Financial Incentives in Multi-layered Organizations: Empirical Evidence from the Community Health Worker Program in Sierra Leone

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1. Introduction

Poor performance of frontline service providers (e.g., teachers, health workers, tax collectors) has generated a large push towards pay-for-performance schemes, especially in developing countries. These schemes have been extensively evaluated, showing promising results (e.g., Basinga et al. (2011a); Gertler & Vermeersch (2013); Miller & Babiarz (2013); De Walque et al. (2013); Singh & Mitra (2017)). However, the literature mostly ignores the fact that frontline service providers work in multi-layered organizations (Tirole (1986, 1992); Gibbons (1996); Holmström (2017)) and incentivizing them can have positive or negative spillover effects on layers above them. Moreover, any organization that is resource constrained - as it is often the case in developing countries - must decide how to allocate pay across the different layers, and raising incentives for the lower tier may entail reducing incentives at the upper tier. This points to the importance of studying incentives in the organization as a whole rather than focusing on one layer only.

This project aims to provide the first empirical evidence of financial incentives at different layers of a large public organization, namely the community health worker program in Sierra Leone. The program is structured around Peripheral Health Units (PHUs), each composed of 2 to 18 community health workers (CHWs), who provide health services to their communities, and a peer supervisor (PS), who is in charge of monitoring and supporting the CHWs under their supervision. In 372 PHUs located throughout the country, we introduced a new incentive scheme in a random sub-sample of PHUs. While we kept the structure of the incentives fixed across all treated PHUs, we experimentally varied across PHUs who receives the incentive: The incentive is paid only to the CHW (bottom-tier incentives), only to the PS (top-tier incentives), or is shared equally between the CHW and the PS (shared incentives). More precisely, in the bottom-tier treatment the CHW receives SSL 2,000 for each health service she performs; in the top-tier treatment the PS receives SSL 2,000 per health service performed by a CHW under their supervision; in the shared-incentives treatment the PS and the CHW each receive SSL 1,000 per health service performed by the CHW. The number of health services performed by a CHW was measured through a novel reporting system, coupled with extensive phone and in-person back checks.

We show that incentivizing both CHWs and PSs in Sierra Leone's community health worker program, rather than only one of those layers, was most effective in increasing household utilization of CHW services and improving household health outcomes. We interpret this to be the result of effort complementarities between the two layers, where CHWs need to be incentivized to provide (high quality) services and PSs need to be incentivized to boost household demand for these services. This has important implications for both the optimal structure of compensation schemes in hierarchical organizations, where such across-layer complementarities are likely to play a role, and the allocation of funds in resource-constrained environments often found in the public sector in developing countries.

Section 2 briefly reviews the related literature, section 3 provides background information about the context of Sierra Leone's community health worker program, section 4 explains our

intervention, section 5 lays out a theoretical framework, section 6 presents our results, and section 7 concludes.

2. Literature review

This paper contributes to three strands of the literature. First, we contribute to the literature on incentives for frontline service providers, such as health workers (e.g., Basinga et al. (2011b); Gertler & Vermeersch (2013); Singh & Mitra (2017); Deserranno (2019)), teachers (e.g., Muralidharan & Sundararaman (2011)), or tax collectors (Khan et al. (2015, 2019)). All of these studies, however, focus on the effort responses of frontline workers themselves, rather than considering the effort response of upper-tier workers. Our study aims to expand this line of research by considering the organization as a whole rather than focusing on a single tier of the organization.

Second, our results speak to the literature on the effects of pay dispersion and pay inequality on job performance (Card et al. (2012); Mas (2017); Breza et al. (2017)). Unlike these studies - which have mostly focused on horizontal pay inequalities in the workplace - we center our attention on vertical inequalities between supervisors and their subordinates. Two related studies analyze the effects of vertical pay differences: Bandiera et al. (2007), who show that introducing performance pay for managers based on lower-tier worker's performance increases both the mean and the dispersion of worker productivity due to targeting of managerial efforts and Cullen & Perez-Truglia (2018), who provide evidence that larger perceived managerial salaries increase effort, output and retention of lower tier workers. Our study is different from previous work in that the core of our analysis is on the spillover effects of incentives between the two layers of the organization, rather than only one (as in Bandiera et al. (2007)) or focusing only on the effects of pay transparency (as in Cullen & Perez-Truglia (2018)). This is of obvious policy relevance given the recent growth of the manager-worker pay ratio and the lack of evidence on vertical inequalities (Ashraf & Bandiera (2018)).

Finally, our paper contributes to the literature evaluating community health worker programs around the globe. In many developing countries, rural populations lack access to basic health services and a widely used strategy to reach these populations is the community-based approach: Health workers are recruited within their villages and are trained to provide basic health services to their community (Singh & Sachs (2013)). While these CHW programs have been proven effective at improving health outcomes in developing countries (e.g. Haines et al. (2007); Bhutta et al. (2010); Gogia & Sachdev (2010); Lewin et al. (2010); Christopher et al. (2011); Naimoli et al. (2012); Perry & Zulliger (2012); Gilmore & McAuliffe (2013); Okwundu et al. (2013); Nyqvist et al. (Forthcoming)), we aim to provide more systematic evidence on the role of financial incentives in their success. More specifically, we will provide evidence on how to structure incentives so as to maximize CHW effort and, through this, improve health outcomes in one of the poorest countries in the world.

3. Background

3.1. Health Care in Sierra Leone

According to the WHO (2015), Sierra Leone had the world's highest maternal mortality rate and the world's 4th highest child mortality rate in 2015. The overview of the country's health care system in Robinson (2019) highlights deficiencies in the supply of health care, which were exacerbated by the 2014 Ebola epidemic, that can partially explain this heavy burden of morbidity and mortality. As of 2016, there were just over 1,000 qualified doctors, midwives, and nurses for a population of more than 7 million people, a number more than 30 times lower than the threshold set in the Sustainable Development Goals. Furthermore, only 30%

of this small workforce serve rural areas while more than 60% of the total population live in rural areas. Most of the 72 private clinics and hospitals are located in Freetown, the country's capital city, and are unaffordable for the vast majority of people. The administration of the public health care system falls under the responsibility of the Ministry of Health and Sanitation (MOHS) at the national level and is supported by a District Health Management Team (DHMT) in each of Sierra Leone's 14 districts.[1] They operate 21 district hospitals and 3 referral hospitals, meaning that the typical rural district only has one district hospital. For large parts of the population this leaves Peripheral Health Units, which make up the primary health care system, as the only option to access a qualified health care provider. There are 3 types of PHUs, which differ in terms of the size of their catchment area and the number and level of qualification of their staff: Community Health Centres (CHCs) are the largest PHUs, followed by Community Health Posts (CHPs), and Maternal and Child Health Posts (MCHPs). Even MCHPs, which are headed by a skilled birth attendant and not a nurse or a doctor, serve up to 5,000 people across multiple villages. In this context, the MOHS founded the Community Health Worker Program in 2012 in order for every village to have a direct contact point with the public health care system.

3.2. Community Health Worker Program

Initially, Community Health Workers in Sierra Leone used to be volunteers, CHW initiatives varied across locations, and multiple international NGOs were in charge of implementation in different areas. In 2016, the national CHW policy was updated substantially in an attempt to professionalize CHWs and to create a unified program across the country that is fully owned and operated by the government. Starting in 2017, CHWs under the new policy have been hired locally (typically a CHW lives in the village they serve), have received a 24 days initial training, and have been required to attend monthly performance assessment meetings afterwards. The main job of CHWs is to provide the following health services to members of their community: (i) Conduct routine household visits to every household in the village every 3 months where they provide health education on sanitation and hygiene and how to prevent and recognize symptoms of malaria, diarrhoea, and pneumonia; (ii) treat non-severe cases of malaria and diarrhea and refer patients with other conditions or danger signs to the PHU for further treatment when necessary; (iii) conduct timely pre-natal and post-natal check-ups. All CHWs are part-time workers who typically maintain other daily occupations such as farming or petty trading. Since the adoption of the new national CHW policy in 2016, CHWs are entitled to a fixed monthly pay of SSL 150,000 (19.5 USD at the start of our study), or 30% of the national minimum wage.[2]

The CHW program is organized around PHUs, where the monthly performance assessment meetings are held, which are supposed to allocate drugs to CHWs, and to which CHWs must refer patients they cannot treat themselves.[3] At each PHU there is one or multiple Peer Supervisors, usually former CHWs who have been promoted, who are in charge

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[1] In the wake of a realignment of chiefdom borders in 2017, the number of chiefdoms increased from 149 to 190, the number of districts increased from 14 to 16, and the number of provinces increased from 4 to 5. Throughout this paper we still reference the old administrative division because the public health system still operated according to the old division during our study period, e.g. there were 14 DHMTs instead of 16.

[2] CHWs who live in locations classified as "hard to reach" by the MOHS are eligible for an additional monthly supplement of SSL 30,000.

[3] The government assigns each PHU a given stock of drug supplies to be divided between the PHU and the CHWs, but drug stock-outs were commonly reported during our study period.

of supervising a group of CHWs. Typically, a PS supervises around 10 CHWs (one CHW per village in the PHU's catchment area), with some variation across PHUs. There are approximately 1,500 PSs and 15,000 CHWs nation-wide. The PS training manual explains the role of PSs in the following way: "CHWs are the first point of access to health care for communities. The PS is responsible for monitoring the performance of their CHWs to ensure 1) that each health worker possesses the technical skills and knowledge necessary to provide primary care services and 2) that all households are receiving the health services that CHWs provide. Monthly performance assessment meetings provide an opportunity for the PS to discuss the gaps in coverage and quality of care that they have observed with the CHWs by giving them further training and address any urgent issues." In practice, PSs responsibilities include: (i) Visiting each CHW in their villages at least once per month to observe the CHW's competency and provide personalized feedback, (ii) liaising with communities in order to sensitize them about the importance of CHW services and build trust between the communities and their CHWs (e.g., by attending community meetings or engaging directly with households), (iii) organizing one performance assessment meeting per month at the PHU with all their CHWs, (iv) creating robust linkages between the CHWs and the health facilities, and (v) ensuring CHWs are provided with drugs to distribute in their community. Each PS also has the discretion to undertake any action to mentor, monitor, and support the CHWs. However, it is not part of their job description to directly provide services to patients. They report to a permanent staff member of the PHU, usually the in-charge. PSs are entitled to a fixed monthly pay of SSL 250,000 (32.5 USD at the start of our study), or 50% of the national minimum wage.

4. Research Design

4.1. Intervention

Our study took place across 6 districts in Sierra Leone and included at least one district per province: Bo district in the Southern Province, Kenema district in the Eastern Province, Bombali, Kambia, and Tonkolili districts in the Northern Province, and Western Area Rural district on the Freetown Peninsula. Our final sample includes 372 PSs and 2,970 CHWs working at 372 PHUs across these 6 districts.

In this final sample of 372 PHUs, we then randomized (a) the introduction of a new piece-rate incentive scheme effective from April 2018 to July 2019 and (b) which layer received the incentive, i.e., only CHWs, only the PS, both, or neither. More specifically, we randomly assigned the 372 PHUs to one out of 4 groups of equal size, with stratification based on district, whether the average distance between the residence of the PS and their CHWs is above or below the median in the sample, and whether the number of CHWs under the PS's supervision is above or below the median in the sample, leading to 24 distinct strata. These are the incentive schemes of our treatment groups:

- $Control$ - No performance-based incentive.
- T_{CHW} - CHW Incentive Treatment (Bottom-tier): Each CHW receives an incentive of
  SSL 2,000 for each service performed. The PS receives no incentive.
- T_{PS} - PS Incentive Treatment (Top-tier): CHWs receive no incentives. The PS receives an incentive of SSL 2,000 for each service performed by each CHW under their supervision.
- T_{SHARED} - Shared Incentive Treatment (Bottom and top-tier): Each CHW receives an incentive of SSL 1,000 for each service performed. The PS receives an

incentive of SSL 1,000 for each service performed by each CHW under their supervision.

We paid the incentive on a monthly basis and, in all treatment groups, it was equal to SSL 2,000 × (number of services performed by the CHW in the past month). We capped the maximum amount to SSL 60,000 per month per CHW in all treatments. Thus, the maximum amount a CHW could earn in T_{CHW} was equal to SSL 60,000 per month, the maximum amount a PS could earn in T_{PS} was equal to SSL 60,000 × (number of CHWs supervised) per month, the maximum amount a CHW could earn in T_{SHARED} was equal to SSL 30,000 per month, and the maximum amount a PS could earn in T_{SHARED} was equal to SSL 30,000 × (number of CHWs supervised) per month. The three treatments are ex-ante budget neutral, i.e., conditional on a given number of performed CHW services, the total amount of incentives disbursed in a PHU is the same across T_{CHW}, T_{PS}, and T_{SHARED}. Importantly, the ex-ante budget neutrality of our treatments combined with the hierarchical organizational structure (with one PS supervising multiple CHWs) implies that we are effectively comparing PHUs in which each CHWs is offered a moderate incentive (those in T_{CHW}) to PHUs in which the PS are offered a very high incentive (those in T_{PS}), with the PHUs in T_{SHARED} being in-between. In order to avoid any delays in the disbursement of the incentives - thus making this new scheme credible - our research team managed the payment structure directly and sent payments through mobile money. Our field teams met PSs and CHWs at their PHUs in April and May 2018 to inform them about the new incentive scheme and accompanying reporting system. All 9 services CHWs are expected to provide were eligible for incentive payments.[4]

4.2. Reporting and Monitoring

For the success of any performance-based incentive scheme it is vital to have a timely and accurate measure of the incentivized performance indicators. We therefore designed a customized reporting system that was used by CHWs during our intervention, which put mechanisms in place to prevent CHWs from both over-reporting (especially relevant for CHWs in T_{CHW} and T_{SHARED}) and under-reporting (especially relevant for CHWs in $Control$ and T_{PS}) the number of services they perform. To be precise, CHWs had to send a text message for each service they provided, which then was sent to a database on our server. Based on this database, we disbursed the monthly incentive via mobile money services and had a team of phone and field monitors back-checking the accuracy of the reports CHWs sent. Section 8.1 contains a detailed description of the reporting and monitoring system. Note that despite the mechanisms we put in place to get reports that are as accurate as possible, we still rely on outcome measures of CHW effort from a household survey in our empirical analysis as even the best monitoring system cannot completely rule out misreporting.

4.3. Data Collection and Measurement

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[4] The only CHW services excluded were irregularly occurring activities such as helping the PHU with outreach campaigns. The 9 eligible CHW services are: (i) Routine household visits (i.e., providing health education on sanitation, hygiene, and disease prevention), (ii) treating/referring a sick child under 5, (iii) treating/referring a sick patient older than 5, (iv) follow-up visits to a child under 5, (v) follow-up visits to a patient older than 5, (vi) pre-natal visits, (vii) accompanying a pregnant woman to the PHU for child birth, (viii) post-natal visits within 1 month of birth, and (ix) child health check-ups (for children aged 1-15 months).

Our field teams conducted baseline and endline CHW and PS surveys as well as an endline household survey. For the endline household survey, which focused on health outcomes and health behaviors, our field teams sampled a random subset of eligible households in the communities in which CHWs work using random walks starting from the house of the CHW and with sampling intervals between households based on the total number of households in the community.[5]

5. Analytical Framework

The goal of our study is to assess how to structure incentives in a vertical organization and to estimate across-layer effects of incentives. Our main outcome variables are health outcomes as well as health inputs (incl. CHW service utilization) of the target population. Ex ante it is unclear which incentive structure will improve these outcomes most. The case for T_{CHW} is fairly straightforward: CHWs are the frontline service providers, so tying (part of) their compensation to the number of services they provide should make them work harder and therefore provide more services. However, there are two factors that could make T_{PS} more effective: Firstly, PSs can potentially affect the demand for CHW services in multiple ways. Given that PSs are more senior workers and typically are more experienced, educated, and knowledgable than CHWs, they can train CHWs and therefore improve the quality of their services, they can lobby at the PHU to disburse more drugs to CHWs, and they can sensitize the community about the importance of utilizing CHW services. Secondly, T_{PS} provides much higher-powered incentives than T_{CHW}. Whereas CHWs can earn at most an additional 40% of their fixed wage in T_{CHW}, the average PS in our sample (who supervises 8 CHWs) can earn almost an additional 200% of their fixed wage in T_{PS}. Yet, T_{SHARED} could dominate both other treatments in either of two scenarios: (i) If health outcomes are an additive linear function of CHW and PS effort, but effort has decreasing marginal returns to income, doubling the incentive will lead to less than double the effort. (ii) If health outcomes are a multiplicative function of CHW and PS effort, i.e., if there are strong effort complementarities, T_{SHARED} will be most effective. Such complementarities would arise if there was low demand for CHW services without PS intervention, which only takes place if PSs are incentivized, and at the same time CHWs only supply (high quality) services if they are incentivized.

6. Results

6.1. Descriptive Statistics and Balance

Table 1 shows descriptive statistics and balance checks for some key household characteristics in our sample of 8,663 households. As we only conducted a household survey at endline, the table only includes variables which are time invariant, exogenous to treatment status, or variables based on questions that ask retrospectively about the status just before the start of our study. The vast majority of the respondents in our sample either have no or only primary education, work as farmers or petty traders, and belong to either the Mende or Temne ethnic

[5] In order to be eligible for the household survey, the respondent had to be female, be one of the primary caregivers in charge of children, cooking, and health care in the household, be between 18 and 49 years old, and have lived in the household for at least 6 months during the study period. We set these eligible criteria so that sampled households belong to the target households for CHW services and chose criteria which are exogenous to the treatment status of the CHW.

groups, which are the two largest ethnic groups in the country. Importantly, there is at least one child under the age of 5 living in around 73% of households in the sample.

Table 2 shows descriptive statistics and balance checks for some key CHW characteristics measured at baseline. A perhaps surprising feature of the CHW program in Sierra Leone is the large share of male CHWs, around 71% in our sample. Around 70% of CHWs completed primary education and around 8% completed secondary or tertiary education. This implies that CHWs on average are substantially more educated than the people they serve. 73% of the CHWs in our sample are Muslim (the remainder being Christian), the majority of CHWs belongs to either the Mende or Temne ethnic group, and just over half of them report to be the main income earner in their household. Around half of CHWs in our sample have worked as CHWs before they joined the current CHW program. They serve around 50 households on average, with substantial variation across CHWs, and self-report to have worked around 15 hours in the week preceding the survey. As with household characteristics, our randomization achieved good balance of observable CHW characteristics across different treatment groups.

Table 3 shows descriptive statistics and balance checks for some key PS characteristics measured at baseline. With around 92%, the share of males is even higher among PSs than among CHWs. Compared to CHWs, a higher share of PSs in our sample completed primary education (around 74%) and secondary or tertiary education (around 25%). While the share of Muslims (around 65%) and the shares belonging to the Mende and Temne ethnic groups are all similar to the respective shares in the CHW sample, a substantially larger share of PSs reported being the main income earner in their household (around 72%). Around 80% of PSs had experience working in another CHW program prior to joining the government CHW program. PSs in our sample are on average supervising around 10 CHWs, in line with the official numbers mentioned in 3.2, and they self-report to have worked 23 hours in the week preceding the survey, around 50% more than CHWs. Again, our randomization achieved good balance of observable PS characteristics across different treatment groups.

6.2. Effects on Health Outcomes

We estimate the following regression model to test which incentive scheme was most effective at improving health outcomes:

$$Health_{ijk} = \alpha + \beta_1 T_{CHW,k} + \beta_2 T_{PS,k} + \beta_3 T_{SHARED,k} + Z_k \Gamma' + \varepsilon_{ijk}$$

$Health_{ijk}$ is a health outcome of household i in village j in the catchment area of PHU k, $T_{CHW,k}$, $T_{PS,k}$, and $T_{SHARED,k}$ are treatment dummies, Z_k is a vector of stratification dummies, and ε_{ijk} is the error term which we cluster a the level of the treatment assignment, the PHU. We use the same specification for the outcomes in sections 6.3 and 6.4.

Table 4 shows effects of our treatments on averaged z-scores for both disease incidence in children under 5 and outcomes related to pre- and post-natal care of women who either gave birth to a child within 2 years before the interview or were pregnant at the time of the interview. Column 1 shows that T_{SHARED} led to a statistically significant reduction in disease incidence by 0.05 standard deviations versus $Control$ and T_{CHW}, but not versus T_{PS}. Actually, the point estimate for T_{CHW} is exactly 0 whereas the point estimate for T_{PS} is -0.03, but the effect is not statistically different from the Control. Column 2 shows a similar pattern for pre- and post-natal care outcomes: Again, T_{SHARED} has the largest estimated effect of the three treatments in terms of improving of pre- and post-natal care outcomes of 0.09 standard

deviations versus the control and again the effect is statistically different from the $Control$ and from T_{CHW} (at the 1% and 10% levels), but not from T_{PS}. The estimated effect of T_{PS} itself is an improvement of 0.05 standard deviations, which is significant versus the $Control$ (at the 10% level) but not versus T_{CHW}. The estimated effect of T_{CHW} is an improvement of 0.04 standard deviations, but it is not statistically different from the $Control$.

Tables 5 and 6 break down the z-score results into the individual components making up the z-score composites shown in table 4. Table 5 shows that the composite results are mainly driven by a reduction in fever incidence, rather than diarrhoea or cough incidence. Table 6 shows that especially for T_{SHARED} there are positive effects consistently across outcomes, although the coefficient is not significant for all of them individually (perhaps due to the limited power).

Taken together, the results on health outcomes a) show that T_{SHARED}, and to a lesser extent T_{PS}, led to moderate improvements in household health outcomes compared to the status quo, and b) suggest that T_{SHARED} was more effective than the other two treatments, although we cannot reject the null that T_{SHARED} and T_{PS} had the same effectiveness. Overall, our results provide novel evidence suggesting that in order to achieve better health outcomes it might generally not be optimal to only incentivize frontline service providers when they are part of an hierarchical organization and the effort of workers in upper layers potentially also affects their performance.

6.3. Effects on CHW Service Utilization

Table 7 shows the effects on CHW service utilization by households between the start of 2019 and the time of the interview in mid-2019. Column 1 shows that all three treatments led to a statistically significant (at the 1% level) increase in the number of CHW services households received. While the estimated increase in services is around 2.1 services versus the $Control$ for both T_{CHW} and T_{PS}, the effect of T_{SHARED} is substantially higher with around 3.3 more services than in the $Control$. The estimate for T_{SHARED} is also significantly different from the estimates for T_{CHW} (at the 10% level) and T_{PS} (at the 5% level). In addition to that, columns 2 and 3 further show that T_{SHARED} also had a significant effect on the number of different health topics the respondent had discussed with the CHW compared with the $Control$ (at the 1% level), T_{CHW}, and T_{PS} (both at the 5% level) and the number of different service types the household received compared to the $Control$, T_{CHW} (both at the 1% level), and T_{PS} (at the 5% level). Table 8, which breaks down column 1 of table 7 by the services CHWs provide, confirms that the effect of T_{SHARED} is not based on an increase in a specific type of service, but rather on positive effects across all services[6]. The point estimate of T_{SHARED} is positive for all services, larger than the point estimates of T_{CHW} and T_{PS} for all services, statistically significant versus the $Control$ for 6 out of 7 services, statistically significant versus T_{CHW} for 4 out 7 services, and statistically significant versus T_{PS} for 3 out of 7 services.

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[6] For better readability of the table, we group together children under 5 and patients older than 5 for both the treatment/referral and follow-up visit service categories, such that the table only has 7 columns while there are 9 distinct CHW services incentivized by the study. The results are very similar when looking at all 9 services individually.

The results on CHW service utilization confirm the results on health outcomes: All treatments increased the number of CHW services households receive, which in turn translated into moderate improvements in health outcomes, but T_{SHARED} outperformed the other two treatments. This is especially striking in the domain of CHW service utilization, as the number of CHW services provided were the incentivized performance indicator and the piece-rate for CHWs in T_{CHW} was twice as high as in T_{SHARED}. Therefore, our results suggest that PSs played a critical role in raising the demand for CHW services in the communities, either indirectly by improving CHW service quality and/or directly by sensitizing communities about the importance of CHW services. At the same time, this alone also does not seem to be sufficient, as the incentives for PSs in T_{PS} were twice as high as in T_{SHARED}. One interpretation of these results is that there are important effort complementarities between CHWs and PSs. In particular, it seems to be the case that in order to maximize CHW service provision it is necessary to both incentivize CHWs to supply services and incentivize PSs to take measures that boost demand for CHW services. The following section will explore which PS measures in particular might have been important in boosting demand for CHW services.

6.4. Effects on PS Supervision and Community Engagement

Table 9 shows treatment effects on outcomes related to PS monitoring and supervision of CHWs based on the CHW endline survey. Column 1, where the outcome variable is a dummy equal to 1 if the PS visited the CHW at least once between March 2019 and the interview in mid-2019, and column 2, where the outcome is a dummy equal to 1 if the PS called the CHW at least once in the month preceding the interview, show that none of the treatments had an effect on the extensive margin of overall PS supervision and monitoring: PSs in the treatment groups did not conduct more community visits to CHWs and did not call their CHWs more often.

Table 10 shows treatment effects on outcomes related to direct PS engagement with communities based on the household endline survey. Column 1 shows the results for a dummy that is equal to 1 if the respondent reported to know the PS when prompted by the enumerator with the name of the PS. There is a positive and significant effect for all three treatments versus the $Control$, but while the magnitude of the coefficient is substantially larger for T_{PS} and T_{SHARED} it is not significantly different across any of the treatments. Columns 2 and 3 show the results for whether the respondent reported that the PS ever visited their home and whether the respondent reported that the PS ever took part in a health-related community meeting. For these two outcomes the estimated effect of T_{PS} is not significantly different from the $Control$ whereas the estimated effects of both T_{PS} and T_{SHARED} are. Importantly, the magnitudes of the estimated effects for all three outcomes are very similar across T_{PS} and T_{SHARED}, although the piece-rate for PSs was twice as high in T_{PS} compared to T_{SHARED}.

All in all, the results on PS supervision and community engagement suggest that a) none of the treatments led to PSs conducting more supervision visits or calls to CHWs, and b) PSs in T_{PS} and T_{SHARED}, who were directly incentivized, were more likely to engage with households and communities directly compared to the $Control$. This is consistent with the previously mentioned mechanism where there are effort complementarities between CHWs, who need to be incentivized to supply services, and PSs, who raise demand for services by engaging with and sensitizing the community.

7. Conclusion

We show that incentivizing both CHWs and PSs in Sierra Leone's community health worker program, rather than only one of those layers, was most effective in increasing household utilization of CHW services and improving household health outcomes. We interpret this to be the result of effort complementarities between the two layers, where CHWs need to be incentivized to provide (high quality) services and PSs need to be incentivized to boost household demand for these services. This has important implications for both the optimal structure of compensation schemes in hierarchical organizations, where such across-layer complementarities are likely to play a role, and the allocation of funds in resource-constrained environments often found in the public sector in developing countries.

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8. Appendix
   8.1. Reporting and Monitoring System

We collaborated with a large mobile network provider in Sierra Leone, which also provides the mobile money services both the government and our research team were using to pay PSs and CHWs, to set up a simple text-message-based reporting system.[7] The reporting system consisted of three steps: (1) Each time a CHW performed a service, they were asked to report the date of the service, the name and phone number of the patient, and a one letter code corresponding to one of the 9 incentivized services by sending an SMS to a toll-free number

[7] Given that government payments were done through the mobile money service of the same provider even before the start of our study, most PSs and CHWs already had a SIM card that enabled them to use our reporting system and receive payments. In the few cases where a PS or CHW either did not have a SIM card at all or shared one with another PS or CHW, our field teams provided them with a new SIM card such that all study participants had a unique phone number that allowed us to attribute all incoming reports to the correct person and make sure that the corresponding incentive amounts were disbursed to the correct recipient.

and by recording the activity by hand in a logbook.[8] For children, the name and phone number reported were those of the primary care giver. If the SMS did not include all the required information, the system returned an error message. (2) The SMS information was automatically uploaded to a server and provided a live database of CHW services, from which the performance incentives were calculated. (3) The SMS information provided by the CHW was continuously back-checked through teams of phone and field monitors. Based on this reporting and monitoring system, we paid a monthly reward of SSL 10,000 for truthful and timely reporting to all CHWs in the study, including those in the Control arm, and our field monitors warned CHWs found over-reporting the number of services they provided that they would not be eligible for any further payments and be reported to the PHU, DHMT, and MOHS if found over-reporting again. Our field teams informed all PSs and CHWs in the study, again also including those in the Control arm, about this new reporting and monitoring system and extensively trained them on how to report correctly during the PHU meetings in April and May 2018.

The monitoring teams started their work immediately after the start of the intervention. A team of 14 phone operators based in Freetown randomly called patients from the SMS reports sent by CHWs and asked them to confirm that the CHW indeed provided the reported service to them at the reported date. Moreover, a team of 20 field monitors conducted monthly in-person spot visits to the villages in which CHWs work. They visited all CHWs in the study at least once during the study period and at least one CHW per PHU per month. In the village, field monitors verified a random subset of recently reported services directly with patients. As with phone operators, field monitors detected over-reporting by asking patients to confirm that the CHW provided the reported service at the reported date and issued stern warnings to CHWs found over-reporting services. On the other hand, to detect under-reporting, field monitors (i) asked CHWs about services they forgot to report through SMS and (ii) checked whether there were any services the CHW had written in their logbook but not reported through SMS.

8.2. Tables

[8] Paper records had two main functions: (i) In case a CHW was unable to report their activities immediately by SMS (e.g. because of poor cell phone coverage), they could refer to the paper records and send the SMS at a later time or in bulk; (ii) these paper forms were used by our team of field monitors to check for under-reporting in the database.

Table 1: Households Characteristics

	(1)	(2)	(3)	(4)
	Mean Full Sample	CHW incentives vs Control	PS incentives vs Control	Group incentives vs Control
Presence of child under 5 = {0, 1}	0.733	0.014	0.023	0.013
	(0.442)	(0.019)	(0.020)	(0.020)
Years in community	12.531	0.390	0.378	0.567
	(10.408)	(0.479)	(0.454)	(0.419)
Completed primary education = {0, 1}	0.248	-0.029*	0.003	-0.011
	(0.432)	(0.016)	(0.017)	(0.016)
Completed secondary or above education = {0, 1}	0.035	-0.003	-0.002	-0.004
	(0.184)	(0.007)	(0.008)	(0.007)
Occupation: Petty trading = {0, 1}	0.252	-0.011	-0.012	-0.000
	(0.434)	(0.018)	(0.019)	(0.019)
Occupation: Farming = {0, 1}	0.601	0.017	0.029	0.024
	(0.490)	(0.026)	(0.024)	(0.023)
Mende group = {0, 1}	0.367	-0.020	-0.012	-0.000
	(0.482)	(0.012)	(0.013)	(0.010)
Temne group = {0, 1}	0.364	0.012	0.032	0.032
	(0.481)	(0.037)	(0.034)	(0.034)
Asset index	-0.000	-0.250	-0.229	-0.364**
	(2.640)	(0.177)	(0.151)	(0.144)
Observations	8,663	8,663	8,663	8,663

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 2: CHW Characteristics

	(1)	(2)	(3)	(4)
	Mean Full Sample	CHW incentives vs Control	PS incentives vs Control	Group incentives vs Control
Male = {0, 1}	0.708	-0.012	-0.009	-0.051
	(0.455)	(0.029)	(0.027)	(0.031)
Completed primary education = {0, 1}	0.697	-0.028	-0.018	-0.059*
	(0.460)	(0.031)	(0.030)	(0.031)
Completed secondary or above education = {0, 1}	0.077	0.009	0.009	0.014
	(0.267)	(0.018)	(0.017)	(0.017)
Muslim = {0, 1}	0.730	0.046	0.023	0.044
	(0.444)	(0.036)	(0.033)	(0.035)
Mende group = {0, 1}	0.380	0.005	-0.005	0.022*
	(0.485)	(0.014)	(0.016)	(0.013)
Temne group = {0, 1}	0.345	-0.031	0.014	-0.030
	(0.475)	(0.045)	(0.042)	(0.043)
Main income earner = {0, 1}	0.523	0.015	0.012	-0.033
	(0.500)	(0.030)	(0.029)	(0.031)
Asset index	-0.000	-0.048	0.005	0.007
	(1.636)	(0.109)	(0.114)	(0.110)
Previous CHW experience = {0, 1}	0.493	0.049	-0.012	0.111***
	(0.500)	(0.034)	(0.029)	(0.030)
Number of households responsible for	48.401	1.006	0.741	-1.593
	(35.768)	(2.846)	(2.639)	(2.951)
Weekly hours of CHW work	14.965	1.078	-0.838	0.007
	(13.749)	(1.052)	(1.132)	(1.150)
Observations	2,970	2,970	2,970	2,970

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 3: PS Characteristics

	(1)	(2)	(3)	(4)
	Mean Full Sample	CHW incentives vs Control	PS incentives vs Control	Group incentives vs Control
Male = {0, 1}	0.919	-0.003	-0.013	-0.011
	(0.273)	(0.037)	(0.038)	(0.039)
Completed primary education = {0, 1}	0.739	-0.037	0.021	-0.085
	(0.440)	(0.064)	(0.061)	(0.065)
Completed secondary or above education = {0, 1}	0.253	0.047	-0.011	0.074
	(0.435)	(0.063)	(0.061)	(0.063)
Muslim = {0, 1}	0.653	0.098	0.150**	0.041
	(0.477)	(0.069)	(0.067)	(0.069)
Mende group = {0, 1}	0.371	0.037	0.016	-0.011
	(0.484)	(0.032)	(0.041)	(0.034)
Temne group = {0, 1}	0.336	-0.027	0.015	-0.016
	(0.473)	(0.055)	(0.054)	(0.055)
Main income earner = {0, 1}	0.723	0.099	0.049	0.066
	(0.448)	(0.061)	(0.056)	(0.060)
Previous CHW or PS experience = {0, 1}	0.798	-0.021	-0.016	0.031
	(0.402)	(0.049)	(0.050)	(0.050)
Number of CHWs responsible for	10.304	-0.227	-1.126**	-0.564
	(3.424)	(0.416)	(0.464)	(0.402)
Weekly hours of CHW work	22.820	1.563	-0.058	-1.560
	(23.515)	(3.403)	(3.841)	(3.348)
Observations	372	372	372	372

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: P4P and Health

	(1)	(2)
Dep. Var.	Incidence of disease (z-score) [conditional on child under-5]	Pre and post-natal care (z-score) [conditional on giving birth]
CHW incentives	-0.000	0.042
	(0.031)	(0.026)
PS incentives	-0.032	0.052*
	(0.033)	(0.027)
Group incentives	-0.050*	0.090***
	(0.027)	(0.028)
Constant	0.179***	-0.092**
	(0.041)	(0.037)
Unit	HH	HH
Observations	6,318	4,437
Mean dep. var.	0.000	0.000
Mean dep. var. in Control	0.022	-0.046
P-value CHW=PS	0.355	0.711
P-value PS=Group	0.555	0.168
P-value CHW=Group	0.071	0.083

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: P4P and Incidence of Disease

	(1)	(2)	(3)	(4)
Dep. Var.	Incidence of disease (z-score) [conditional on child under-5]	Incidence of fever [conditional on child under-5]	Incidence of cough [conditional on child under-5]	Incidence of diarrhoea [conditional on child under-5]
CHW incentives	-0.000	-0.037*	0.018	0.002
	(0.031)	(0.022)	(0.011)	(0.006)
PS incentives	-0.032	-0.023	-0.003	-0.005
	(0.033)	(0.027)	(0.011)	(0.005)
Group incentives	-0.050*	-0.062***	-0.005	0.001
	(0.027)	(0.021)	(0.011)	(0.005)
Constant	0.179***	0.343***	0.122***	0.020**
	(0.041)	(0.031)	(0.017)	(0.008)
Unit	HH	HH	HH	HH
Observations	6,318	6,309	6,311	6,313
Mean dep. var.	0.000	0.189	0.073	0.018
Mean dep. var. in Control	0.022	0.221	0.071	0.018
P-value CHW=PS	0.355	0.566	0.103	0.203
P-value PS=Group	0.555	0.110	0.846	0.205
P-value CHW=Group	0.071	0.165	0.054	0.814

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: P4P and Pre- and Post-Natal Care

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	Pre and post-natal care (z-score) [conditional on giving birth]	Child up to date with recommended vaccines = {0 1}	Post-natal care visit at PHU within 2 days after birth = {0 1}	At least 4 ante-natal care visits at PHU = {0 1}	Institutional and assisted delivery = {0 1}	At least six months of breast feeding = {0 1}
CHW incentives	0.042	0.013	0.022	0.024	0.025	-0.007
	(0.026)	(0.017)	(0.025)	(0.022)	(0.021)	(0.023)
PS incentives	0.052*	0.040**	-0.011	0.040*	0.033*	0.016
	(0.027)	(0.018)	(0.022)	(0.023)	(0.019)	(0.024)
Group incentives	0.090***	0.037**	0.026	0.062***	0.028	0.035
	(0.028)	(0.019)	(0.025)	(0.023)	(0.019)	(0.024)
Constant	-0.092**	0.193***	0.323***	0.688***	0.835***	0.634***
	(0.037)	(0.026)	(0.033)	(0.036)	(0.026)	(0.030)
Unit	HH	HH	HH	HH	HH	HH
Observations	4,437	4,437	4,437	4,437	4,437	4,437
Mean dep. var.	0.000	0.236	0.306	0.783	0.870	0.668
Mean dep. var. in Control	-0.046	0.213	0.294	0.752	0.850	0.657
P-value CHW=PS	0.711	0.128	0.190	0.459	0.646	0.302
P-value PS=Group	0.168	0.864	0.153	0.319	0.721	0.404
P-value CHW=Group	0.083	0.206	0.899	0.070	0.881	0.057

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 7: P4P and CHW Service Utilization

	(1)	(2)	(3)
Dep. Var.	Number of health services received from the CHW since start of the year	Number of health topics discussed with the CHW since start of the year	Number of health service types received from the CHW since start of the year
CHW incentives	2.096***	0.159	0.256***
	(0.557)	(0.127)	(0.095)
PS incentives	2.113***	0.160	0.325***
	(0.504)	(0.131)	(0.102)
Group incentives	3.328***	0.513***	0.560***
	(0.491)	(0.135)	(0.093)
Constant	2.742***	1.415***	0.921***
	(0.686)	(0.176)	(0.123)
Unit	HH	HH	HH
Observations	8,606	8,606	8,606
Mean dep. var.	7.314	2.247	1.748
Mean dep. var. in Control	5.360	2.024	1.450
P-value CHW=PS	0.979	0.990	0.524
P-value PS=Group	0.037	0.018	0.030
P-value CHW=Group	0.051	0.015	0.003

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 8: P4P and Disaggregated CHW Services

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	Routine visit = {0 1}	Treatment/ referrals = {0 1}	Follow-up visit = {0 1}	Pregnancy visit = {0 1}	Accompanied woman for birth to PHU = {0 1}	Pre and post-natal visit = {0 1}
CHW incentives	0.068**	0.053**	0.043**	0.039**	-0.005	0.027
	(0.033)	(0.025)	(0.022)	(0.016)	(0.007)	(0.018)
PS incentives	0.088***	0.071**	0.030	0.027*	0.004	0.038*
	(0.030)	(0.028)	(0.024)	(0.016)	(0.008)	(0.020)
Group incentives	0.149***	0.112***	0.080***	0.064***	0.008	0.048***
	(0.029)	(0.025)	(0.021)	(0.017)	(0.008)	(0.017)
Constant	0.336***	0.202***	0.084***	0.099***	0.026***	0.067***
	(0.041)	(0.034)	(0.026)	(0.022)	(0.010)	(0.023)
Unit	HH	HH	HH	HH	HH	HH
Observations	8,606	8,606	8,606	8,606	8,606	8,606
Mean dep. var.	0.519	0.504	0.201	0.180	0.041	0.133
Mean dep. var. in Control	0.439	0.442	0.161	0.146	0.039	0.103
P-value CHW=PS	0.571	0.529	0.620	0.481	0.199	0.593
P-value PS=Group	0.047	0.142	0.045	0.037	0.662	0.585
P-value CHW=Group	0.016	0.019	0.102	0.159	0.072	0.215

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 9: P4P and PS Supervision

	(1)	(2)
Dep. Var.	PS called CHW in the past year = {0 1}	PS visited CHW in the past year = {0 1}
CHW incentives	0.009	-0.001
	(0.041)	(0.045)
PS incentives	0.003	0.012
	(0.041)	(0.044)
Group incentives	-0.054	0.003
	(0.043)	(0.047)
Constant	0.675***	0.460***
	(0.057)	(0.061)
Unit	CHW	CHW
Observations	2,927	2,870
Mean dep. var.	0.664	0.577
Mean dep. var. in Control	0.677	0.576
P-value CHW=PS	0.873	0.771
P-value PS=Group	0.176	0.860
P-value CHW=Group	0.132	0.920

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1

Table 10: P4P and PS Community Engagement

	(1)	(2)	(3)
Dep. Var.	HH knows who the PS is = {0 1}	PS met the HH during home visit in the past year = {0 1}	PS met the HH during community meeting in the past year = {0 1}
CHW incentives	0.056*	0.014	0.017
	(0.030)	(0.016)	(0.013)
PS incentives	0.085**	0.035**	0.024*
	(0.033)	(0.018)	(0.014)
Group incentives	0.088***	0.037**	0.028**
	(0.030)	(0.016)	(0.011)
Constant	0.231***	-0.002	-0.002
	(0.041)	(0.018)	(0.014)
Unit	HH	HH	HH
Observations	8,614	8,470	8,470
Mean dep. var.	0.511	0.142	0.065
Mean dep. var. in Control	0.450	0.118	0.045
P-value CHW=PS	0.399	0.256	0.672
P-value PS=Group	0.929	0.898	0.781
P-value CHW=Group	0.308	0.170	0.416

Notes: All regressions include stratification variables. Standard errors clustered at the PHU level. *** p<0.01, ** p<0.05, * p<0.1