

¹ Financial Incentives and Healthcare Provision: Evidence
² from an Experimental *Aedes aegypti* Control Programme
³ in Brazil*

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⁵ 24 February 2021

*We thank Taylor Boas, Saad Gulzar, Cathy Hafer, Daniel Hidalgo, Dimitri Landa, Rebecca Morton, Adam Przeworski, Catarina Roman, Renard Sexton, David Skarbek, Denis Stukal, and participants at EGAP, MPSA, NYU PE Seminar, and SPSA for their valuable comments. We also thank the FGV Applied Research Centre for funding this research. Each named author has equally contributed to conducting the underlying research and drafting this manuscript. To the best of our knowledge, the authors have no conflict of interest, financial or otherwise. Replication materials are available at <http://github.com/danilofreire/incentives-healthcare>.

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6

Abstract

7 **Background.** Mosquito control is the most effective means of reducing *Aedes aegypti* infections worldwide.
 8 In many developing countries, however, vector management programmes fail to reach their goals due
 9 to low worker productivity. Research suggests that financial incentives may increase the productivity
 10 of health personnel, yet there is little evidence about the impact of monetary rewards on *A. aegypti*-
 11 reduction strategies. We evaluated whether individual and collective financial incentives improve the
 12 performance of healthcare workers fighting *A. aegypti*, as well as their effect on city-level numbers of
 13 dengue hospitalisations.

14 **Methodology/Principal findings.** We hired and trained subjects to visit households, find *A. aegypti*
 15 breeding sites, and eliminate mosquito larvae in the city of Rio Verde, Brazil. We randomly assigned
 16 workers into three groups. The control group received a flat compensation for their tasks, while workers
 17 in the two treatment groups received individual and collective monetary bonuses, respectively. Financial
 18 rewards increased the number of cleaned breeding sites in both treatment groups (individual and team
 19 bonuses), and the collective treatment also improved larvae extermination. The intervention lowered
 20 dengue hospitalisations in 10.3%, but the result was not consistent across all model specifications.

21 **Conclusions/Significance.** *A. aegypti* control programmes may benefit from alternative compensation
 22 schemes, especially when provided to teams. For this strategy to succeed, financial incentives have to be
 23 distributed widely as their aggregate effect is limited. More research is needed to assess whether higher
 24 worker productivity decreases dengue hospitalisations.

25

Author Summary

26 Diseases transmitted by the *Aedes aegypti* mosquito, such as chikungunya, dengue, yellow fever, and
 27 Zika, continue to affect thousands of people per year. As there are no safe vaccines for most of these
 28 infections, insecticide spraying and breeding site elimination are the best means to fight the mosquito. In
 29 several developing countries, which host the majority of *A. aegypti* infections, anti-mosquito campaigns
 30 are carried out inconsistently, thus it is crucial to find ways to improve the productivity of healthcare
 31 workers in charge of these tasks. We designed a randomised field experiment that provided individual and
 32 collective financial incentives to healthcare agents in a Brazilian city, and we tested the effect of monetary
 33 rewards on their productivity and on city-level dengue hospitalisations. We find that financial bonuses
 34 improved the number of cleaned breeding sites in both treatment groups (individual and team incentives)
 35 and that the collective treatment also improved larvae extermination. The impact of our treatment on
 36 city-level hospitalisations was not consistent across all specifications. In sum, financial incentives may be
 37 used to boost field productivity in anti-*A. aegypti* programmes, but further research is required to evaluate
 38 how healthcare worker productivity impacts dengue outcomes.

39 **Keywords:** *Aedes aegypti*, dengue, financial incentives, mosquito control, preventive healthcare, ran-
 40 domised field experiment, worker productivity

41 1 Introduction

42 The *Aedes aegypti* mosquito is the major worldwide vector of several arboviral diseases, including
43 chikungunya, dengue, yellow fever, and Zika [1, 2, 3, 4, 5]. Over the last decades, arboviral incidence
44 has increased exponentially, with estimates suggesting that dengue is endemic in over 100 countries
45 and causes 400 million infections and 22 thousand deaths each year [6, 7]. Since there are no
46 safe vaccines for most *Aedes*-transmitted diseases [8], we have seen a number of dengue and Zika
47 outbreaks in Asia, the Caribbean, South America, and the United States [9, 4]. Chikungunya virus,
48 previously endemic only to Africa, has already been reported in every region of the world [10, 11, 12].

49 Mosquito control is the primary strategy to prevent *Aedes*-borne infections [13, 14]. The World
50 Health Organization recommends the cleaning of containers and the use of insecticide to reduce
51 vector breeding, especially in settings where human-vector contacts are frequent, such as schools,
52 hospitals, and workplaces [15, 16]. However, breeding site elimination and insecticide spraying are
53 labour-intensive processes, which are often carried out inconsistently by developing states [17, 18, 15].
54 In this regard, improving their health agency's performance in mosquito control is essential to the
55 effectiveness of anti-*Aedes* programmes.

56 Research shows that financial incentives may increase the productivity of healthcare workers
57 [19, 20, 21]. Nevertheless, systematic reviews indicate that the internal validity of the available
58 evidence is limited due to methodological shortcomings, as several studies suffer from selection
59 bias and inadequate experimental blinding [22, 23, 24]. The reviews also point out that it remains
60 unclear which rewarding schemes have a stronger impact on healthcare worker performance [25]
61 and whether monetary incentives have any sustained effects on patient outcomes [26, 27].

62 In this paper, we explore how financial incentives affect the productivity of healthcare personnel
63 involved in *A. aegypti* control and how they impact dengue hospitalisations. We ran a randomised
64 field experiment in the city of Rio Verde, Brazil, which has experienced a peak in dengue infections
65 in recent years. We hired and trained teams of healthcare workers to perform simplified procedures
66 designed to exterminate *A. aegypti* breeding sites. Our experiment consisted of two treatment arms
67 plus a control condition. We offered individual or collective bonuses to those allocated in the two
68 treatment groups, while the control group received a fixed compensation for completing their tasks.
69 We then measured how the different reward schemes affected the number of breeding sites discovered,
70 larvae exterminated, and city-wide dengue incidence.

71 We find that monetary rewards increase the number of cleaned breeding sites in both treatment
72 conditions (individual and team bonuses), and that collective financial incentives also improve larvae
73 extermination. Our results show that the control group has a high number of houses visited in less
74 than two minutes apart from each other, which suggests that workers may cheat in the absence of
75 monetary incentives. When we combine both treatments, we also find that the intervention decreases
76 dengue incidence in 10.3%, but the results are not robust. In summary, we provide experimental
77 evidence that performance bonuses enhance public service delivery and that small financial incentives
78 may improve patient outcomes and reduce hospitalisations in *Aedes*-endemic countries.

79 2 Methods

80 We conducted a randomised field trial in Rio Verde, a municipality in the Brazilian Midwestern state
81 of Goiás. In 2017, Rio Verde had 229,000 inhabitants and 1,156 confirmed dengue cases, one of highest
82 counts in the state [28]. We used Facebook advertisements to recruit potential participants. The
83 advertisements directed applicants to Google Forms, where we asked for their contact information.
84 We sent a pre-treatment demographic survey to every applicant who provided a valid email address.
85 At this stage, we excluded all individuals under 18 years old and invited the remaining applicants to
86 our training session, which we ran on the 4th of May, 2018. The meeting involved a lecture on *A.*
87 *aegypti* vector biology and practical instructions on how to find and exterminate mosquito breeding
88 sites. Those who did not attend the session were also excluded from the study.

89 Table 1 displays the attrition rates and the covariance balance tests for our experiment. The
90 last two tables report the values for our territorial assignment before and after applying propensity
91 score matching [29] on census tract characteristics. We observe no significant differences regarding
92 attrition rates, indicating that the treatment was correctly randomised. Participant demographics are
93 also similar across all groups, which suggests that the matching technique successfully balanced the
94 territorial assignment.

95 The intervention took place on the 5th of May, 2018. We randomly assigned subjects into three
96 groups and directed each group to separate headquarters to avoid spillovers. In the control group (n =
97 58), we told participants that they would receive a flat payment regardless of their performance (BRL
98 110 / USD 25 per subject). In the individual treatment group (n = 64), we informed participants that
99 we would rank each one of them separately and double the compensation for those who performed

Table 1: Covariate Balance on Individual Characteristics

Variable	Attrition	Control	Individual	Collective	F-Statistic	P-Value
Panel A: Attrition Pattern Test						
Age	26.62	24.74	26.02	26.19	1.056	0.367
Female	0.73	0.81	0.72	0.7	0.723	0.539
Has Vehicle	0.37	0.29	0.34	0.41	0.666	0.574
N	263	58	64	74		
Variable	Control	Individual	Collective	F-Statistic	P-Value	
Panel B: Covariate Balance on Individual Characteristics						
Age	24.74	26.02	26.19	0.751	0.473	
Altruist	0.62	0.66	0.61	0.176	0.839	
Religiosity	0.52	0.38	0.43	1.257	0.287	
Pol. Engagement	0.64	0.66	0.7	0.335	0.716	
Soc. Engagement	0.55	0.59	0.64	0.467	0.627	
Above Two Min. Wage	0.34	0.38	0.28	0.671	0.513	
Facebook Popularity	0.53	0.58	0.49	0.576	0.563	
Panel C: Unmatched Covariate Balance on Territorial Assignment						
Number of Houses	276.41	243.58	255.2	2.368	0.098	
Number of Households	885.67	750.34	785.18	3.765	0.026	
Avg. Household Size	3.21	3.07	3.07	6.566	0.002	
Log Avg. Income	6.47	6.86	6.85	9.213	0	
Cases Before Treatment	13.78	5.94	4.66	15.638	0	
Panel D: Matched Covariate Balance on Territorial Assignment						
Number of Houses	276.41	282.04	283.5	0.178	0.837	
Number of Households	885.67	903.04	907.14	0.154	0.858	
Avg. Household Size	3.21	3.21	3.2	0.019	0.981	
Log Avg. Income	6.47	6.45	6.46	0.071	0.931	
Cases Before Treatment	13.78	10.24	10.91	1.791	0.171	
Pairs	29	32	37			
N	58	64	74			

above the sample median (BRL 220 / USD 50 per subject). In the collective treatment group ($n = 74$), we explained that we would rank the performance of each group and double the payment for those teams whose results were higher than the sample median (BRL 220 / USD 50 per subject). Participants worked in pairs and were aware of other groups, but they did not know about the different treatment conditions. The teams received a leaflet with a map of the area they should cover. Each route included around 120 houses in two or three blocks.

A typical household visit consisted of the following steps. First, participants rang the doorbell and explained that the municipality had experienced a dengue fever outbreak. They instructed dwellers on how to lower dengue incidence and handed them a leaflet with information about dengue

¹⁰⁹ prevention practices. Then, subjects asked whether they were allowed to inspect the resident's house
¹¹⁰ yard. If granted permission, they entered the household and searched for clean breeding sites, such
¹¹¹ as pots filled with clear water, and for recipients containing larvae. Upon exterminating a breeding
¹¹² site (pouring out the accumulated water, for example), subjects had to report their task by taking a
¹¹³ photo on their cellphones. When they discovered larvae, participants had to record a short video
¹¹⁴ showing the larvae before exterminating them. At the end of each visit, subjects had to take a picture
¹¹⁵ of the household to account for their presence in the location.

¹¹⁶ This study evaluates two outcomes. The first outcome is the field productivity of healthcare
¹¹⁷ providers. We measure worker productivity by coding cellphone data collected during the intervention
¹¹⁸ into four indicators: 1) the number of breeding sites removed and cleaned; 2) the number of
¹¹⁹ exterminated larvae; 3) the number of houses visited; 4) the number of houses visited within less
¹²⁰ than two minutes. We analyse the data using ordinary least squares with robust standard errors [30].
¹²¹ We estimate the statistical power of the study assuming a treatment effect of 0.15 standard deviations.

¹²² The second outcome of interest is dengue incidence in the municipality of Rio Verde measured
¹²³ 4, 8, 12, and 16 days after the intervention. The Rio Verde Mayor's Office provided us with its
¹²⁴ annual healthcare report, which contains the dates and personal information of patients who had
¹²⁵ dengue fever and received hospital treatment from January to September 2018. We georeferenced
¹²⁶ the home addresses of the patients and compared the incidence map with the distribution of our
¹²⁷ intervention. We also compare dengue incidence in each of the treatment statuses with incidence
¹²⁸ figures in the control group. In both models, the unit of analysis is the census tract. We employ a
¹²⁹ differences-in-differences estimator to measure the treatment effects [31].

¹³⁰ We pre-registered the experiment on the Evidence in Governance and Policy (EGAP) website
¹³¹ (<https://osf.io/6q8vu/>), and received IRB approval from New York University (IRB-FY2017-17)
¹³² and Fundação Getulio Vargas (IRB-01/2017). The funders of this study had no influence over the
¹³³ formulation, organisation, analysis, and interpretation of the outcomes. Healthcare workers gave
¹³⁴ written consent upon filling the Qualtrics questionnaire. During the intervention, the occupants of
¹³⁵ households inspected for breeding sites and larvae gave oral consent. For more information on the
¹³⁶ experimental design, sample characteristics, exclusion criteria, and estimation methods, please refer
¹³⁷ to the Supplementary Material.

¹³⁸ 3 Results

¹³⁹ We find that financial incentives significantly increase the field productivity of healthcare workers
¹⁴⁰ fighting *Aedes aegypti*. Subjects in both the individual and the collective bonus groups locate more
¹⁴¹ mosquito breeding sites and exterminate more larvae than participants in the control condition. Our
¹⁴² results also show the intervention decreases city-wide levels of dengue incidence, but the coefficients
¹⁴³ only reach statistical significance when we combine the two treatments and contrast them with the
¹⁴⁴ control group. Overall, the findings suggest that monetary payments are an effective method of
¹⁴⁵ improving health worker performance, yet more research is needed to assess whether higher labour
¹⁴⁶ productivity leads to fewer dengue-related hospitalisations.

¹⁴⁷ 3.1 Field Productivity

¹⁴⁸ Table 2 summarises the experimental results. Subjects who receive monetary incentives find and
¹⁴⁹ clean more breeding sites than those who earned a flat compensation fee. Workers in the individual
¹⁵⁰ treatment group find 25.118 (CI: [16.51, 33.726]) more breeding sites than the non-incentivised control
¹⁵¹ group. The effect for those in the collective bonus group is 21.921 (CI: [15.235, 28.607]), slightly
¹⁵² smaller than for the individual treatment. This finding suggests that the treatment does improve the
¹⁵³ performance of healthcare workers.

Table 2: Field Productivity

	<i>Dependent variable:</i>			
	Breeding Sites Terminated	Larvae Terminated	Houses Visited	Houses Visited in Less than Two Minutes
	(1)	(2)	(3)	(4)
Individual Bonus	25.118*** (5.208)	0.039 (0.056)	-9.081* (4.836)	-7.385* (3.960)
Collective Bonus	21.921*** (4.045)	0.184** (0.075)	-6.267 (4.371)	-5.438 (3.524)
Observations	196	196	196	196
Residual Std. Error (df = 193)	30.540	0.421	27.187	22.062

Note:

*p<0.1; **p<0.05; ***p<0.01
Robust standard errors in parenthesis.

154 Teams who received collective bonuses are the most effective in finding larvae. Subjects who
155 worked under this treatment status have a 18.4% (CI: [6.1%, 30.7%]) higher likelihood of finding larvae
156 than those in the control group. Locating mosquito larvae is a difficult task, thus the probability of
157 successfully completing the task increases when subjects work in teams. Furthermore, our collective
158 bonus scheme was not excludable within the teams, thus healthcare workers had an incentive to
159 cooperate and receive higher rewards.

160 Subjects who received monetary incentives visited fewer houses than those who did not earn
161 financial rewards. The result is statistically significant for the individual treatment group. While the
162 finding seems counter-intuitive, it actually attests the effectiveness of the treatment. This is because
163 we offered incentives for subjects to exterminate larvae and find breeding sites, not to visit a greater
164 number of households. As a result, participants in the treatment groups did a thorough job in each
165 household, which explains the lower number of visits during the allotted time. We find that subjects
166 in the individual and in the collective bonus groups visited -9.081 (CI: [-17.073, -1.088]) and -6.267
167 (CI: [-13.491, 0.956]) households, respectively.

168 Our last indicator, the number of houses visited within less than two minutes, provides further
169 evidence in favour of our argument. On average, participants in the individual bonus treatment arm
170 visited -7.385 (CI: [-13.931, -0.84]) houses than the control, and those in the collective bonus group
171 visited -5.438 (CI: [-11.263, 0.387]). Again, the result for the individual bonus group is statistically
172 significant at the 10% level.

173 3.2 Disease Incidence

174 We employ two models to evaluate the effect of monetary incentives on dengue incidence. The first
175 is a differences-in-differences estimation that tests whether the intervention *per se* had any effect on
176 dengue hospitalisations in the city of Rio Verde. The second model compares dengue incidence in
177 each of the treatment statuses with incidence figures in the control group. The unit of analysis is the
178 census tract. Table 3 displays the results for our first model, in which we measure the impact of our
179 intervention after 4, 8, 12, and 16 weeks. The last column shows how collective incentives compare
180 with individual bonuses, with the latter considered as the control group.

181 The intervention lowered dengue incidence in 10.3% (CI: [-18.9%, -1.6%]) if we take both treatments
182 together and compare them with the control group. The result is consistent around fewer weeks

Table 3: Differences-in-Differences Model

	Disease Incidence Before and After Intervention:			
	Four Weeks Window	Eight Weeks Window	Twelve Weeks Window	Sixteen Weeks Window
	(1)	(2)	(3)	(4)
Dif-in-Dif	-0.097 (0.166)	-0.167 (0.118)	-0.130 (0.091)	-0.103* (0.053)
Observations	828	1,656	3,312	7,452
Residual Std. Error	1.513 (df = 824)	1.442 (df = 1652)	1.319 (df = 3308)	1.004 (df = 7448)

Note:

*p<0.1; **p<0.05; ***p<0.01

Robust standard errors clustered at the census tract level in parentheses.

¹⁸³ before and after the intervention, but it does not reach conventional levels of statistical significance.

¹⁸⁴ This suggests that the treatment effect is probably small.

Table 4: Disease Incidence

	Number of Reported Hospital Cases:					
	Before Int.	Fifteen Days After Int.	Thirty Days After Int.	Sixty Days After Int.	Ninety Days After Int.	Btw. Thirty & Sixty Days After Int.
	(1)	(2)	(3)	(4)	(5)	(6)
Individual Bonus	-3.534 (2.818)	0.116 (1.262)	0.551 (2.000)	1.551 (2.929)	1.534 (2.936)	0.936 (1.050)
Collective Bonus	-2.871 (3.762)	-1.269 (1.298)	-0.780 (1.794)	0.444 (2.863)	1.212 (3.179)	1.121 (1.367)
Observations	139	139	139	139	139	139
Residual Std. Error (df = 136)	7.147	2.792	4.025	5.735	6.028	2.190

Note:

*p<0.1; **p<0.05; ***p<0.01

¹⁸⁵ In our second model, we measure the effect of reward schemes on the number of hospitalisations

¹⁸⁶ per census tract. Table 4 shows hospitalisation counts before the intervention, and then 15, 30, 60, 90,

¹⁸⁷ and between 30 to 60 days after the treatment. Note that 96 pairs of healthcare workers analysed 139

¹⁸⁸ census tracts. This is because 43 of those pairs worked in more than one census tract at once.

¹⁸⁹ We see that neither treatment has an impact on disease incidence in the Rio Verde census tracts.

¹⁹⁰ The treatment effect is not statistically different from zero in any model specification. Yet, the

¹⁹¹ coefficients are negative, which indicates that had an impact occurred, the intervention would have
¹⁹² lowered dengue incidence in the treated areas.

¹⁹³ 4 Discussion

¹⁹⁴ We show that monetary incentives increase the productivity of community health care workers
¹⁹⁵ in Brazil. We contrast a control group (which received a flat performance fee) with two treatment
¹⁹⁶ groups, one which received an individual performance bonus, and second one that received a
¹⁹⁷ collective performance incentive. We find that both treatments increase the number of breeding sites
¹⁹⁸ encountered, and that collective incentives outperform individual performance rewards when the
¹⁹⁹ task is more laborious and excludable (exterminating larvae). Lastly, the control group presented
²⁰⁰ a high incidence of houses visited in less than two minutes apart from each other, which suggests
²⁰¹ that the workers may not carry their tasks as intended in the absence of incentives. In a nutshell,
²⁰² monetary incentives work.

²⁰³ Our conclusions are consistent with results from comparable studies conducted in other settings,
²⁰⁴ such as in education [32] and in private firms [33]. The findings also lend further evidence that
²⁰⁵ incentivising teams is particularly effective when they carry out labour-intensive tasks, which opens
²⁰⁶ a new avenue for research in preventive healthcare.

²⁰⁷ Regarding the effect of incentives on city-level dengue incidence, we find only mixed results.
²⁰⁸ Why did the treatment not work as we planned? We believe the treatment was not as strong as it
²⁰⁹ needed to be. Our treatment probably did not cover enough areas to ensure there was no mosquitos
²¹⁰ around the assigned blocks. As mosquitos can travel for long distances, the treatment might not have
²¹¹ been sufficient. Also, Rio Verde had significant rates of dengue incidence during our experiment,
²¹² reaching 3,411 reported infections from January to September 2018 [28]. Therefore, the treatment
²¹³ might have stronger effects only when applied for longer periods of time or in more neighbourhoods.

²¹⁴ In this respect, our study suggests is that even though healthcare workers may be motivated,
²¹⁵ their efforts do not necessarily lead to a reduction in mosquito infections. Higher field productivity
²¹⁶ does not guarantee that the *Aedes aegypti* mosquito can be eradicated. To our knowledge, this issue
²¹⁷ has received little attention in the literature. Future research may explore the reasons why this is the
²¹⁸ case and if the disconnect between the two can also be identified in other areas.

²¹⁹ **4.1 Limitations**

²²⁰ The study has several limitations. First, we ran our experiment for a small period of time and in
²²¹ a particular Brazilian city, thus the findings may not generalise to other locations. Second, our
²²² experiment needs a broader coverage to measure whether the treatment has a significant impact on
²²³ dengue incidence, as the effect size is smaller than we expected. Third, we included a post-treatment
²²⁴ adjustment to ensure the balance of our territorial variables. Although using matching estimators to
²²⁵ improve balance is good statistical practice, the method requires additional assumptions. Finally, the
²²⁶ experiment only measures the impact of financial rewards on worker performance, and it does not
²²⁷ assess the effect of non-monetary incentives, such as motivational messages or constant feedback,
²²⁸ which may be useful alternatives in jurisdictions where legal or financial constraints prevent the
²²⁹ government from distributing financial bonuses to civil servants.

²³⁰ **4.2 Public Health Implications**

²³¹ The experiment has important lessons for policy-making. *A. aegypti*-borne diseases are a significant
²³² public health concern, especially in developing nations. Results of this study indicate that monetary
²³³ rewards play a major role in motivating civil servants, and that peer incentives are more cost-effective
²³⁴ than individual bonuses. Finally, the article shows that anti-mosquito campaigns require a sustained
²³⁵ effort to guarantee their success, and we still have no robust evidence that worker productivity alone
²³⁶ is sufficient to reduce dengue infections.

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