) indicator for whether the firm reported having seen an electricity use report card that showed electricity usage for both clutch and servo motors and was made available to the information and installation treatment (T2) arm. Outcome in columns 2 and 4 is a 0/1 indicator for whether the firm reported discussing servomotors with a T2 firm among other discussions on business-related activities. The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p $<$0.10; **p $<$0.05; ***p $<$0.01. The randomization inference p-values for the coefficient on the realized exposure term are based on the test statistic recommended by Borusyak and Hull (2023).

Effects on Beliefs and WTP

	Including T2		Excluding T2	
	beliefs about servo kWh/day (1)	WTP (2)	beliefs about servo kWh/day (3)	WTP (4)
T1	-0.020	0.267	-0.021	0.260
	(0.013)	(0.087)***	(0.014)	(0.091)***
	[0.018]	[0.143]*	[0.018]	[0.142]*
T2	-0.082	0.259		
	(0.011)***	(0.094)***		
	[0.018]***	[0.162]		
Exposure (500m)	-0.013	0.084	-0.026	0.035
	(0.029)	(0.232)	(0.032)	(0.272)
	[0.030]	[0.282]	[0.035]	[0.297]
Exp. Exposure (500m)	-0.073	-0.102	-0.091	0.009
	(0.042)*	(0.418)	(0.048)*	(0.362)
	[0.050]	[0.450]	[0.060]	[0.475]
Dep var at baseline	0.051	0.199	0.057	0.133
	(0.041)	(0.050)***	(0.049)	(0.020)***
	[0.031]	[0.046]***	[0.039]	[0.050]***
Observations	473	473	325	325
Baseline mean	0.466	3.104	0.465	3.071
Upazila FE	Y	Y	Y	Y
Strata FE	Y	Y	Y	Y
Rand. Inf. p-value (Exposure)	[0.575]	[0.781]	[0.344]	[0.929]

Notes: Estimates of equation 1 on endline survey data. Exposure (500 m) is a 0/1 indicator for having one or more T2 firm within walking distance of 500 m. Exp. Exposure (500 m) is mean of Exposure from 1,000 counterfactual treatment assignment draws. Dependent variable for columns 1 and 3 is the mean of the distribution of beliefs about electricity use of a servo motor. Dependent variable for columns 2 and 4 is a firm's willingness-to-pay for a servo motor in levels (000s of BDT) and logs, elicited using the Becker, DeGroot and Marschak (1964, BDM) procedure. Bids are in thousands of BDT. Exchange rate is approximately 100 BDT/USD. The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p <0.10; **p <0.05; ***p <0.01. The randomization inference p-values for the coefficient on the realized exposure term are based on the test statistic recommended by Borusyak and Hull (2023).

Effects of Other Channels of Exposure on Adoption

	Network Exposure		Shared-Supplier Exposure		Shared-Mosque Exposure	
	Purchased 1+ servo motors (1)	Purchased 2+ servo motors (2)	Purchased 1+ servo motors (3)	Purchased 2+ servo motors (4)	Purchased 1+ servo motors (5)	Purchased 2+ servo motors (6)
T1	0.102	0.050	0.109	0.054	0.097	0.047
	(0.036)***	(0.018)***	(0.036)***	(0.018)***	(0.036)***	(0.019)**
	[0.042]**	[0.034]	[0.043]**	[0.034]	[0.042]**	[0.034]
Exposure	0.103	0.093	-0.029	-0.044	0.045	0.039
	(0.093)	(0.093)	(0.048)	(0.029)	(0.051)	(0.036)
	[0.085]	[0.069]	[0.074]	[0.054]	[0.075]	[0.057]
Exp. Exposure	-0.116	-0.133	0.110	0.082	0.039	0.007
	(0.119)	(0.154)	(0.059)*	(0.041)**	(0.116)	(0.086)
	[0.113]	[0.095]	[0.085]	[0.065]	[0.093]	[0.068]
Observations	325	325	325	325	325	325
Upazila FE	Y	Y	Y	Y	Y	Y
Strata FE	Y	Y	Y	Y	Y	Y
Rand. Inf. p-value (Exposure)	[0.132]	[0.090]	[0.607]	[0.362]	[0.476]	[0.462]

Notes: Dependent variables are 0/1 indicators for having purchased or received (from us) 1+ or 2+ servo motors between baseline and endline. Exposure, network is 0/1 indicator for whether the firm reported asking for advice about new technology with 1 or more T2 firm(s) at the baseline or midline survey rounds. Expected Exposure (network) is average of Exposure (network) over 1,000 counterfactual treatment assignments. The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p <0.10; **p <0.05; ***p <0.01. The randomization inference p-values for the coefficient on the realized exposure term are based on the test statistic recommended by Borusyak and Hull (2023).

qualitative

Effects of Other Channels of Exposure on Info. Flows

	Network Exposure		Shared-Supplier Exposure		Shared-Mosque Exposure	
	Shown report by T2 firm (1)	Discussed servos w/ T2 firm (2)	Shown report by T2 firm (3)	Discussed servos w/ T2 firm (4)	Shown report by T2 firm (5)	Discussed servos w/ T2 firm (6)
T1	-0.010	0.015	-0.009	0.037	-0.011	0.024
	(0.014)	(0.039)	(0.015)	(0.033)	(0.016)	(0.031)
	[0.018]	[0.045]	[0.019]	[0.047]	[0.018]	[0.047]
Exposure	-0.011	0.219	0.025	-0.023	0.027	0.036
	(0.018)	(0.071)***	(0.013)*	(0.055)	(0.040)	(0.079)
	[0.030]	[0.097]**	[0.013]*	[0.073]	[0.038]	[0.079]
Exp. Exposure	0.029	0.186	-0.010	0.145	-0.004	0.011
	(0.095)	(0.242)	(0.008)	(0.066)**	(0.061)	(0.126)
	[0.055]	[0.153]	[0.022]	[0.089]	[0.053]	[0.103]
Observations	325	325	325	325	325	325
Upazila FE	Y	Y	Y	Y	Y	Y
Strata FE	Y	Y	Y	Y	Y	Y
Rand. Inf. p-value (Exposure)	[0.769]	[0.038]	[0.002]	[0.741]	[0.358]	[0.593]

Notes: Estimates are of equation 1 in text. Data are from endline survey. Outcome in columns 1 and 3 is a (0/1) indicator for whether the firm reported having seen an electricity use report card that showed electricity usage for both clutch and servo motors and was made available to the information and installation treatment (T2) arm. Outcome in columns 2 and 4 is a 0/1 indicator for whether the firm reported discussing servomotors with a T2 firm among other discussions on business-related activities. The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p <0.10; **p <0.05; ***p <0.01. The randomization inference p-values for the coefficient on the realized exposure term are based on the test statistic recommended by Borusyak and Hull (2023).

Effects on Costs, Electricity, Sales & Employment

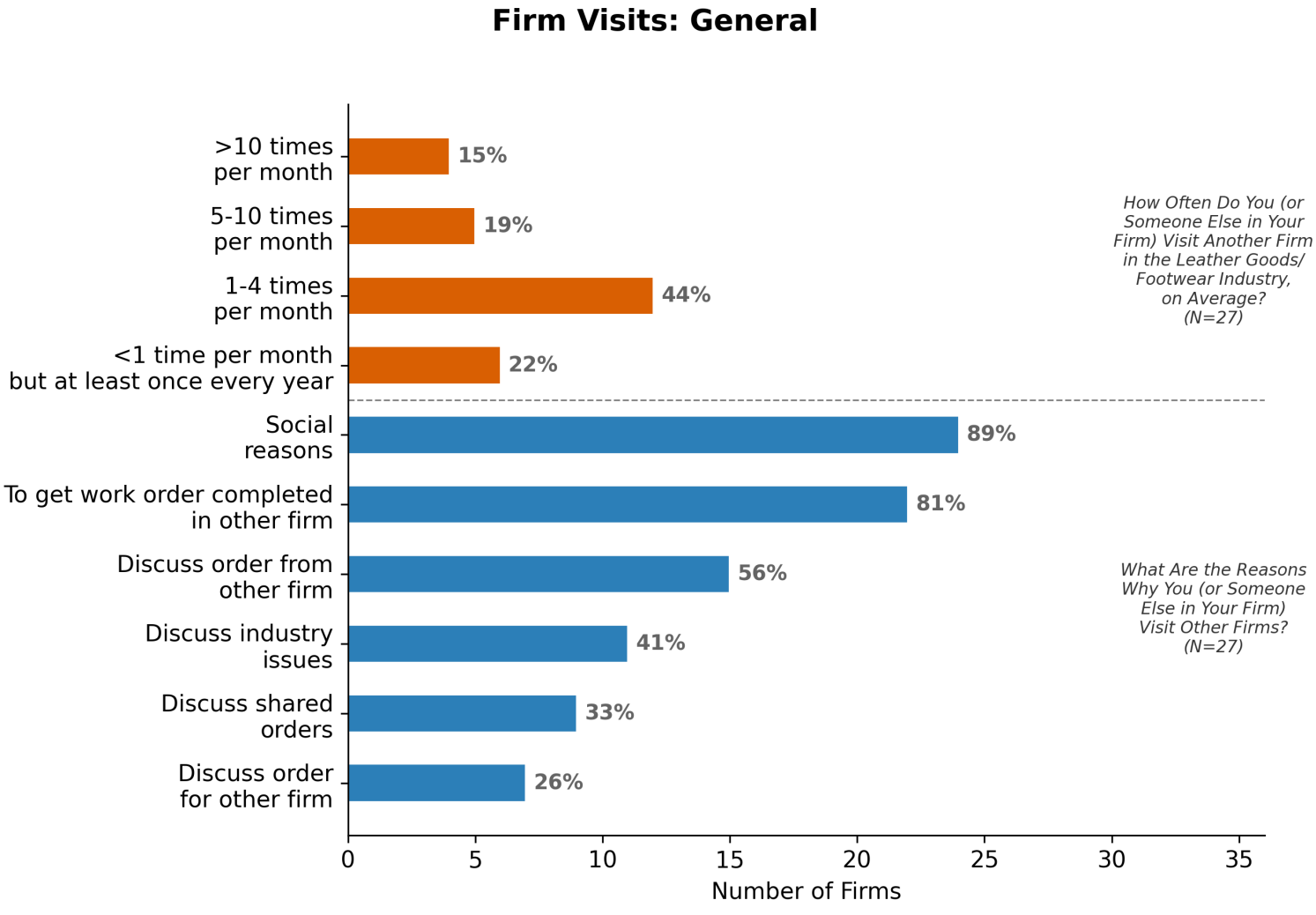
	Including T2				Excluding T2			
	log operating costs per worker (1)	log electricity costs per worker (2)	ihs sales, previous month (3)	log employment (4)	log operating costs per worker (5)	log electricity costs per worker (6)	ihs sales, previous month (7)	log employment (8)
T1	-0.165 (0.049)*** [0.106]	-0.043 (0.042) [0.093]	-0.063 (0.096) [0.170]	-0.023 (0.060) [0.064]	-0.162 (0.045)*** [0.107]	-0.052 (0.037) [0.093]	-0.056 (0.063) [0.169]	-0.029 (0.056) [0.065]
T2	-0.211 (0.071)*** [0.106]**	-0.148 (0.079)* [0.095]	-0.255 (0.236) [0.214]	0.024 (0.043) [0.068]				
Exposure (500m)	0.121 (0.190) [0.177]	0.039 (0.090) [0.140]	0.043 (0.207) [0.212]	-0.003 (0.140) [0.131]	-0.012 (0.207) [0.200]	0.072 (0.119) [0.159]	-0.127 (0.239) [0.234]	0.027 (0.153) [0.136]
Exp. Exposure (500m)	-0.512 (0.303)* [0.292]*	-0.466 (0.216)** [0.238]*	-0.601 (0.333)* [0.334]*	-0.239 (0.194) [0.201]	-0.353 (0.330) [0.335]	-0.446 (0.271)* [0.279]	-0.350 (0.426) [0.376]	-0.383 (0.220)* [0.223]*
Dep var at baseline	0.454 (0.050)*** [0.066]***	0.664 (0.062)*** [0.066]***	0.507 (0.058)*** [0.068]***	0.675 (0.070)*** [0.047]***	0.516 (0.072)*** [0.077]***	0.638 (0.073)*** [0.084]***	0.518 (0.078)*** [0.080]***	0.630 (0.083)*** [0.057]***
Observations	473	473	473	473	325	325	325	325
Upazila FE	Y	Y	Y	Y	Y	Y	Y	Y
Strata FE	Y	Y	Y	Y	Y	Y	Y	Y
Rand. Inf. p-value (Exposure)	[0.464]	[0.767]	[0.797]	[0.981]	[0.965]	[0.563]	[0.492]	[0.809]

Notes: The dependent variable in columns 1 and 3 is log cost of operations per worker; in columns 2 and 4 it is log cost of electricity per worker. Exposure (500m) is 0/1 indicator for having a T2 firm within a walking distance of 500m. Expected Exposure (500m) is average of Exposure (500m) over 1,000 counterfactual treatment assignments. The standard errors in parentheses use the spatial correction from Conley (1999). The standard errors in square brackets are heteroskedasticity-robust (without the correction for spatial correlation). *p <0.10; **p <0.05; ***p <0.01. The randomization inference p-values for the coefficient on the realized exposure term are based on the test statistic recommended by Borusyak and Hull (2023).

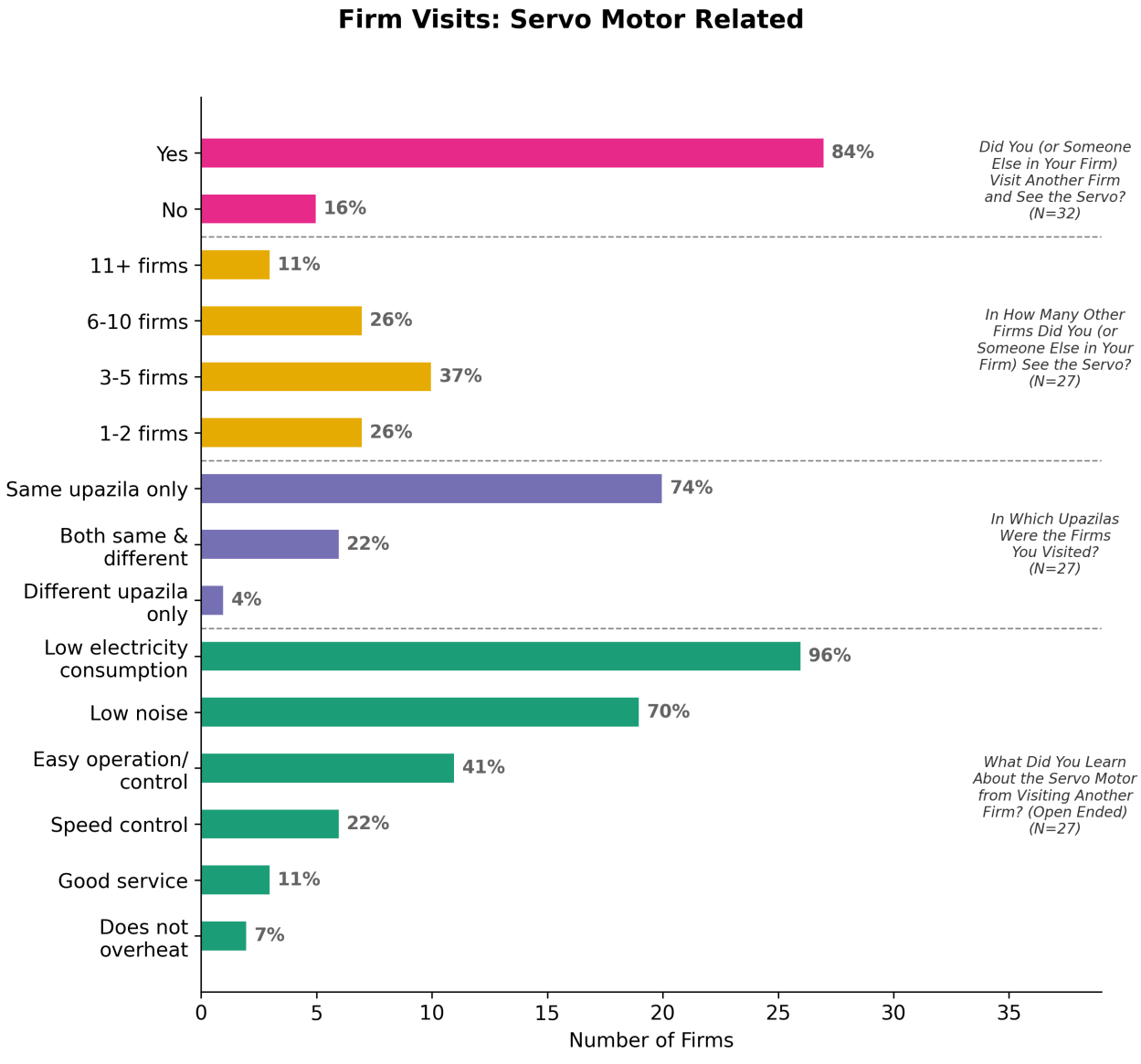
Post-endline Qualitative Survey

- Post-endline, we conducted a qualitative survey with "spillover adopters" to get descriptive evidence on
  - firm-to-firm interactions
  - reasons for adopting servo motors
  - what made the information trustworthy
  - financial calculations/payments for servo motors

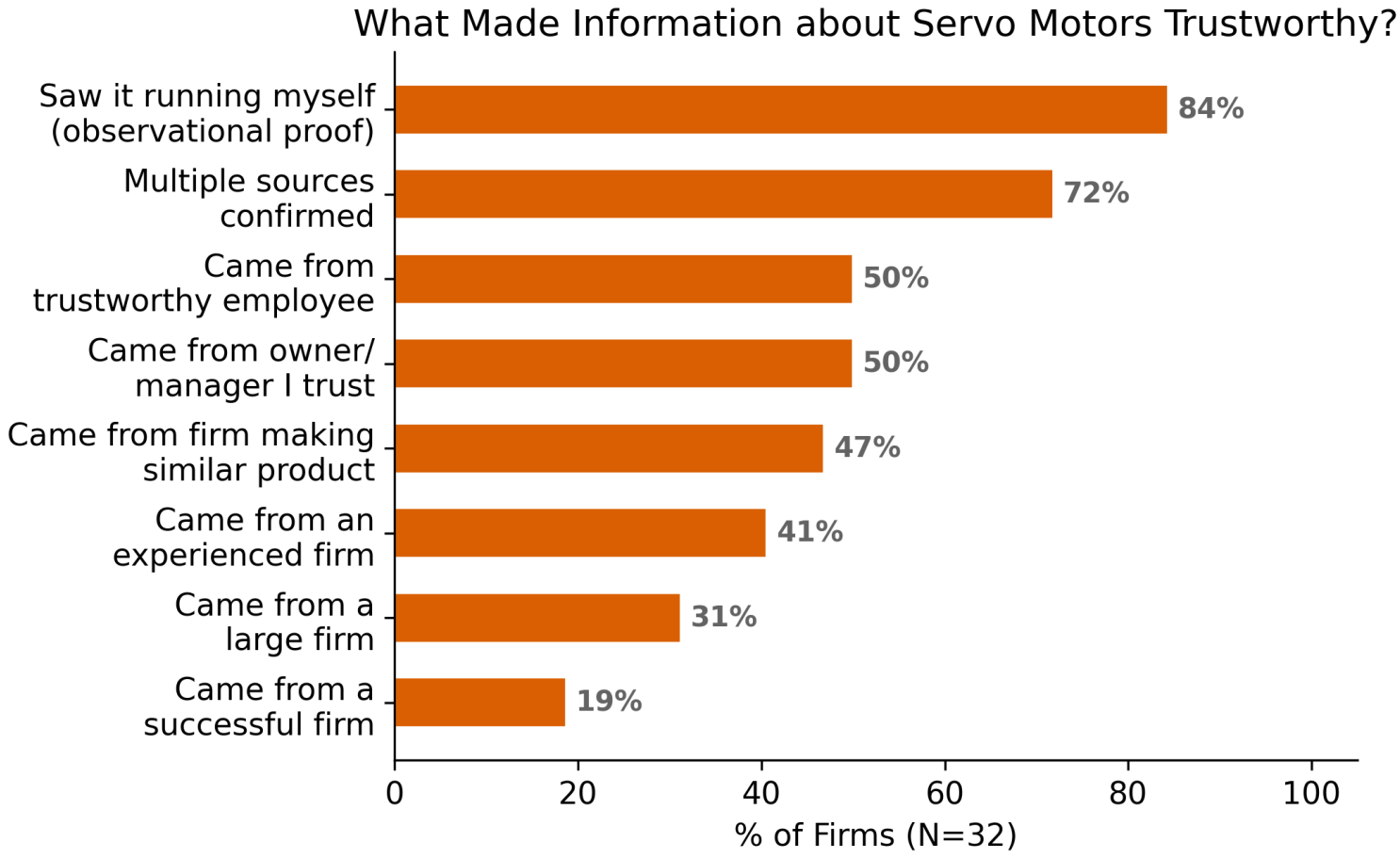
Firm-to-firm interactions (general)



Firm-to-firm interactions (servo motor related)

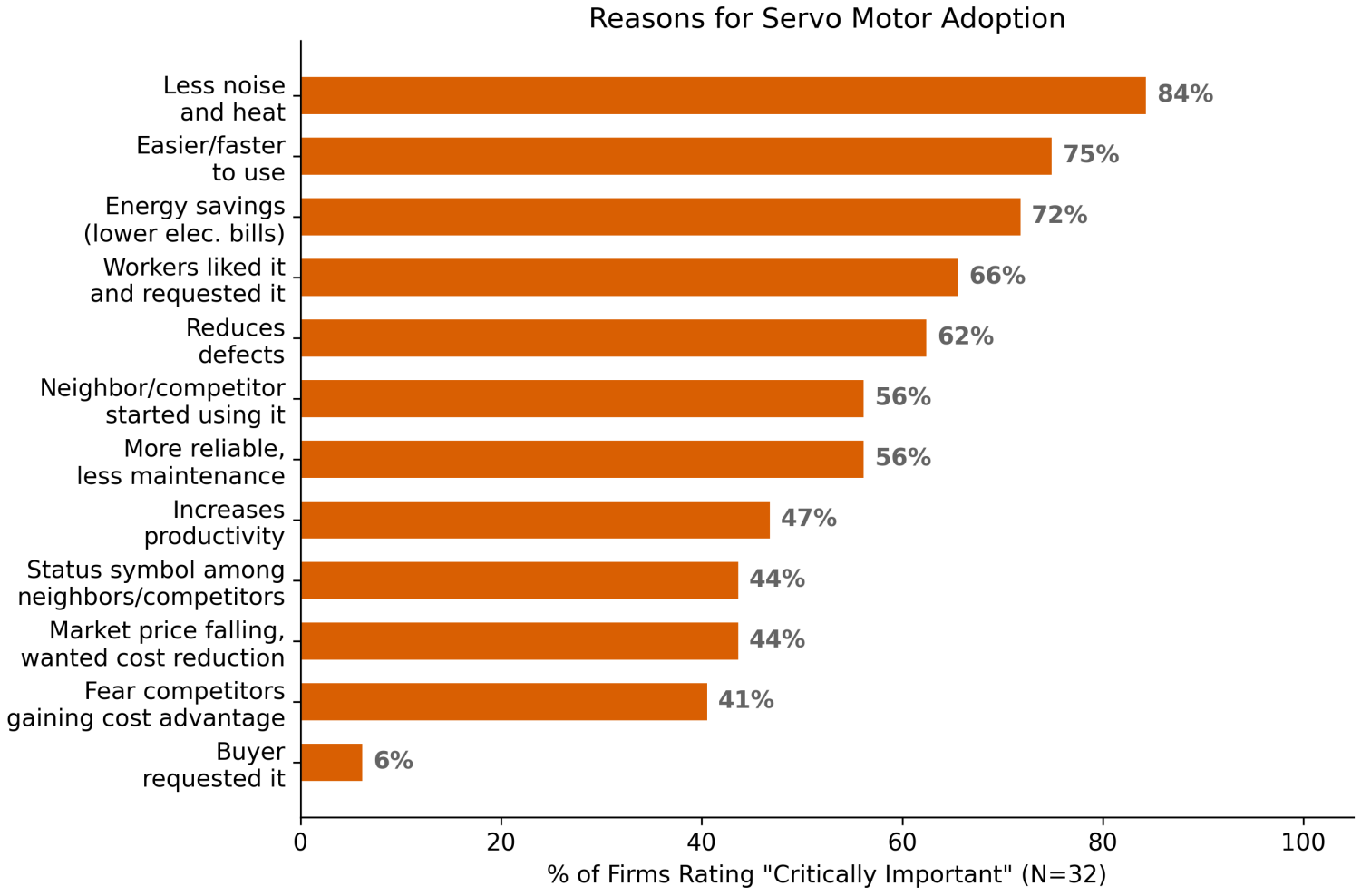


What made the information trustworthy?



Notes: The enumerator emphasized that "adoption" refers to the replacement of a clutch motor with a servo motor on an existing machine. "Information" also relates to the replacement of clutch motors with a servo motor on an existing stitching machine.

Reasons for adopting servo motors



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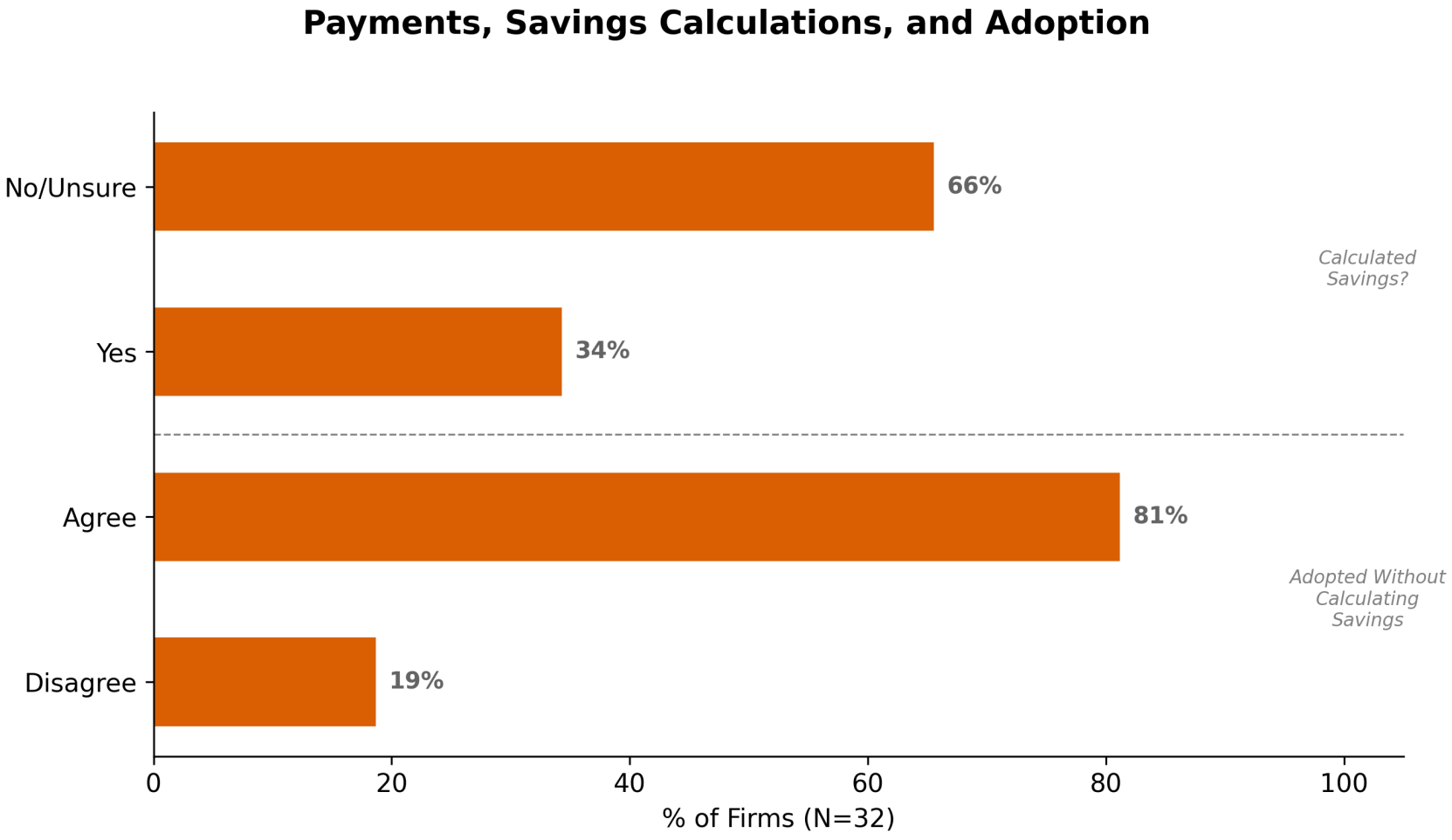
Financial calculations/payments for servo motor



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  - Estimates, qualitative survey consistent with "seeing is believing" interpretation.
- Marginal Vaue of Public Funds (MVPF) calculation: adoption subsidies cost-effective, esp. taking learning spillovers into account.
  - Rationale for green industrial policy in this setting.

MVPF

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Approaches to Estimating Spillovers

- Duflo, Glennerster and Kremer (2008) identify three main approaches:
  1. Saturation designs:
     - e.g. Duflo and Saez (2003).
     - In manufacturing, hard to find enough distinct clusters (using similar technology).
  2. Manipulating social networks:
     - e.g. Cai and Szeidl (2018), Hardy and McCasland (2021), Fafchamps and Quinn (2018).
     - Hasn't been done with a commonly used technology.
  3. Exploiting differences in density:
     - e.g. Miguel and Kremer (2004).
- We pursue 3 in manufacturing context, applying Borusyak and Hull (2023).

return

Electricity in Bangladesh

- Generation is reliant on fossil fuels:
  - 73.1% natural gas
  - 20.1% oil
  - 5.5% coal
  - 1% hydro/solar/wind (in 2021)
  - Many firms use diesel-fueled backup generators.
- Consumption is subsidized (BPDB, 2023):
  - Cost of BPDB own generation: 11.3 BDT/kWh.
  - Cost from independent producers (63% of supply): 14.62 BDT/kWh.
  - Avg. price paid by firms in sample: 12.5 BDT/kWh.
  - Operating revenue/operating expenses for BPDB: 54%.
  - Government subsidy (2022-23): 395b BDT ($\sim$ \$3.95b USD)
- Price to be increased, under pressure from IMF (Byron, 2024).
- Social cost of producing electricity is even higher, given carbon emissions.

return

Payback Period

- Payback period calculation:
  - Avg. kWh/hr clutch motor: 0.064
  - Avg. kWh/hr servo motor: 0.019
  - Electricity cost: 12.5 BDT/kWh

return

Payback Period

- Payback period calculation:
  - Avg. kWh/hr clutch motor: 0.064
  - Avg. kWh/hr servo motor: 0.019
  - Electricity cost: 12.5 BDT/kWh
  - Cost savings per month (assuming 160 hrs/mo):

$$160 * (.064 - .019) * 12.5 = 90 \text{ BDT} \approx \$0.90 \text{ USD}$$

return

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return

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  - Payback period: 4600/90 $\approx$ 51 months.

return

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- Decent return on investment: \$10.8/\$46 = 23.4%/annum

return

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- Decent return on investment: \$10.8/\$46 = 23.4%/annum
- But adoption is not a no-brainer based on electricity costs alone.

return

Opinions about Servo Motors

A. Manager Opinions, Conditional on Perceiving Differences

	Share of managers who perceived difference	Mean score (5 pt. scale) cond. on perceiving difference
Speed	55.18	4.74
Noise	60.04	4.89
Stitching	33.83	4.51
Comfort	56.45	4.76
Heat	57.29	4.77

B. Manager Opinions, Conditional on Having Worked with Servo Motor

	Mean score (5 pt. scale) cond. on owning or working w/ servos
Durability	4.04
Overall Satisfaction	4.87

C. Employee Opinions, Reported by Managers

	Share of managers who discussed servos w/ employee	Mean employee opinion (5 pt. scale)
Employee Opinion	29.18	4.76

Notes: Responses are from endline. N = 285 for Panels A & B, N = 473 for Panel C.

return

Where Firms Learned about Servo/Clutch Swap

		Mean				
	N.Obs	Only Shoes	Only Bags	Mixed	Full Sample	St.Dev
Knows clutch motor is replaceable with servo	473	0.98	1.00	1.00	0.99	0.08
Information Source						
Other firms in the sector	473	0.27	0.42	0.45	0.39	0.49
Other firms in the same locality	473	0.01	0.10	0.08	0.07	0.26
Other firms from a different locality / sector	473	0.02	0.02	0.03	0.02	0.15
Suppliers or buyers	473	0.07	0.05	0.07	0.06	0.24
From (prev.rd/baseline) intervention materials	473	0.88	0.64	0.73	0.73	0.45
Other	473	0.04	0.00	0.05	0.02	0.19

return

Concerns

- Did we induce adoption in control group through BDM procedure?
  - Many firms said at endline that they learned from us (in BDM procedure) that servo can be swapped for clutch motor. Where Learned
  - But we see comparable levels of adoption among "disqualified" firms that did not do BDM. Adoption, Disqualified Firms
- Are we just observing a normal process of diffusion (not driven by experiment)?
  - Could be happening. But it would not explain why re-centered exposure is significant.

Balance at Baseline

	Means			P-value	P-value
	Control	T1	T2	Control=T1	Control=T2
	(1)	(2)	(3)	(4)	(5)
Firm Characteristics					
Num. employees (paid and unpaid)	10.66	10.39	12.17	(0.88)	(0.52)
Production costs, last month ('000,000 BDT)	0.47	0.39	0.50	(0.36)	(0.95)
Profits, last month ('000 BDT)	30.95	26.15	37.63	(0.66)	(0.58)
Sales, last month ('000,000 BDT)	0.52	0.41	0.54	(0.25)	(0.93)
Electricity costs, last month ('000 BDT)	6.27	4.67	5.05	(0.34)	(0.33)
Direct exports, as % of sales	2.03	1.36	1.56	(0.45)	(0.52)
Exporter, direct (0/1)	0.05	0.05	0.03	(0.96)	(0.16)
Respondent Characteristics					
Respondent is male (0/1)	0.96	0.98	0.96	(0.18)	(0.91)
Respondent's years of education	6.09	6.58	6.52	(0.24)	(0.46)
Respondent's age	35.88	36.23	35.34	(0.77)	(0.47)
Respondent's experience	15.47	15.68	14.94	(0.83)	(0.40)
Employees					
Num. employees on payroll	10.66	10.39	12.17	(0.88)	(0.52)
Num. permanent, full-time workers	9.66	9.44	10.88	(0.92)	(0.65)
Num. managers, skilled professionals	1.38	1.48	1.57	(0.62)	(0.39)
Num. production-line workers (total)	9.97	9.62	11.41	(0.86)	(0.53)

Notes: Share of firms by main product: 24% only shoes, 49% only bags, 27% mixed/other. Costs, sales, employment variables winsorized at 1st/99th percentiles. Data are from baseline survey. N = 505.

return

Balance at Baseline (cont.)

	Means			P-value	P-value
	Control	T1	T2	Control=T1	Control=T2
	(1)	(2)	(3)	(4)	(5)
Number of Machines					
Num. machines (total)	5.93	6.12	6.62	(0.65)	(0.59)
Num. machines (non-motorized)	0.25	0.16	0.16	(0.18)	(0.16)
Num. machines (w/ ext. motor)	0.18	0.19	0.24	(0.86)	(0.51)
Num. machines (w/ clutch motor)	4.99	4.81	5.39	(0.72)	(0.83)
Num. machines (w/ servo motor)	0.68	0.83	0.80	(0.56)	(0.92)
Firm has Servo at Baseline (0/1)	0.15	0.19	0.15	(0.25)	(0.63)
Beliefs					
Beliefs, elec usage (kwh/day) for clutch motor	0.66	0.67	0.70	(0.79)	(0.22)
Beliefs, elec usage (kwh/day) for servo motor	0.47	0.46	0.47	(0.79)	(0.79)
BDM bid ('000 BDT)	3.05	3.10	3.16	(0.73)	(0.60)
Beliefs, price of electricity (BDT/kwh)	11.17	10.94	10.96	(0.24)	(0.31)
Knows servo can swap for clutch (0/1)	0.59	0.53	0.54	(0.24)	(0.26)

return

Willingness-to-Pay Elicitation

- Becker, DeGroot and Marschak (1964, BDM) procedure.
  - Give subject a voucher for 10,000 BDT ($\sim$ \$100).
  - Show subject the servo motor.
  - Start with minimal price. Ask: would you purchase at this price?
  - If so, raise price and ask again. Repeat until reach max WTP.
  - Subject draws price chit from bag.
  - If drawn price is below stated max price, reduce voucher amount by drawn price, return later to install servo motor.
  - Transfer remainder from voucher via mobile money account.

return

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  - Transfer remainder from voucher via mobile money account.
- Treatment arms corresponded to different bags of chits.
  - All bags had prices between 0 and 10,000 BDT.
  - C, T1a, T1b: right-skewed (almost all prices near 10,000 BDT).
  - T2: left-skewed (almost all prices near 0).
  - Small number of C/T1 firms got low price, T2 firms got high price.

return

Belief Elicitation

- We elicited the distribution of subjects' beliefs about:
  - Electricity usage of clutch motor
  - Electricity usage of servo motor
  - Price of electricity
  - Payback period for servo motor

return

Belief Elicitation

- We elicited the distribution of subjects' beliefs about:
  - Electricity usage of clutch motor
  - Electricity usage of servo motor
  - Price of electricity
  - Payback period for servo motor
- For half of sample, we incentivized reports using Quadratic Scoring Rule (Schotter and Trevino, 2014):
  - Divide range into n bins.
  - r_k = probability assigned to bin k, where $\sum_{k=1}^{n} r_k = 1$.
  - $I_k = 0/1$ indicator if bin is correct.

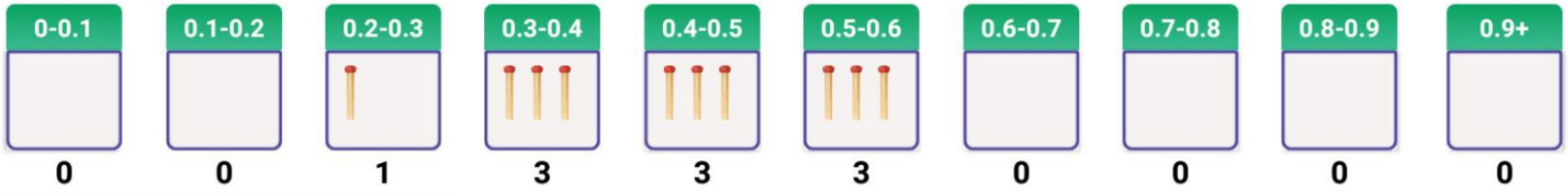
$$\begin{aligned} QSR(\vec{r}) &= \alpha - \beta \left[\sum_{k=1}^{n} (I_k - r_k)^2 \right] \\ &= \alpha - \beta (1 - r_j)^2 - \beta \left(\sum_{k \neq j} r_k^2 \right) \end{aligned}$$

  where j is correct bin.
  - Induces truth-telling if individuals are expected utility maximizers and risk-neutral.

return

Belief Elicitation

1) Imagine a firm similar to yours. For the firm, think of the number of units of electricity (kWh) used by a typical sewing machine with a clutch motor in an average day with an eight-hour shift and normal scheduled breaks. What is the probability that the firm will have electricity usage (in kWh per day) for that machine in each of the following bins?



Box	Earned
If 0-0.1 is correct	180.0
If 0.1-0.2 is correct	180.0
If 0.2-0.3 is correct	230.0
If 0.3-0.4 is correct	330.0
If 0.4-0.5 is correct	330.0
If 0.5-0.6 is correct	330.0
If 0.6-0.7 is correct	180.0
If 0.7-0.8 is correct	180.0
If 0.8-0.9 is correct	180.0
If 0.9+ is correct	180.0

Drag from here

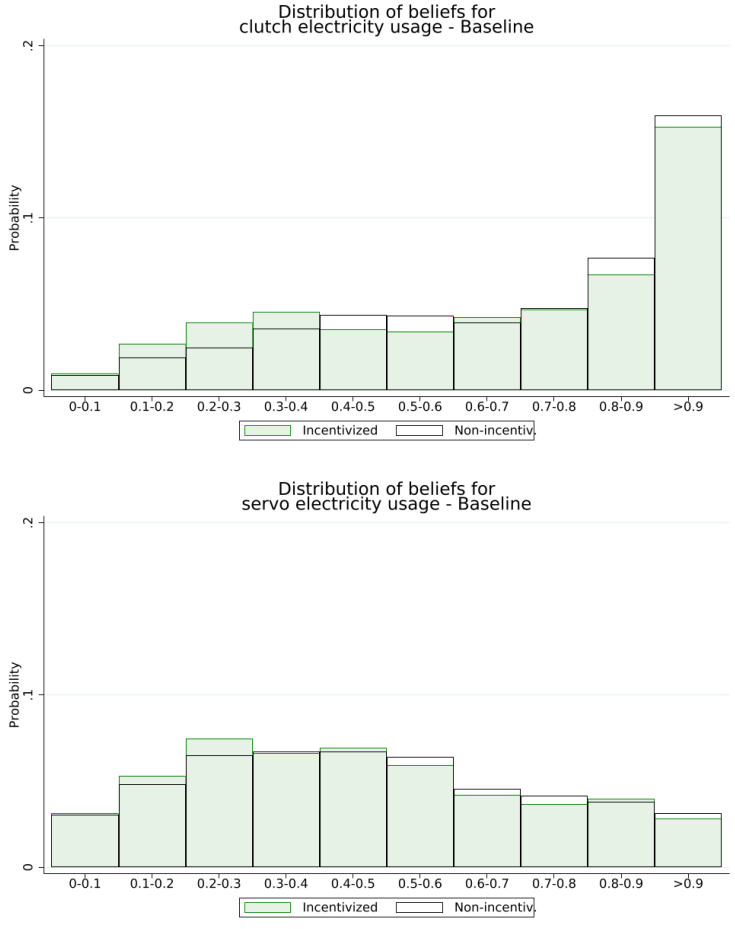
0

Click on icon and drag it to your desired box

SUBMIT

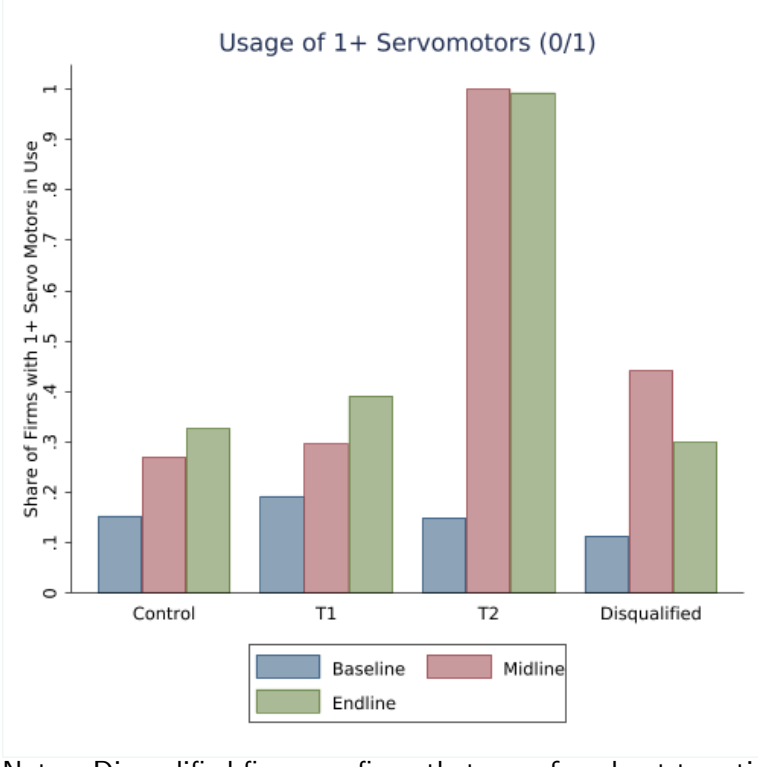
return

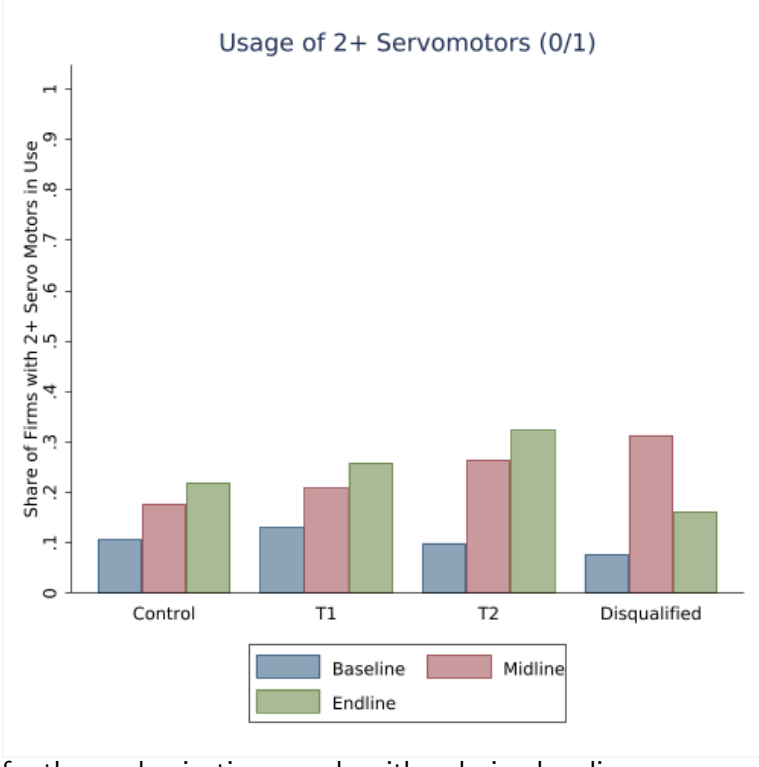
Incentivized vs. Non-Incentivized Beliefs, Baseline



return

Simple Comparisons, Incl. Disqualified Firms

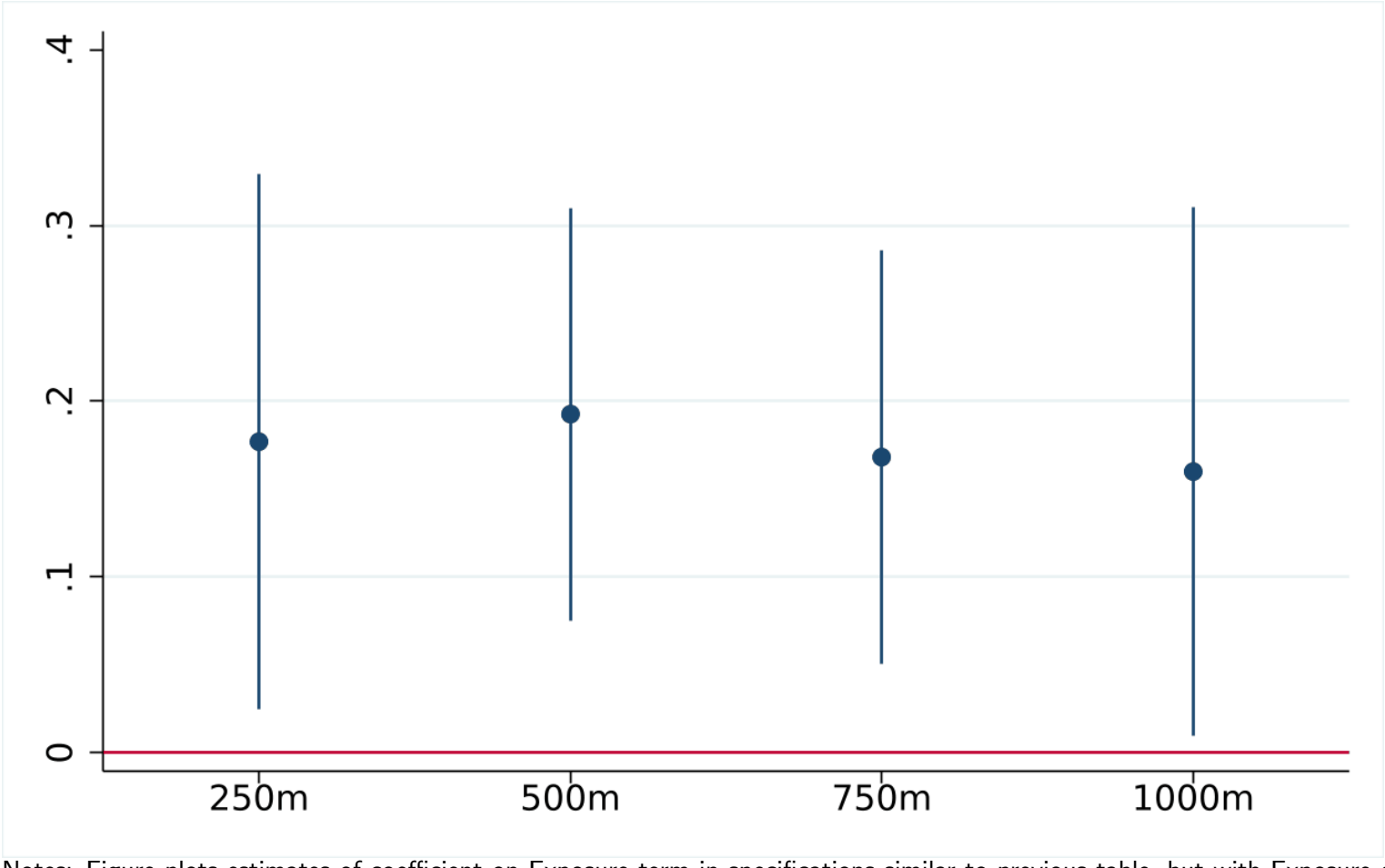




Notes: Disqualified firms are firms that were found not to satisfy criteria for the randomization sample, either during baseline survey or before implementation of BDM. The usage of servomotors reflects whether the firm reported using at least one (or at least two) machines with a servo motor at the time of the survey round.

Return

Spillovers in Adoption, by Distance



Notes: Figure plots estimates of coefficient on Exposure term in specifications similar to previous table, but with Exposure defined as any T2 firm within a walking distance of Xm. T2 firms excluded from estimation sample; regressions are similar to Column 3 of previous table.

spillovers-by-distance-adoption-nt2

Return

Why Did Firms Not Adopt?

		Mean				
	N.Obs	Only Shoes	Only Bags	Mixed	Full Sample	St.Dev
Financial constraints	396	0.42	0.37	0.29	0.36	0.48
Sewing machine operators unwilling	396	0.06	0.06	0.22	0.11	0.31
Don't know where to find a servo motor	396	0.25	0.11	0.16	0.16	0.37
Would adopt if current motor breaks	396	0.05	0.07	0.04	0.06	0.23
Would adopt if upgrading all machines	396	0.00	0.02	0.01	0.01	0.10
No need	396	0.10	0.16	0.18	0.15	0.35
No experience with Servo Motor	396	0.05	0.02	0.00	0.02	0.15
Low on business or workers	396	0.06	0.04	0.03	0.04	0.20
Not Satisfied, or Other Reason	396	0.00	0.01	0.02	0.01	0.10
Satisfied with Clutch Motor	396	0.06	0.06	0.08	0.06	0.24

Notes: The sample is restricted to firms that had not purchased an additional servomotor by the endline survey round.

return

MVPF Calculation

- Marginal Value of Public Funds (Mayshar, 1990; Slemrod and Yitzhaki, 1996; Kleven and Kreiner, 2006; Hendren and Sprung-Keyser, 2020; Hahn et al., 2024):

$$MVPF = \frac{\sum_i WTP_i}{\text{net cost to govt}}$$

  - Allows for direct comparisons across policies.
  - Hendren and Sprung-Keyser (2020), Hahn et al. (2024) consider MVPFs>5 to be high.
  - We follow Hahn et al. (2024), who show how to incorporate learning externalities into calculation.

return

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- We consider MVPF of fully subsidizing adoption of 1 servo motor.

return

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- We consider MVPF of fully subsidizing adoption of 1 servo motor.
- Net cost to government: $46.

return

MVPF Calculation (cont.)

- Need to consider three groups of beneficiaries:
  1. T2 firms induced to adopt by subsidy ("adopter T2s").
  2. T2 firms that would have adopted anyway ("inframarginal T2s").
  3. Spillover adopters.

return

MVPF Calculation (cont.)

- Need to consider three groups of beneficiaries:
  1. T2 firms induced to adopt by subsidy ("adopter T2s").
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  3. Spillover adopters.
- We simulate spillovers using our estimates, allowing for 1st & 2nd degree spillovers, assuming 1/3 of firms are treated.
  $\Rightarrow$ 1.5 spillover adopters per T2 firm.

return

MVPF Calculation (cont.)

- Need to consider three groups of beneficiaries:
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- We simulate spillovers using our estimates, allowing for 1st & 2nd degree spillovers, assuming 1/3 of firms are treated.
  $\Rightarrow$ 1.5 spillover adopters per T2 firm.
- CO2 emissions abatement:
  - Electricity savings per hour: .064 - .019
  - Hours per year: 160 * 12
  - Operating Margin Grid Emission Factor for Bangladesh (U.N. Framework Convention on Climate Change, 2021): 528 grams of CO2 emissions per kWh

  $\Rightarrow$ 0.046 metric ton reduction per servo motor per year
  - Social cost of carbon (EPA, 2023): \$193/metric ton.
  - Assume 2% discount rate (Hahn et al., 2024).
  - Assume servo motors operate for 10 years.

  $\Rightarrow$ PDV of environmental benefit from switching one machine to servo motor: $\sim$\$80.

return

MVPF Calculation (cont.)

- Need to consider three groups of beneficiaries:
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  - Assume servo motors operate for 10 years.

  $\Rightarrow$ PDV of environmental benefit from switching one machine to servo motor: $\sim$\$80.
- PDV of private benefit (\$.90/month): $\sim$\$99.

return

MVPF Calculation (cont.)

	Adopter type			
	Adopter T2	Inframarginal T2	Spillover adopter	Total
(A) Number of adopters per subsidized motor	0.84	0.16	0.59	1.59
(B) Private WTP per adopter	PDV of electricity savings (=98.95)	Subsidy value (=46.00)	PDV of electricity savings minus cost of motor (=52.95)	197.90
(C) Social WTP per adopter	PDV of C02 averted valued using SCC (=80.26)	None	PDV of C02 averted valued using SCC (=80.26)	160.52
(D) Total WTP per subsidized motor = A*(B + C)	150.54	7.36	78.36	236.26
(E) Public cost per subsidized motor	46.00	46.00	46.00	46.00
MVPF = D/E	3.27	0.16	1.70	5.14

Notes: The calculation uses the US Environmental Protection Agency (EPA) estimate of the Social Cost of Carbon (SCC) of $193 in 2020 (EPA, 2023) and a discount rate of 2% per annum for consistency with the MVPF estimates reported in Haaland et al. (2023). New servo motors are assumed to have a life of 10 years. The estimate of the number of spillover adopters per subsidized motor, 1.5, includes first and second degree spillovers, assuming a T2 seeding rate of 1 in 3, as discussed in subsection **??**. The direct adoption causal impact per subsidized motor, 0.8, is based on the main T2 impact estimate reported in table **??**. Benefits from the abatement of other greenhouse gases and local pollution benefits, such as PM2.5 abatement, are not included.

return

Pre-Analysis Plan Debate

- In RCT registration (AEARCTR-0007432), outcomes were:
  - Adoption
  - Beliefs
  - Willingness to pay
  - Electricity cost savings, sales, employment
- Did not specify T1a vs. T1b; only had T1 information-only group.
- We did not pre-specify regressions.
  - Influenced by Banerjee et al. (2020):
    - PAPs may discourage new theories/ideas from being explored.
    - New techniques may become available.
  - Influenced by experience in Atkin et al. (2017):
    - One learns a lot in the process.
    - Especially in areas where not a lot of work has been done.
- PAPs seem especially important when:
  - Stakes are high, e.g. drugs.
  - Literature is mature, e.g. conditional/unconditional cash transfers.
- Many problems can be solved by (a) registration and (b) replications.