Leveraging Patients' Social Networks to Overcome Tuberculosis Underdetection: A Field Experiment in India*

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Abstract

Peer referrals are a common strategy for addressing asymmetric information in contexts such as the labor market. They could be especially valuable for increasing testing and treatment of infectious diseases, where peers may have advantages over health workers in both identifying new patients and providing them credible information, but they are rare in that context. In an experiment with 3,182 patients at 128 tuberculosis (TB) treatment centers in India, we find peers are indeed more effective than health workers in bringing in new suspects for testing, and low-cost incentives of about $US 3 per referral considerably increase the probability that current patients make referrals that result in the testing of new symptomatics and the identification of new TB cases. Peer outreach identifies new TB cases at 25%-35% of the cost of outreach by health workers and can be a valuable tool in combating infectious disease.

Keywords: tuberculosis, referrals, social networks, case finding, incentives, India, health
JEL Codes: O1, I1

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1 Introduction

Tuberculosis (TB) is currently the leading infectious cause of death globally, with nearly 1.7 million deaths in 2016. (Chaisson, 2018).[1] About 10.4 million people worldwide, 3 million of them in India alone, developed active TB in 2016.[2] The disease is most common among vulnerable populations in poor countries in Africa and Asia (World Health Organization, 2017). Mortality from untreated TB is high (World Health Organization, 2017) and the disease is highly debilitating, with serious–often devastating–consequences for human productivity.

Despite the high personal cost of illness and the availability of highly effective treatment that is free to patients in developing countries, a large share of those infected with TB are not in treatment. In India, estimates suggest about 40% of TB cases are not reported (Cowling et al., 2014). Underdetection of TB poses a key challenge to health officials because the success of any treatment program relies on identifying those with the disease. This highlights the importance of increasing screening and testing, especially among high-risk populations.[3]

Imperfect and asymmetric information contributes to the underdetection of TB. First, people infected with TB are disproportionately from vulnerable populations, are often unaware of the significance of their symptoms, and have incomplete or incorrect information about the importance of testing and the availability and efficacy of treatment. Second, outreach to these marginalized populations is costly for health workers in terms of time and resources. Even in contexts with high TB prevalence, large numbers of individuals must be screened to identify symptomatics. For example, Charles et al. (2010) report findings from a large-scale TB screening program implemented in southern India. More than 18,000 individuals were screened, resulting in the identification of 640 people with symptoms requiring TB testing.[4]

In this paper, we investigate the potential role of peer referrals in resolving informational barriers to case detection. Patients who are already in treatment for TB are likely to know other people who are infected both because they share risk factors and because the disease is contagious. In particular, they may have connections to vulnerable people who are hard for health workers to identify and reach in a timely manner. These current patients might also be

[1] There were 1.3 million TB deaths among HIV-negative people and 374,000 TB deaths among HIV-positive people; the latter are classified as HIV deaths in official reports (World Health Organization, 2017).

[2] Between 1 and 2 billion people globally are estimated to have "latent" TB (Chaisson, 2018). These are individuals infected with tuberculosis who do not have the disease and cannot spread the infection to others. However, without treatment, 5%-10% of individuals with latent TB develop active TB at some point (CDC 2011).

[3] Omar et al. (2015) conducted a postmortem study of adults who died at home from "natural causes" (and had no antemortem TB diagnosis) in a high TB-burden setting in South Africa, and found laboratory evidence of TB in 32% of cases.

[4] In Charles et al. (2010), the prevalence of so-called "chest symptomatics" was 2.7% in rural areas and 4.9% in urban areas; as we will see below, the corresponding rates for the population targeted in our study were close to 80%.

able to credibly vouch for the quality of the health care provider and the benefits of treatment, providing personal testimonials that could be more compelling to some prospective patients than information from health workers.

Despite this potential, referrals from one patient to another are uncommon.[5] There are two main explanations for this low prevalence. First, the importance of referring other individuals who might have the disease for testing might not be sufficiently salient to current patients. Second, because of the stigma associated with TB (Kelly, 1999; Atre et al., 2011), current patients may find it costly to either reveal their status or to suggest that a contact would benefit from testing or treatment.

To learn whether existing patients' social networks could be used to improve TB detection, and to explore the mechanisms through which referrals could operate, we designed a study to test strategies to encourage or incentivize peer referrals, and to compare outreach modalities based on these referrals. Specifically, we conducted a randomized field experiment in India in partnership with Operation ASHA, an NGO that runs Directly Observed Treatment Short Course (DOTS) centers in several cities in 11 Indian states. A total of 3,182 current TB patients in 128 DOTS centers were randomized into either a control group or one of nine treatment groups varying the presence and conditionality of the incentives, the method of outreach, and whether the newly identified suspects knew who identified them. The intervention was implemented in five waves between March 2016 and October 2017. To avoid spillovers between experimental conditions, we randomized at the DOTS center level, stratifying by city and ensuring balance on average age of patients and percent of patients at baseline who were women.

Even without incentives, simple encouragement might increase referrals from current patients to others who may be infected with TB, if the crucial barrier is lack of information or insufficient salience of the social relevance of making referrals. Financial incentives have been used in several health contexts in developing countries to help overcome obstacles to adopting certain behaviors.[6]. In our context, incentives might help to overcome psychological or social costs associated with approaching individuals in patients' social networks to suggest they get tested for TB. Varying the conditionality of the incentive (whether payment depends on the new suspect's test results) is informative regarding the extent to which current patients have

[5] Recent WHO guidelines encourage high TB-burden countries to incorporate community-based outreach in national campaigns to prevent and treat TB. These guidelines, called the ENGAGE-TB approach (Haileyesus Getahun et al., 2012), include a specific emphasis on the role of communities in assisting in the detection of TB, especially in its early stages. The guidelines emphasize referrals by community health workers and volunteers.

[6] For example, incentives have proven effective to encourage people to reduce the risk of contracting HIV and sexually transmitted diseases in Malawi (Baird et al., 2012; Kohler and Thornton, 2011) and Tanzania (Walque et al., 2012); to learn the results of their HIV tests in Malawi and Kenya (Thornton, 2008; Kremer et al., 2009); to promote anemia reduction among children in rural China (Miller et al., 2012); and to improve maternal and child health services in Rwanda (Basing et al., 2011)

concrete information about the health status of their social contacts, and whether unconditional incentives generate opportunistic behavior (e.g., patients might invite their friends to get tested even though they show no symptoms). Moreover, varying the degree of current patients' engagement allows us to disentangle the effect of their information about prospective targets from the effect of peer outreach activity. Finally, within the health worker outreach arm, we vary whether or not the new suspects are told the identity of the TB patient who named them. To the extent that social stigma is an important constraint, patients who are guaranteed anonymity should be more likely to provide contact information for prospective patients because of the resulting reduction in the social cost of making a referral.

Our primary outcomes are administrative measures of TB detection: the number of referrals current patients made, the number of those referrals who were symptomatic and recommended for testing, the number of new symptomatics who got tested, and, ultimately, the number of new TB-positive case detections. In absolute numbers, the referrals schemes we tested led to the screening of 222 symptomatic individuals and the diagnosis of 36 previously untreated cases of TB, a much higher rate of identification than reported by Charles et al. (2010), also in India. Twenty-eight percent of symptomatics in our experiment who were tested turned out to have active TB, more than twice the 12% among all those tested at government facilities. Relative to encouragement alone, financial incentives doubled the number of referrals made by current patients, and had statistically significant effects on outcomes from screening to identification of patients with active TB. Our other innovation, peer outreach, was also more than twice as effective in identifying patients for screening and finding individuals who had TB as the alternative method of contact tracing by health workers. Both financial incentives and peer outreach are highly cost-effective, costing approximately $US 100 for each case of active TB identified through peer outreach, compared to $US 300-$US 450 for contact tracing by health workers.

A large literature documents the effects of social networks on individuals' economic outcomes and behaviors (Jackson, 2011). In the face of informational gaps and uncertainty, individuals obtain and act upon information from various sources, choosing which source to follow based on their preferences and objectives (Balat et al., 2018). Social phenomena such as organic "word of mouth" (i.e., based on current customers who are intrinsically motivated to influence others), as well as referrals, have been documented and studied in several contexts. Firms often use incentivized referrals to expand their customer base. For example, in a series of randomized field experiments, Kumar et al. (2010) assess the effectiveness of cash incentives offered to current customers of a financial institution to attract new ones. Godes and Mayzlin (2009) consider the impact of word of mouth generated by customers of a casual dining restaurant chain and by agents of an independent word-of-mouth marketing agency on the chain's sales outcomes.

Firms also use referrals to attract and screen workers (Bryan et al., 2010; Heath, forthcoming; Kugler, 2003). The potential role of referrals in attracting candidates with specific characteristics in employment settings has been measured in experimental studies in India (Beaman and Magruder, 2012) and Malawi (Beaman et al., 2018), as well as in experimental and nonexperimental studies in the United States (Burks et al., 2015; Friebel et al., 2018). By studying the potential role of incentives for referrals in a highly policy-relevant health context, our study unifies the literature about the role of social networks, referrals, and incentives for health behaviors. Results from marketing or employment contexts may or may not generalize to a health context. In labor markets, homophily might lead to undesirable outcomes from referrals by limiting diversity in hiring (Beaman et al., 2018; Hoffman, 2017) or inducing nepotism (Wang, 2013), which in some cases could cause referrals to have negative net welfare effects. In our context, homophily is likely to benefit disadvantaged populations because our referrer population is marginalized and thus likely to reach out to other marginalized individuals. At the same time, it is possible that excessive reliance on a referrals mechanism might disadvantage individuals who do not enjoy large social networks. This highlights the importance of analyzing, as our study does, precisely which types of individuals are recruited through the various referrals schemes.

Following recent WHO guidelines emphasizing the use of community-based outreach strategies for infectious diseases (Haileyesus Getahun et al., 2012), public health scholars and practitioners have begun to explore peer referrals as a case-finding tool. Some studies focus on HIV case finding among high-risk communities (see, e.g., Glasman and de Mendoza (2016); Gwadz and Kutnick (2017); Shangani and Operario (2017)), and one study considers identification of malaria cases ((Faye, 2012)). In the context of TB, Joshi and Brouwer (2017) implement a peer-led screening project in Nepal involving 30 volunteers who received intensive training to perform TB screening, collect sputum samples, accompany the newly diagnosed patients to obtain treatment, and support them during treatment. Similar strategies were implemented in the Democratic Republic of the Congo ((Munyanga Mukungo and Kaboru, 2014); (André and de Waroux, 2018)). These studies (which do not include experimental control groups and are not designed to investigate mechanisms) included intensive training of groups of selected former TB or HIV patients who deployed as community health workers, often for prolonged periods of time. Methodologically, our study differs from existing research in using an RCT to identify causal impacts of various referral and incentive schemes and to distinguish between competing barriers to information sharing. Operationally, it mobilizes current patients during the course of their treatment and requires minimal training.

More broadly, our work also relates to a growing set of studies documenting the respective effects of social interactions, networks, and peers on health behaviors including obesity (Christakis and Fowler, 2007), smoking (Christakis and Fowler, 2008), and the use of hygiene products (Oster and Thornton, 2012), as well as on the choices of HIV treatment (Balat et al., 2018), hospital (Pope, 2009), and health insurance (Sorensen, 2006). The potential efficacy of peer counseling has also been studied, including to promote exclusive breastfeeding (Anderson et al., 2005), to deliver parenting advice to promote child development (Rockers and Fink, 2018), and among individuals recently diagnosed with cancer (Harris and Larsen, 2007) or HIV (Giese-Davis et al., 2006). We add to this literature by exploring the effects of peers in a context where social interaction could potentially be highly beneficial (both to individuals themselves and society as a whole), but where peer influence is uncommon due to stigma and other personal and social costs.

As mentioned above, a novel aspect of our study varies whether the referrer only provides information about potential patients to health providers, or also does the outreach to those patients. As a result, we can distinguish between different mechanisms through which referrals might provide value. In contrast, in existing studies of customer, employee, and patient referrals, the referrer always does the outreach. We are aware of only one marketing study that contrasts the effectiveness of outreach by current customers (analogous to patients in our context) and independent agents (Godes and Mayzlin, 2009). In that study, outcomes cannot be directly associated with specific individuals on either side of the interaction since the relationship being measured is between aggregate sales in a market and the total amount of word of mouth delivered by customers and agents in that market.

In addition to contributing to the academic literature on networks, referrals, and incentives, our study is relevant to public health policy. It is closely aligned with and designed to study potential improvements to the strategies used by both the WHO and India's Revised National TB Control Programme to fight tuberculosis. Moreover, other communicable diseases such as HIV/AIDS present challenges similar to those posed by TB. These diseases also affect vulnerable, marginalized populations and carry strong social stigma. Therefore, insights from the TB context may prove useful in the HIV/AIDS context and possibly even suggest ways in which campaigns to combat the two diseases (TB is the most common illness and a major cause of death among HIV-positive individuals) can strengthen each other.

In the next section, we present the simple conceptual framework we used to guide our analysis. In Section 3, we describe the context and the experimental design; in Section 4, we present the results; and in Section 5, we offer our conclusions.

2 Conceptual Framework

The conceptual framework that guides our experimental design and analysis considers the choices of current patients, who face potential costs and benefits from referring others for TB screening. The model is based on Beaman and Magruder (2012), who applied the framework to the more traditional context of job referrals.

We assume that each current patient (CP) i undergoing TB treatment at a certain health care provider is endowed with a given number of contacts $j = 1, ..., n_i$. From the perspective of CP_i, the individual making the referral, each of his contacts j is a potential subject of the referral and is characterized by:

1. A social reward s_{ij} that CP_i receives when referring contact j to the provider. The social reward includes the cost or disutility of the interaction due to the stigma and discrimination associated with TB, the time cost of meeting with contact j, the value of any intrinsic utility generated by the interaction (such as the "warm glow" described by Andreoni (1990) that CP_i experiences from knowing he helped contact j improve her health), and any financial exchange between the two parties. The social reward s_{ij} can therefore be positive or negative, depending on whether its positive or negative components prevail.

2. A fixed payment from a third party, f_i, received for referring contact j, if j presents with symptoms consistent with TB, irrespective of the test results.

3. A contingent payment from the third party, p_i, received only if contact j tests positive for TB. Implicitly, p_i is conditional on j getting tested and testing positive.

4. The subjective probability π_j that contact j has TB, as assessed by CP_i after observing signals such as whether person j presents symptoms consistent with the disease.

5. The probability $\lambda_{ij}(X_j,q_{ij})$ that contact j will present for screening; that is a function of person j's characteristics, X_j, as well as q_{ij}, the quality of information available to person j about the costs and benefits of screening and treatment, which can be influenced by her interactions with CP_i.

An individual CP_i will make a referral if his net expected benefit from the referral is positive, i.e., if:

$$s_{ij} + \lambda_{ij}(f_i + \pi_j \times p_i) > 0 \tag{1}$$

Due to lack of awareness of the social benefits of making referrals, and because of the stigma associated with TB, the social reward s_{ij} for making a referral is likely to be small or negative. This explains why, in the absence of other incentives, referrals in this context are rare–in contrast to the job referral context, where the social reward for a referral is typically positive. Our experiment includes an "encouragement" condition without any financial incentives; this increases the salience of the social importance of testing anyone with TB symptoms and therefore the perceived positive component of s_{ij}; it also potentially motivates the current patient to improve q_{ij}, thereby increasing the probability that person j presents to get screened.

The payment to the referrer may be entirely fixed ($f_i > 0$ and $p_i = 0$) or depend on the new patient's TB test results ($p_i > 0$).[7] When the reward is fixed, each CP_i has an incentive to refer any contact who may be willing to be screened for TB, whether or not the person has symptoms consistent with TB. If a person's willingness to get screened and tested (λ_{ij}) increases with π_j, the likelihood that they have the disease, then current patients have private incentives to target referrals to contacts most likely to be infected even under a system of fixed payments only. However, current patients and their contacts could behave strategically to take advantage of fixed payments. Introducing contingent payments allows us to determine the extent of such opportunistic behavior. When contingent payment is introduced, CP_i's expected payment depends directly on his information about a contact's characteristics, and CP_i has stronger incentives to make use of his knowledge about his contact's health. Therefore, the probability that any new symptomatic actually has TB is greater when that new symptomatic is referred by a current patient eligible for contingent payments p_i than a current patient eligible for a fixed payment f_i of equal expected value.[8]

In our experiment, referrals can be operationalized in one of two ways. The first involves personal contact between i and j. Alternatively, i could provide contact information for j to a third party, such as a health worker. The health worker could either reveal i's identity as the impetus for the contact or conceal it. These strategies vary in their implications for q_{ij}, the quality of information received by contact j, and s_{ij}, the social cost to CP_i of referring contact j. Direct conversation between i and j can transmit both objective (symptoms of TB, location of testing and treatment centers, duration of treatment, etc.) and subjective (personal experience with health workers, experience with side effects of medication, etc.) information. That information may carry additional weight because of the preexisting relationship between i and j. In contrast, outreach by a health worker transmits objective information but not the subjective experience of a personal contact. The perceived quality of the information conveyed by the health worker may be enhanced when the health worker indicates that she visits at the behest of contact i. Whether the ultimate quality of information received by j is higher or lower for outreach by current patients or health workers depends on

[7]As we describe in more detail below, we calibrate the payment structure in our experiment such that the total expected value of third-party payments for a new referral are the same for current patients assigned to pure fixed payment incentives or to a combination of a fixed payment plus a contingent reward.

[8]One additional requirement for conditional incentives to result in more referrals and more symptomatics identified is that symptoms that are observable by current patients must be correlated with the probability of having TB.

the weight j places on subjective versus objective information and on the effectiveness and accuracy of current patients relative to health care workers in communicating about tuberculosis. If potential TB patients value subjective information highly or trust their contacts substantially more than health workers, then outreach by current patients could raise q_{ij} by more than outreach by health workers.

Varying whether outreach is conducted by current patients or health workers also manipulates s_{ij}, the social cost to CP_i of referring contact j. While personal contact between i and j may facilitate the exchange of information about the benefits of treatment, i incurs time costs for the interaction and by design, it also reveals i's status as a TB patient to j and therefore increases i's costs. If, instead, a health worker reaches out to j and conceals i's identity, this removes the negative component of the social reward term s_{ij} but does not necessarily affect its positive component because CP_i may still enjoy the "warm glow" of having helped someone (and is free to personally tell person j if he so chooses). Thus, if stigma is an important deterrent to referrals and enters s_{ij} strongly negatively, then we expect more referrals in experimental conditions that conceal the current patient's identity.

The predictions we have discussed thus far relate to how changes in the value of fixed and contingent third-party payments affect the probability that a current patient i refers a social contact j for TB screening. We now consider two additional implications of the model and experimental design. The first relates to the characteristics of the social contacts $j = 1, ..., n_i$ who are referred for TB screening. While current patients likely face lower costs of outreach than health workers because they interact with people who share their risk factors for TB in the course of their usual routines, their contacts vary in vulnerability and marginalization. On one hand, the more vulnerable may be more likely to have TB (and less likely to have access to information about testing and treatment). On the other, social costs associated with referring a more vulnerable or marginalized contact may be higher because of lower social reward or higher time cost for the interaction. Therefore, both types of incentives may change the composition of referred symptomatics by increasing the chance that vulnerable individuals are identified.

3 Context and Experimental Design

3.1 Context

Tuberculosis is a disease caused by bacteria that spread from person to person through the air. Although it can affect other body parts such as the brain and kidneys, TB typically affects a person's lungs. The TB bacteria attack the body, destroying tissue. Symptoms of pulmonary TB include chest pain, persistent cough, coughing of blood or phlegm, weakness or fatigue, night sweats, and weight loss. The disease is thus highly debilitating, and, when untreated, has a high mortality rate. TB is currently the ninth leading cause of death and the leading cause of death from a single infectious agent worldwide. The WHO estimates that 10.4 million people developed TB in 2016 globally, 45% of them in Southeast Asia. In the same year, 1.3 million HIV-negative and 374,000 HIV-positive people died of TB.

Tuberculosis can be treated and cured. Treatment consists of several antibiotics that kill the TB bacteria; multi-drug regiments that cure TB have been available since the 1950s. A typical treatment course takes six months and patients take medicines two to three times per week. In India, these medicines are available at no cost to patients, and are provided by the government in partnership with the WHO. Laurence and Vassall (2015) report that in India, the cost of a full course of medication for drug-susceptible TB was $15 per patient as of 2005; on average across low income countries, the cost was $49/patient. Although patients typically start to feel better after taking the medicines for a few weeks, in order to be cured, it is important to take them as prescribed and to complete the entire treatment course. Failure to complete the treatment not only results in failure to be cured, but it may also make the bacteria resistant to the medicines, causing Drug-Resistant TB (DR-TB) or Multi-Drug Resistant TB (MDR-TB) or even rarer and harder to treat strains. DR-TB and MDR-TB are, by definition, more difficult (and more expensive) to treat than simple TB because the bacteria are resistant to one or more drugs.

Tuberculosis is a major public health problem in India. India has the largest number of TB cases in the world and accounts for more than one-quarter of the global TB burden. Almost 3 million people develop active TB each year and it caused 435,000 deaths in India in 2016. The country is among the WHO's "high burden" countries for TB, TB/HIV co-infections, and MDR-TB (World Health Organization, 2017). The Revised National Tuberculosis Control Programme (RNTCP) is the Indian Government's TB control initiative.[9] The RNTCP is coordinated by TB officers appointed at the district and state level. TB services are delivered through the existing health infrastructure, in which primary and community centers serve as treatment centers to administer and monitor DOTS to patients. Nongovernmental and private providers are systematically and actively engaged under the RNTCP. In 2008, about 3,000 NGOs and 20,000 private practitioners were part of the RNTCP effort.

For our study, we partnered with Operation ASHA, an Indian NGO that operates about 200 community-based DOTS centers in several cities in 11 Indian states. Operation ASHA employs community health workers, known as "providers" or "counselors," whose job description includes detection and outreach to new patients as well as monitoring of drug therapy for

[9]India launched its National Tuberculosis Programme (NTP) in 1961. Later, in order to standardize TB treatment and implement the DOTS strategy, the Revised National Tuberculosis Control Programme (RNTCP) was started in 1997. Over the next nine years, it expanded across the country.

patients under treatment. Although Operation ASHA is a nongovernmental organization, it works within the existing structure of the RNTCP. When prospective patients ("suspects") are identified as presenting symptoms consistent with TB ("symptomatics"), they are directed to a government testing center for a sputum test. Those who test positive for TB are then enrolled with one of Operation ASHA's treatment centers, where their medication is dispensed at no charge to them, according to DOTS standards and conforming with RNTCP guidelines and protocols. Patients present at the center to take their medication according to treatment regimen and start date. As part of the proprietary biometric monitoring system employed by Operation ASHA, counselors verify patients' fingerprints before dispensing medication. At the end of the prescribed treatment period, all patients are tested to determine whether they have been cured.

3.2 Experiment setup

Our study consisted of a randomized controlled trial implemented in 128 Operation ASHA centers in 10 cities across 4 states (Delhi NCR, Madhya Pradesh, Rajasthan, and Odisha). The intervention was implemented by JPAL-South Asia at IFMR in five waves between January 2016 and October 2017.

We augmented Operation ASHA's traditional use of community health workers and DOTS treatment by incorporating financial incentives to encourage referrals from current patients to new suspects. More specifically, we used a cross-randomized design to test, respectively, three types of incentives for referrals and three types of outreach to potential TB patients (described in detail below). The baseline sample was drawn from all Operation ASHA patients receiving treatment who were at least two weeks into their TB medication course by the time the baseline surveys commenced. We expanded the sample to include patients who had completed their six-month treatment in the three months before the start of the baseline surveys. Current patients were either in the intensive phase (IP) of treatment, where they came to the centers three times per week, or in the continuing phase (CP) of treatment (typically following IP), which required them to come to the center once a week. Patients suffering from MDR-, XDR-, or TDR-TB were not included in the sample.[10] In cases where the patient was a minor, the survey questions were addressed to their legal guardian. The experiment was rolled out in five waves between March 2016 and October 2017. A total 3,182 patients were included in our study.[11]

[10] XDR-TB is Extremely Drug-Resistant and TDR-TB is Totally Drug-Resistant.

[11] The Operation ASHA lists we received included 4,203 patients. Of these, 3,402 (81% of the total) were surveyed at baseline and thus enrolled in the study. Reasons why some patients were not surveyed included: a move to another city or district, inability to track them after three enumerator visits, or a diagnosis of MDR-TB. There was no economically or statistically significant association between the proportion of listed patients who could not be surveyed at baseline and experimental conditions. An additional 220 patients were

In both treatment and control centers, each current patient was visited by a survey enumerator in a private location such as the patient's home. Enumerators obtained informed consent and then administered a baseline survey. Information was collected on the current patient's socioeconomic characteristics, physical and psychological health, and TB treatment, as well as on information-sharing networks. At the end of the survey, patients at both control and treatment centers were prompted to think about individuals outside of their households they believed might be affected by TB. ("Please think of people you know who have TB symptoms.") According to RNTCP protocol, immediate family members of TB patients should be tested for TB automatically, and were, as such, excluded from our referrals scheme because they were already known to the system. Then, for treatment centers only, all patients were told, "We are promoting outreach for tuberculosis to encourage more people to get tested and treated, and we invite you to join this effort." They could do this by recommending TB testing for people they knew socially and believed to have symptoms. New suspects would be given referral cards with information about the screening process. An example of a referral card to be distributed by current patients is provided in Figure 2. The cards contained information about Operation ASHA, names and addresses of local providers and treatment centers, a list of TB symptoms, and an ID number used by Operation ASHA and the research team to link the card to the referrer and to distribute incentives according to the study design. New suspects were expected to bring these referral cards to the Operation ASHA centers, where they would be screened by health providers and sent for further testing (if required) as per RNTCP mandates.

This process, from the referral's arrival at the health center to screening, was recorded in referral registers placed at the Operation ASHA centers that were updated with the relevant outcomes at each step, including the result of the screening, whether the new symptomatic got tested, the results of the test (for individuals who got tested), and whether the newly identified TB-positive cases enrolled in treatment.

3.3 Experimental variation: incentive conditions

The first type of experimental variation was in the reward offered for each new suspect who sought screening and presented a referral card linked to a current patient. In one-third of centers, there was no financial reward, only encouragement to participate for the good of the community. In these centers, both f_i and p_i were thus zero. In another third of centers, current patients were offered Rs. 150 for each new suspect who got screened at their behest. This treatment condition corresponds to $f_i = 150$ and $p_i = 0$. This amount corresponds to

interviewed at baseline but were omitted from the sample because a change in Operation ASHA's relationship with the leadership at the government testing center in Bhubaneshwar, Odisha meant we were not permitted to access administrative endline data for these patients.

about $US 3 and is roughly equivalent to the median daily income in India.[12]

Finally, in the remaining third of centers, current patients were offered Rs. 100 for each new suspect who got screened and an additional Rs. 150 if the suspect tested positive for TB. This corresponds to $f_i = 100$ and $p_i = 150$. The fixed payment provided some insurance to the referrer; the size of the fixed payment and the bonus was calibrated such that the conditional and unconditional incentives were of equal expected value based on the rate of positive tests in a pilot study conducted between June and September 2012. These, as we will show below, turned out to be roughly the same in the full study.

3.4 Experimental variation: outreach conditions

The second type of experimental variation is in the nature of the referral itself. We compare peer outreach to two types of health worker-facilitated outreach. In the one-third of centers assigned to the peer outreach condition, referral cards were given to current patients. They were asked to approach people they knew socially and believed to have TB symptoms, inform them about the consequences of TB and the treatment, give them cards, and encourage them to get tested. Current patients had up to 30 days to deliver the cards, and new suspects had an additional 30 days to present at the Operation ASHA center for screening.[13] The enumerators asked the patients to emphasize to the new suspects the importance of bringing the card when coming for screening. Patients were also told they were free to request additional cards, if needed; this was done to avoid creating a perception of scarcity that might have resulted in different opportunity costs of providing cards in the various experimental conditions.

The health worker outreach conditions represent the current best practice regarding outreach and treatment of communicable disease. In these treatment centers, current patients were asked to provide names and contact information of people in their social network who might benefit from getting tested for TB, in order for a health worker to follow up by visiting these individuals. The current patients were shown the referral cards and told that the Operation ASHA health worker would deliver the cards to the people they named. As in the peer conditions, the patients were told that they had 30 days to provide names and the new suspects would have 30 days to present for screening after receiving cards from a health worker.

Half of the health worker outreach centers were assigned to the "referrer-identified" condition, in which current patients were told their names would be used when the health worker approached new suspects on their behalf; the specific language was, "[Name] was concerned about your health and asked me to visit you." This condition is comparable to the peer

[12] Diofasi and Birdsall (2016) report median daily incomes of $2.50 in rural India and $3.50 in urban India.

[13] A new suspect who arrived outside the 60-day window would still be screened, tested, and treated if necessary, but the current patient would not receive credit for the referral per study protocols.

outreach condition in terms of stigma, because the current patient's TB status is revealed to new suspects he names. The remaining health worker outreach centers were assigned to the "anonymous" condition, in which current patients were told their names would not be revealed to the individuals they referred. Instead, health workers would tell the new suspects, "Someone was concerned about your health and asked me to visit you."

To ensure that current patients in the peer conditions received the same level of priming as those in the contact-tracing conditions, patients in the peer conditions were also asked to provide names and contact information of people they knew who might benefit from getting tested for TB.[14]

Note that while all incentive treatments designate financial rewards to be paid to the current patient, it is possible that current patients and the new suspects they identified chose to divide the money between themselves according to a sharing rule of their own election. This does not undermine our research design; such side payments are simply part of the social reward that composes part of the expected benefit (or cost) of making a referral. The policy-relevant estimate of the effect of incentives allows for side payments to take place naturally at the discretion of current patients and new suspects.

While effort by peers is an outcome of the study, we monitored the Operation ASHA health workers closely to ensure they visited all the individuals named by the current patients. Health workers were told that the JPAL team would survey each referral and ask them whether they had been visited by the Operation ASHA representative and given the referral cards. Health workers were compensated for their participation in the outreach and monitoring activities required by the study. They received fixed monthly payments if the JPAL team determined they completed required activities. Compliance was high: 87.5% of new suspects named in the contact-tracing arms were visited by health workers (85% in the encouragement arms and 88.4% in the incentivized arms).

This experimental variation in outreach strategy relates to the social cost of a referral, s_{ij}. Peer referrals carry two types of costs: the time cost of the interaction itself and the stigma cost of revealing one's own TB status to a peer. Referrer-identified contact tracing eliminates the time cost to the current patient (and shifts it to a health worker) but, because the health worker explicitly names the peer who provided the referral, it maintains the stigma cost. Anonymous contact tracing carries neither time nor stigma costs at the margin.

s_{ij} captures net social costs and incorporates social benefits from referrals. It is unclear how to rank the treatments in terms of their social benefits to current patients. Current patients may experience a "warm glow" from helping others even if their contribution is

[14] Of course, patients in the peer condition were not limited to reaching out to the contacts they named. As shown in Appendix Table A2, patients in peer conditions named fewer names than those in the contact-tracing arms. However, they made more referrals than the names they provided at baseline.

anonymous. Or, they may feel greater satisfaction–or receive gratitude from their peers–for in-person or identified outreach strategies. Since peer referrals may have higher costs and benefits than identified or anonymous contact tracing, the question of which strategy will generate more referrals is an empirical one.

In the public health context, the information conveyed to the new symptomatic is paramount. Health workers and peers may differ in q_{ij}, the content of the information they convey to symptomatics, and in the credibility with which the information is perceived. On one hand, health workers may be better informed about symptoms and treatment of TB, and their expertise may be respected by potential patients. On the other hand, current patients are able to provide firsthand testimonials about the experience and benefits of treatment from a patient's perspective. Furthermore, because current patients are asked to speak to people they know personally and believe to have symptoms of TB, the personal connection may also build trust and enhance the value of the information exchanged. In the identified contact-tracing condition, where health workers reveal the identity of the referring current patient, some of that credibility may be recovered through the endorsement.

The final design thus randomly assigned 128 clinics to a pure control condition or one of nine treatment conditions; Figure 3 summarizes the research design and indicates how many centers and patients were assigned to each experimental condition.

3.5 Incentivized elicitation of outreach effort

After responding to the endline survey (details on data collection are given in the next section), participants were offered the opportunity to return unused referral cards to the enumerators for a payment of Rs. 10 for each card returned. This provided an incentive-compatible measure of how many cards were not distributed (in contrast to simply asking respondents, who may exaggerate the number of cards distributed because of experimenter demand effects). By combining this measure of the number of cards not distributed with administrative data about the number of cards brought to Operation ASHA providers, we were able to compute the number of cards distributed by current patients but not redeemed by suspects–information that helped us better identify the nature of the barriers to referrals and testing. Patients were not told about the card buyback in advance in order to prevent strategic or risk-averse behavior with regard to card distribution.

4 Data and Results

4.1 Data

Our analysis combines administrative data from Operation ASHA and two rounds of surveys with current patients and the new suspects they identified. The administrative data include rosters of baseline patients and new suspects (collected as part of their normal outreach and enrollment procedures), ID numbers for current patients who referred each new suspect, and information on treatment adherence for all patients. Baseline surveys of current patients measured their socioeconomic characteristics, physical and psychological health, risk- and information-sharing networks, and attitudes toward Operation ASHA and TB treatment. After the intervention, endline surveys were conducted with current patients to capture information on health outcomes, satisfaction with Operation ASHA, and questions about the referrals scheme to learn what information current patients had shared about incentives or other aspects of the program. Surveys were also administered to the new referrals identified through the scheme. Intake surveys of new suspects measured their characteristics and their relationship with the patient who referred them.

4.2 Patient characteristics and balance tests

Tables 1 and 2 provide the means and standard errors of patients' baseline characteristics overall as well as by incentive condition and outreach type. As a result of working with a large provider operating in multiple states, our sample is not only large but also heterogeneous on many sociodemographic dimensions. The average current patient in the study was approximately 37 years old, and about 40% of baseline patients were women (World Health Organization (2017) reports that 65% of new incident TB cases are male). About 70% of the patients had some literacy, 30% had secondary education, and 61% had a bank account. Eighty-three percent of the respondents had never been previously treated for TB.

Tables 1 and 2 show that the randomization resulted in patients having similar characteristics across experimental conditions. To formally test for balance, we conducted an analog of the omnibus balance test for a two-arm randomized controlled trial by estimating a multinomial logit for assignment to one of the three incentive conditions versus the control, and for one of the three outreach strategies versus the control, respectively, on patient baseline characteristics. These include sex, religion, literacy, education, asset ownership, bank account access, social inclusion (measured by the number of social contacts in the previous 24 hours), and history of TB treatment (including timing of past treatment and lag between onset of symptoms and initiation of treatment), as well as a set of city fixed effects. The p-value for the chi-square test that these characteristics jointly predict assignment to an incentive condition is 0.0039 and the p-value for the analogous test for assignment to an outreach strategy is p=0.3001. The p-value for the F-test for the comparison between any treatment group (pooling across the nine treatment arms) and the pure control group is 0.3516.

We also implemented standard omnibus balance tests that compare pairs of treatments using linear probability models. Specifically, we compared the probability of assignment to each of the three incentive treatments (separately) relative to the control group and to the other incentive treatments, and to each of the three outreach treatments (separately) relative to the control group and to the other outreach treatments. These tests involve 12 separate regressions: six comparing an incentive or outreach treatment to the pure control group, three comparing pairs of incentive treatments, and three comparing pairs of outreach treatments. The p-values for the F-tests that the covariates included in Tables 1 and 2 jointly predict assignment are reported in Appendix Table A1. Six specifications compare a treatment arm to the pure control group. In five, we fail to reject the null that the covariates jointly predict assignment at the 90% confidence level; the p-value for the test that covariates jointly predict assignment to the unconditional incentive treatment relative to the pure control group is 0.076. Among the outreach treatments, covariates are well-balanced between each of the three possible pairs of treatments (peer-to-peer compared to identified contact tracing; peer-to-peer compared to anonymous contact tracing; and identified compared to anonymous contact tracing), with p-values of 0.2 or greater for the three between-treatment comparisons. We also fail to reject the null that covariates are well-balanced between the unconditional incentive and encouragement treatments. However, the p-value for the test that the coefficients on covariates are jointly zero when comparing the conditional incentive to the encouragement treatment is less than .001, and the p-value for the comparison between the conditional and unconditional incentives is 0.044.

Thus, of 12 tests, we obtain two p-values less than 0.05. In economic magnitude, only the asset index appears to exhibit meaningful differences across treatment groups. While our preferred specifications include only city fixed effects, the magnitudes and statistical significance of our estimates are virtually unchanged by the inclusion of baseline covariates. These alternative specifications are reported in the Appendix.

4.3 Overview of aggregate outcomes

Although our experiment is designed to measure the effects of various referral schemes on an individual patient's behaviors, we begin by presenting the aggregate outcomes of the study.

The 3,182 current patients who were invited to participate in the referral scheme under one of the nine treatment conditions generated a total of 222 new suspects who were screened by Operation ASHA health workers. Of these, 176 (almost 80%) presented symptoms consistent with TB and were sent for testing at the government testing centers. Compared to other case-finding efforts in India, this effort identified a large number of symptomatics, especially relative to the scale of outreach. For example, Charles et al. (2010) conducted outreach to 18,417 individuals and found 640, or 3.5%, to have symptoms consistent with TB.

In our study, 129 individuals who had been screened subsequently presented themselves for testing at a government center. Thirty-six were found to have active TB, of which 34 began treatment immediately. All of these cases were previously unknown to the health care system, and because of the study's stringent requirements, none of these patients were immediate family members of the current patients who referred them.[15] The 28% infection rate of the new symptomatics who were identified and tested through our referral schemes is more than twice as large as the 12% average TB-positive rate reported in official RNTCP statistics (the average rates in the states where we conducted our study were 14% in Delhi and Madya Pradesh, 13% in Odisha, and 17% in Rajasthan).[16]

4.4 Analysis

We study current patients' responses to incentives and their efficacy as outreach agents by matching new suspects who are screened and tested to the current patients who referred them through the unique ID codes embedded in the referral cards. We report seven nested outcomes, each an integer value and measured at the level of the current patient. First, we measure the total number of new suspects linked to a current patient who presented for screening at the Operation ASHA centers.

Next, we measure the number of these symptomatics who are sent for testing. This distinction is important because it indicates whether the referral strategies in this experiment result in targeted testing of symptomatic individuals, or whether current patients are unable (or unwilling) to distinguish between peers with symptoms of TB and those without. As part of its partnership with the RNTCP, Operation ASHA routinely screens prospective patients and sends only those with symptoms indicative of TB for testing. It plays the same gatekeeping role in screening prospective patients identified through the referrals scheme. Then, we measure the number of symptomatics who actually get tested, as testing is a necessary condition to obtain treatment but requires effort by symptomatics (who have to report to a district microscopy center) and represents a critical juncture for loss to follow up. Finally, we measure and report the number of positive cases of TB attributed to the outreach

[15] Referrals in the contact-tracing conditions were neighbors (47%), relatives (41%), and friends or coworkers (12%) of the current patients who referred them. The corresponding percentages in the peer-to-peer conditions were 48%, 35%, and 17%, respectively. The provision of incentives did not have any economic or statistically significant effects on the relationship between referrer and referral.

[16] In a study in Nepal that used peer volunteers to identify TB cases (Joshi and Brouwer, 2017), 6,046 suspects were tested over a period of 16 months, resulting in 287 TB diagnoses, or 4.3%.

of each current patient in the sample.

Note that we had procedures to capture any peer referrals made by current patients of pure control clinics (we asked Operation ASHA health workers at all centers to keep a record of the source of each new suspect screened during the intervention period), but in practice, and in accordance with the extremely low rate of peer referrals that motivated this study, all outcomes equal zero for current patients in the pure control group.

Also note that the outcome variables we study are the union of behavior by current patients who decide whom to approach or refer to a health worker, how much effort to exert, and what information to share, with that of the suspects who decide whether to visit Operation ASHA for screening and to follow up when testing is recommended. Each of the referral modalities we consider has advantages and disadvantages. Our approach is to test the relative performance of each type of referral with reduced-form specifications that capture the total effects of the ways these strategies differ in costs, benefits, and information provided. Nonetheless, a comparison of the effects of various incentive types and outreach modalities informs different mechanisms through which referrals may (or may not) prove valuable in this context.

4.4.1 Financial incentives

To measure the effect of incentives on referrals generated by current patients, we use OLS to estimate linear models of the form:

$$y_{ijc} = \alpha + \beta_1 \text{Encouragement}_{jc} + \beta_2 \text{Conditional}_{jc} + \beta_3 \text{Unconditional}_{jc} + \Gamma_c + \epsilon_j \qquad (2)$$

where i indexes current patients, j are clinics (the level of treatment), and c are cities. Γ_c are city fixed effects, which absorb state and wave fixed effects (randomization was stratified by city). The omitted category in this specification is pure control clinics, so β_1 is the effect of encouraging current patients to make referrals, relative to the status quo; β_2 is the effect of offering current patients Rs. 100 for each new patient screened at their recommendation, plus an Rs. 150 bonus for any referrals who test positive for TB (corresponding to $f_i = 100$ and $p_i = 150$); and β_3 is the effect of offering current patients Rs. 150 for any new patient screened at their recommendation, regardless of test outcome ($f_i = 150$ and $p_i = 0$). We also report p-values for the tests that $\beta_1 = \beta_2$ and $\beta_1 = \beta_3$, in order to measure the effect of financial incentives relative to encouragement, and for the test that $\beta_2 = \beta_3$ to compare the conditional and unconditional incentive structures. Recall that treatment is assigned at the clinic level; standard errors are therefore clustered at the clinic level.[17] [18] Additionally, we report p-values adjusted for testing 12 hypotheses (three coefficients and four outcomes), using the false detection rate methodology of Benjamini and Hochberg (1995). All of our specifications are robust to including the patient-level covariates from the balance tests, and those specifications are provided in the Appendix.

While encouragement without financial reward does increase referrals relative to the pure control condition, the results from the main OLS specifications reported in Table 3 clearly indicate that incentives matter. From column (1), patients at clinics assigned to the encouragement arm referred, on average, 0.044 new suspects. Patients eligible for conditional incentives referred 0.102 new suspects and those eligible for unconditional incentives referred 0.096 new suspects. The p-value for the difference between encouragement and the conditional incentive is 0.09, and the p-value for the difference between encouragement and the unconditional incentive is 0.03. While money matters, conditionality apparently does not: the p-value for the test that the conditional and unconditional incentives have equal effect is 0.84. The pattern persists in other measures of referrals, though is less precise as outcomes are defined more granularly and with correspondingly lower variation. Note in particular that the vast majority of suspects identified through this scheme were sent for testing, indicating that current patients were able and willing to identify true symptomatics (column 2). As noted in section 4.3 above, more than one-quarter (28%) of the new symptomatics identified through any of the treatment arms who got tested were ultimately diagnosed with TB, a higher rate than in the public sector in India during the same time period. As shown in column (4), current patients in the unconditional incentive treatment group identified, on average, 0.013 new TB patients, and current patients in the conditional incentive treatment group identified 0.005 new TB patients (the p-value for the test that the effect of all three treatments is jointly zero is 0.07). In the encouragement group, current patients were responsible for detecting an average of 0.003 cases of TB. The difference between the encouragement group and the unconditional group is significant at the 90% confidence level (p=0.09), and the difference between the encouragement group and the conditional incentive group is not significant at conventional levels (p=0.30).

We interpret these results as evidence that current patients respond to encouragement and, especially, financial incentives to share information about treatment for a communicable disease. Screening, testing, and identification of TB patients are all measures of welfare in a context with a high disease burden, where it is important to either diagnose TB or rule it out

[17]Our primary results are from linear models. Below, we also report estimates from linear probability specifications for binary definitions of the outcomes; these specifications omit the pure control group because there were no referrals among current patients in that treatment arm.

[18]In the Appendix, we reestimate equation (2) at the clinic level, where outcomes are clinic level averages and regressions incorporate Stata's analytic weights to account for different sized clinics.

as a cause of illness. Behavioral responses by current patients–identifying more new suspects when offered a financial incentive to do so–translate into small but economically meaningful and statistically significant increases in case finding.

4.4.2 Outreach strategies

The second set of current patient-level analyses focuses on the effects of peer outreach and two variants of contact tracing, identified and anonymous, relative to a pure control condition. In all clinics, including the pure control group, health workers are tasked with routine outreach to and screening of the immediate household members of newly diagnosed patients. This analysis focuses on patients who are screened and tested because of the recommendation of a current patient, not through Operation ASHA's standard operating procedures. Outcomes for current patients in the control group are equal to zero in practice, though not by definition.

As in the previous section, we pool across treatment arms to estimate regressions of the form:

$$y_{ijc} = \alpha + \gamma_1 \text{Peer}_{jc} + \gamma_2 \text{Identified}_{jc} + \beta_3 \text{Anonymous}_{jc} + \Lambda_c + \mu_j \tag{3}$$

Any peer-facilitated outreach is more effective than the status quo; 10 of the 12 coefficients reported in Table 4 are significantly different than zero even after adjustment for multiple hypothesis testing, and we reject that the joint effect of the three treatment arms is equal to zero for all four outcomes. Peers are more effective than trained and paid health workers at convincing suspects to get screened and tested, even though the patients approached in both contact-tracing arms are identified by current patients. The interaction between a current patient and a suspect increases the probability of screening and testing. Current patients asked to recruit new suspects directly through peer-to-peer interaction bring an average of 0.124 new suspects in for screening, compared to 0.054 for those approached by health workers on behalf of a named peer (identified contact tracing) or 0.056 for those approached by health workers on behalf of an unnamed peer (anonymous contact tracing). The p-values for the differences between peer outreach and the two contact-tracing arms are 0.01 and 0.03, respectively. The three treatments are comparable in their efficacy in increasing the number of patients tested. Peer referrals have a statistically significant effect (at the 95% level) on the number of TB cases found (0.010 per current patient in the peer outreach arm), but differences with respect to the contact-tracing arms are estimated imprecisely.

Peer outreach results in the screening of twice as many new suspects as contact tracing by health workers, despite the additional transaction costs borne by current patients in the peer outreach condition. This suggests that peers are more effective in conveying information about the benefits of treatment to convince symptomatics to seek health counseling, intuition that is confirmed by the analysis of complementarities between financial incentives and peer outreach in Section 4.4.4 below.

4.4.3 Extensive margin

The magnitude of the individual response to incentives is substantial. The previous sections consider the number of new patients detected, but for the purpose of comparing the magnitudes of our results to the related literature on job referrals, and for a more complete understanding of the referral process, we also estimate linear probability models that correspond to equations (1) and (2) but have binary dependent variables: any new suspects screened, any new suspects sent for testing, any new suspects who get tested, and any new suspects whose sputum test results are positive. Since the modal number of new patients screened conditional on making any referrals is one, it is not surprising that the extensive margin results are qualitatively very similar to the results in the previous sections; both the financial incentives and outreach interventions operate primarily at the extensive margin.

Some 3.8% of current patients in the encouragement treatment arm made at least one referral resulting in a screening, compared to 6.1% of patients who received the unconditional incentive of Rs. 150 for each new symptomatic screened; the difference of 2.3 percentage points is statistically significant at the 90% level (see Appendix Table A8). In the conditional incentive arm, 4.9% of current patients made at least one referral resulting in the screening of a new suspect, an effect that is significantly different from zero but not from the point estimates for either encouragement only or the unconditional incentive.

In an experiment with a similar design but a different context for social costs and benefits, Beaman and Magruder (2012) found that an unconditional incentive of Rs. 110 (in 2009, equivalent to Rs. 184 in 2017) increased the probability of referring a contact for a day of paid employment by 7.7 percentage points, from a base probability of 69.5. In percentage terms, similar economic incentives had a bigger effect on referrals in our public health context than in the employment context. This is striking since the total social costs s_{ij} of referrals for TB testing and treatment may be higher due to stigma and because job referrals may generate income a contact can share with a referrer, but health referrals do not, at least in the short term.

4.4.4 Complementarities between incentives and outreach modalities

Next, we investigate whether there are complementarities between incentives for referrals and outreach modality. Peer outreach is more costly to current patients than providing names to health workers because of the time and effort required to perform outreach activities as well as the social cost of interacting with others to discuss a potentially uncomfortable subject. Therefore, we hypothesize that incentives might be particularly effective under the peer outreach modality.

Because the results in sections 4.4.1 and 4.4.2 indicate no economically or statistically meaningful differences of the conditionality of incentives or anonymity of contact tracing, we test for complementarities between financial incentives and peer outreach by pooling the two incentive types and the two contact-tracing variants to estimate the following regression:

$$y_{ijc} = \alpha + \psi_1 \text{no\$Peer}_{jc} + \psi_2 \text{no\$Contact tracing}_{jc} + \psi_3 \text{\$Peer}_{jc} + \psi_4 \text{\$Contact tracing}_{jc} + \Gamma_c + \epsilon_j \quad (4)$$

where no$ denotes conditions with no incentives and $ groups with incentives.

The results from this exercise, shown in Table 5, indicate strong complementarities between financial incentives and peer outreach. Each current patient in the peer outreach condition produced, on average, 0.178 new suspects (significantly different from zero in the control group at the 99% level) when incentives were provided, compared to 0.036 (not statistically significant) in the absence of incentives. The p-value for the test that peer outreach is equally effective with and without incentives is 0.01. Similar patterns are observed for the other outcome variables, with incentives significantly enhancing the effect of peer outreach on the number of new suspects recommended for testing, the number of symptomatics actually tested, and the number of new TB cases detected.

In contrast, the estimated effects of contact tracing are similar with and without financial incentives. For example, each patient in the contact-tracing condition resulted in 0.063 new suspects screened (significantly different from zero at the 95% level) with incentives and 0.048 new suspects (significant at the 99% level) screened without incentives. We cannot reject that contact tracing with and without financial incentives is equally effective for all four outcomes. Moreover, the differential effectiveness of peer outreach relative to contact tracing is driven by the interaction with financial incentives.

4.4.5 Effort by current patients

Recall that we obtain an incentivized measure of effort from current patients assigned to the peer outreach treatment arm. (Only these current patients were given physical cards; in the contact-tracing arms, cards were distributed by health workers). After the endline survey, we offered to buy back any remaining referral cards. Some patients reported they had lost their cards; of 869 respondents assigned to peer outreach, the 195 who returned zero cards represent those who distributed 10 cards and those who lost or discarded the materials. The number of cards returned is a lower bound on the number of cards *not* distributed to new suspects. Nonetheless, a comparison of the number of cards returned by current patients eligible for different incentive schemes provides some information about the margin of effort. In the encouragement arm, current patients returned an average of 7.24 cards. Current patients eligible for unconditional incentives returned an extra 0.28 cards and those eligible for conditional incentives returned an extra 0.24 cards; relative to the encouragement arm, those differences are neither statistically nor economically significant.[19] This is striking because financial incentives strongly complemented peer outreach in increasing the number of new suspects screened and tested. It suggests financial incentives increased current patients' effort in improving the quality of information they conveyed to new suspects (q_{ij}) or in identifying suspects with characteristics–including observable symptoms of TB–that made them more likely to get screened conditional on receiving a card (higher λ_{ij}).

4.4.6 Heterogeneity by current patient characteristics

Our analysis of heterogeneous treatment effects reverts to separate specifications for incentive type and outreach type, and focuses on five characteristics that potentially predict differential responses: asset ownership, social connection, delay in seeking treatment for TB symptoms, phase of treatment, and gender.

Current patients with higher asset levels are likely to enjoy higher levels of consumption and to have higher opportunity cost of time. Wealthier current patients may be less responsive to incentives because the payments represent a smaller fraction of consumption. Wealthier patients may also be less effective when tasked with peer-to-peer referrals because of their higher opportunity cost of time.

Current patients who are more socially connected (measured by their number of contacts in the previous 24 hours) may face lower costs (lower s_{ij}) for each referral, predicting both more referrals on average and possibly a stronger response to financial incentives. The lower s_{ij} may also give these highly connected patients an advantage over less-connected patients in making peer referrals.

Current patients who seek treatment quickly may receive a higher social benefit (and therefore a lower net social cost s_{ij}) because of their own motivation or the perceived intrinsic value of making a referral. These patients may also be more effective in convincing peers to seek testing and treatment; this information can improve q_{ij} only if it is conveyed directly in the peer outreach treatments but not indirectly in the contact-tracing arms. Therefore, we expect more referrals from patients who do not delay seeking treatment for their own symptoms when they are assigned to the encouragement treatment (and have no clear prediction

[19]Results available upon request; the regression specification corresponds to equation (7) and the sample includes all patients assigned to the peer outreach treatment arm.

for the response to financial incentives). We also expect these patients to be more effective than patients who delay their own care in finding new symptomatics through peer referrals. They may also make more referrals in contact-tracing arms, but only through naming more contacts and not through communicating their own experiences.

Current patients in the intensive phase of treatment have realized fewer benefits of treatment than those in the continuation phase. They are more likely to experience side effects from the higher doses of medication they take and are required to take observed doses more frequently than those in the continuation phase. Therefore, they may bear higher costs of conducting outreach (higher s_{ij}), leading to predictions opposite those for patients with many social contacts: fewer referrals on average, a weaker response to financial incentives, and less willingness to make peer referrals. The patients in the intensive phase have also reaped fewer benefits of treatment, so they may be less effective in communicating its benefits.

Finally, we consider heterogeneity by gender. This analysis is standard in public health and in studies of India, a highly gendered society. It is particularly relevant in the context of our study, because in at least some of the communities where we worked, women's movement outside the household is strictly limited and social relationships are strictly gendered: men socialize with other men, and women socialize with other women. This means women may have lower ability to make peer referrals and that new symptomatics they refer (who are disproportionately likely to be women themselves) may be less likely to report to Operation ASHA for screening.

To test these predictions, we create indicators for above-median asset ownership, connection, starting TB treatment without delay, and for being in the intensive phase of treatment, respectively,[20] as well as for being female. We then estimate interacted versions of equations (1) and (2); the specification for the tests of incentives is:

$$\begin{aligned} y_{ijc} = \alpha &+ \delta_0 \text{Above median} + \delta_1 \text{Encouragement}_{jc} + \delta_2 \text{Conditional}_{jc} + \delta_3 \text{Unconditional}_{jc} \\ &+ \delta_4 \text{Above median} \times \text{Encouragement}_{jc} + \delta_5 \text{Above median} \times \text{Conditional}_{jc} \\ &+ \delta_6 \text{Above median} \times \text{Unconditional}_{jc} + \Gamma_c + \epsilon_j \end{aligned} \tag{5}$$

[20]The intensive phase lasts for the first two months of treatment and the continuation phase for months three through six. However, many patients require more than six months to complete treatment due to missed doses or other considerations. We set the indicator for intensive treatment equal to 1 for patients in the first two months of treatment and 0 for those in months 3-24. The indicator is coded as missing for the less than 1% of patients who reported that they started treatment more than 24 months before the survey.

and the specification for the test of outreach strategies is:

$$\begin{aligned} y_{ijc} = \alpha &+ \theta_0 \text{Above median} + \theta_1 \text{Peer}_{jc} + \theta_2 \text{Identified}_{jc} + \theta_3 \text{Anonymous}_{jc} \\ &+ \theta_4 \text{Above median} \times \text{Peer}_{jc} + \theta_5 \text{Above median} \times \text{Identified}_{jc} \\ &+ \theta_6 \text{Above median} \times \text{Anonymous}_{jc} + \Gamma_c + \epsilon_j \end{aligned} \tag{6}$$

Note that while we use the notation "above median" for convenience, the relevant indicator is coded as 1 for female patients and for those in the intensive and continuation phases of treatment, respectively, in the three specifications that consider those dimensions of heterogeneity. To maximize power and reduce the number of reported outcomes, we estimate these equations for only one outcome: the number of referred patients (corresponding to the outcome in column 1 of Tables 3 and 4).

We begin with Table 6, which estimates equation (3). As predicted, and shown in column (1), when assigned to the encouragement treatment, high-asset current patients make fewer referrals than current patients with below-median assets. While highly socially connected patients make more referrals on average, they do not respond differentially to the financial incentives. In the encouragement arm, patients who begin their own TB treatment without delay make marginally more referrals than those who delay seeking treatment, but there is no differential response to financial incentives. There is no clear pattern of differential response based on treatment phase; the interaction with the unconditional incentive is positive and imprecisely estimated, and the interaction with the conditional incentive is negative, of similar magnitude, and also imprecisely estimated. Finally, women do not make fewer referrals on average or respond differently to financial incentives than men.

Table 7 reports results for estimates of equation (4). While this specification confirms that highly connected patients make marginally more referrals (column 2), there is almost no evidence of differential effectiveness across the three outreach modalities. The exception is that patients with above-median asset ownership make fewer referrals in the anonymous contact-tracing condition than do those with below-median asset ownership. In most cases, the interaction effects are precisely estimated zeros. The statistical significance of the outreach strategies, the magnitudes of the coefficients, and the pattern that peer outreach generates approximately twice as many referrals as either of the contact-tracing strategies is similar to that in Table 4.

4.5 Effects of interventions on the characteristics of referred patients

The previous sections focused on the number of patients screened and tested, and relied on administrative outcomes. This section considers as outcomes the characteristics of the patients who were referred to Operation ASHA and screened by a counselor (corresponding to outcomes in column (1) of Tables 3 and 4).[21] The unit of analysis is the new symptomatic. The objective is to learn whether financial incentives and peer outreach, respectively, are effective tools to identify disadvantaged individuals in need of TB care. We consider four outcomes, gender, and three measures of social status: literacy, asset ownership, and social inclusion.

First, we compare new symptomatics to current patients at baseline and present group means in Table 8. Forty percent of current patients and 37% of the new symptomatics were female. On other dimensions, the new symptomatics appear disadvantaged relative to the current patients, despite being drawn from the same social networks by design. Almost 70% of current patients have at least some literacy, compared to 45% of the new symptomatics (the p-value for the test that current patients and new symptomatics have equal literacy rates is 0.00). Current patients spoke to an average of 2.6 people outside their households in the 24 hours before the baseline survey, while new symptomatics were less well-connected, with an average of 1.4 contacts (p=0.01). Of course, this may reflect that the new symptomatics were in poor health, while the current patients were on the way to recovery. Finally, there is suggestive evidence to indicate that the new symptomatics are poorer than the current patients: while current patients have a mean asset index value of 0.031, the new symptomatics average -0.144. The difference is imprecisely estimated (p=0.43) but large in magnitude.

Next, we study whether outreach strategies differed in their ability to identify disadvantaged individuals. For this analysis, each new symptomatic is assigned the treatment condition of the clinic where the referral originated. Since no patients were screened as a result of referrals in the control clinics, the specifications in this section omit the control clinics. In the first set of results, we estimate:

$$y_{ijc} = \alpha + \delta_1 \text{Conditional}_{jc} + \delta_2 \text{Unconditional}_{jc} + \Gamma_c + \epsilon_j \quad (7)$$

and the encouragement condition is the reference category. While the sample is both small and selected, Table 9 provides descriptive evidence about the characteristics of prospective patients identified under various schemes.

There is no indication that financial incentives cause current patients to identify relatively

[21] Of the 222 referrals screened, field teams were able to survey 172. Others had moved, refused to participate in the survey, or could not be tracked.

better-off patients than when they are asked to participate for altruistic reasons only. While the point estimates in Table 9 indicate little effect of incentives on the gender or literacy level of new symptomatics, those identified by incentivized current patients have lower asset levels than those identified by current patients in the encouragement treatment condition. The differences of -0.808 and -0.515 points, respectively, on the asset index are large relative to the mean asset score for symptomatics identified in the encouragement group (0.02), and the effect of being identified under the unconditional incentive is significantly different from zero. The p-value for the joint test that incentives result in identification of symptomatics with different asset levels than encouragement is 0.06, and we cannot reject that conditional and unconditional incentives have the same effect on the identification of patients based on asset level.

We estimate similar specifications to compare the characteristics of symptomatics identified under each of the three outreach strategies. In these specifications, the reference category is peer outreach:

$$y_{ijc} = \alpha + \theta_1 \text{Anonymous}_{jc} + \theta_2 \text{Identified}_{jc} + \Gamma_c + \epsilon_j \tag{8}$$

Suspects identified via peer referrals appear more disconnected than those identified through the contact-tracing strategies. On average, new symptomatics identified via peer referrals had 1.96 social contacts in the 24 hours preceding the survey, and those identified through anonymous and identified contact tracing had 1.49 and 2.16 more contacts in the same period, respectively. The difference between peer referrals and identified contact tracing is statistically different from zero, and the p-value that contact tracing identifies symptomatics with different degrees of social connectedness than peer referrals is 0.07. It is striking that peer referrals result in the screening of symptomatics with statistically and meaningfully *fewer* social contacts than outreach via health workers. These results suggest peers can effectively reach disconnected patients.

4.6 Cost analysis

The academic research questions posed by this experiment concern the behavior of current patients. From a policy perspective, the key parameters of interest are the costs of detecting individuals with symptoms of TB (who require screening, even if negative tests ultimately rule out TB and indicate the need for different treatment) and of identifying those who have the disease. We consider four categories of recurring expenses: incentive payments made for referrals, printing of referral cards, time costs of explaining the scheme to current patients, and wages paid to health workers. We calculate costs per treatment arm, aggregating as in the previous sections. We calculate average costs per treatment arm by dividing the total number of symptomatics screened or new cases detected, respectively, by the total across the four categories of costs within the treatment arm.

Incentive payments are straightforward to calculate and reflect actual amounts paid to current patients, depending on the rules of the treatment arm to which they were assigned. They are zero by definition in encouragement arms.

The referral cards printed for the project cost Rs. 8 ($US 0.12) per card. In peer arms, each current patient was given 10 cards, and we include the cost of all those cards even though not all were distributed to symptomatics. In the contact-tracing arms, cards were distributed to health workers based on the number of referral names provided during the baseline survey, so the per-current-patient cost of cards was actually lower in contact-tracing arms than in peer arms.

We use administrative data captured by our computer-assisted interview interface to track the amount of time spent explaining the referral scheme to current patients, and arrive at an estimate of 10 minutes per patient to explain the scheme, in both peer and contact-tracing arms. Computed at the daily wage for field staff, these explanations cost Rs. 10.42 ($0.15) per current patient.

Finally, while the health workers in this study were paid regular wages by Operation ASHA, the contact tracing required by this project was outside their usual scope of work. Our project offered a fixed stipend of Rs. 1,800 ($US 26.44) per month (increased to Rs. 2,000 per month in the second year of the project) to health workers in the contact-tracing arms to cover time and transportation costs for outreach. The stipend was worth about 22.5% of their average monthly salaries and was the minimum compensation deemed acceptable by Operation ASHA's senior leadership.[22] Operation ASHA estimates that its DOTS providers allocate one-third of their time to outreach activities, though the vast majority of these efforts are devoted to tracing members of current patients' households (a population not targeted by our intervention). This outreach is considered part of health workers' core job responsibilities and covered by the monthly salary, though they also receive small financial incentives and penalties for a range of activities including treatment initiation and completion.

Table 11 summarizes the results of this exercise by incentive type (Panel A) and outreach type (Panel B). Based on costs incurred during the study, it was less expensive to use financial incentives to identify a patient with TB than without. Each positive case of TB identified cost $US 233 in the conditional treatment arms or $US 173 in the unconditional arms, relative to $US 479 in the encouragement arm. This is because while the financial incentives themselves

[22] To implement health worker-led contact tracing for the first time also requires training the health workers. We have omitted this fixed cost from our calculations; including it would make peer outreach relatively more cost-effective.

were small relative to other costs–especially of outreach (balanced across the incentive types because of the cross-randomized design)–they were effective in increasing the number of cases detected. Costs per patient screened are, by definition, lower: $US 32 using conditional incentives, $US 35 using unconditional incentives, or $US 70 without financial incentives.

The cost-effectiveness of peer outreach is even more pronounced. In peer arms, the average cost per detection was $US 100. Active case finding by health workers was three to four times as expensive: $US 452 per case detected in the identified contact-tracing arm and $US 302 per case detected in the anonymous contact-tracing arm. Costs per symptomatic screened were $US 13 in the peer outreach arm and $US 74 and $US 70 in the identified and anonymous contact-tracing arms, respectively. The differences across treatment arms are driven by the greater number of patients screened and detected as a result of peer outreach, as indicated in Table 4, and the higher costs of compensating health workers (via stipends) than current patients.

We made every effort to minimize costs in all treatment arms during the study. Yet having completed it, we recognize two areas in which future implementation of these schemes could further reduce costs. The first is to distribute fewer cards to current patients for peer referrals. Ninety percent of current patients in the peer outreach arms distributed 5 or fewer cards, so we reestimate costs assuming that 5 cards rather than 10 were printed and distributed to each current patient in the peer referrals treatment. The second is to reduce the stipend to health workers. Our data do not offer guidance about the optimal stipend level, but as a benchmark, we consider reducing the stipend to health workers by half, to Rs. 900 ($US 13.22) per month. Table A10 presents estimates for this alternate scenario, which has the biggest effect on the comparison between peer outreach and contact tracing by health workers. While the differences between peer outreach and contact tracing are smaller in this hypothetical than the realized costs in our study, they still clearly indicate the cost advantage of using peers for active case finding: costs would fall to $US 63 for each case detected through peer outreach, compared to $US 236 for identified contact tracing and $US 158 for anonymous contact tracing. In fact, assuming the same detection rates as in the current study and distributing the original 10 cards per current patient, peer outreach remains more cost-effective than case finding by health workers for any stipend above Rs. 370 ($US 5.69) per month, 21% of the actual stipend paid to health workers in the study.

Few estimates of the cost of outreach are available in the literature. A study from South Africa estimates the cost of identifying a TB patient among a high-prevalence sample (of HIV patients, where co-infection increases patients' risk but decreases the average cost of detection) to be $US 381 (Kranzer et al., 2012). While incentivized peer outreach should not replace other outreach strategies, it is clearly an effective complement with the potential to reach marginalized patients.

5 Conclusion

Underdetection of tuberculosis has serious health consequences for infected individuals, their families, and others exposed to the disease. Despite the availability of free treatment throughout India, an estimated one million people with TB have not been tested and are not receiving treatment. The public health system and not-for-profit providers working under its auspices are overwhelmed and unable to mount intensive contact-tracing efforts, and existing outreach strategies may be insufficient to overcome informational barriers that prevent some people with symptoms from seeking treatment. In contrast, people who are currently undergoing treatment for TB have relatively lower time costs for identifying and reaching others with symptoms, and may have particularly relevant information about the benefits of treatment. However, peer referrals are virtually unheard of, partly due to the stigma associated with TB.

The results of our field experiment in India demonstrate that this sort of peer outreach can be highly effective. Financial incentives induce current patients to refer others in need of testing, which results in new symptomatics being tested and new TB cases being detected. Our experimental design allowed us to discover that peer referrals are effective not only because current patients have useful information about members of their social network who need screening for TB, but also because they are directly involved in outreach to these contacts. Among peer referrers, incentives increased the number of potential patients who were screened without affecting the number of cards distributed, suggesting that financial incentives increased the quality of information conveyed or outreach target selected.

Peer outreach was more effective than health worker outreach. Outreach by current patients resulted in an average of 1 new suspect screened for every 10 current patients, and 1 new symptomatic tested for every 14 current patients. These outcomes were more than two times larger than when outreach was conducted by health workers. Incentives strongly complemented peer outreach: on average, incentivized peer outreach resulted in 1 new suspect screened for every 5 current patients. Because of the effectiveness of small financial incentives and the comparatively lower cost of time for current patients than health workers, incentivized peer outreach in TB detection is highly cost-effective when compared to the international standard, contact tracing. We estimate that peer outreach identifies new TB cases at 20%-35% of the cost of outreach by health workers.

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Figures

Figure 1: Study locations

Figure 2: Sample referral card (English translation)

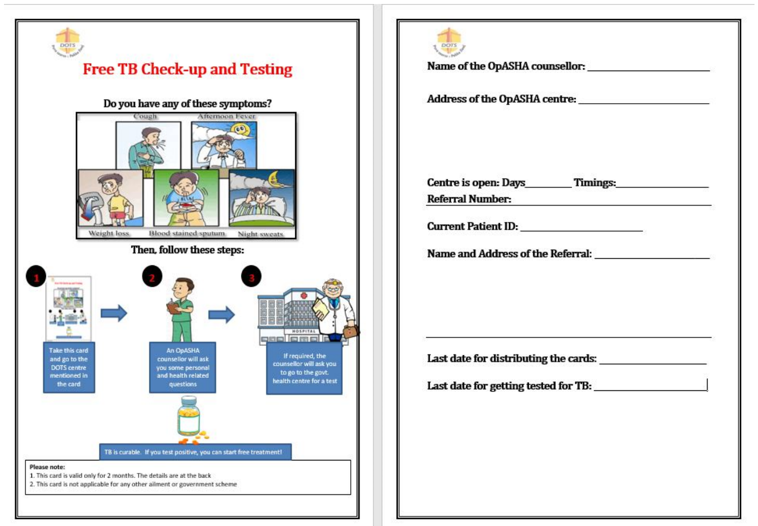

Figure 3: Experimental design

		Outreach type		
		Contact tracing (anonymous)	Contact tracing (identified)	Peer-to-peer outreach
Incentive type	Encouragement	12 clinics 355 patients	15 clinics 330 patients	16 clinics 387 patients
	Rs. 150 unconditional	12 clinics 352 patients	14 clinics 454 patients	16 clinics 289 patients
	Rs. 100 + Rs. 150 if TB positive	11 clinics 274 patients	14 clinics 363 patients	15 clinics 393 patients

Tables

Table 1: Summary statistics, by incentive type

	(1) Control	(2) Conditional incentive	(3) Encouragement	(4) Unconditional incentive	(5) Overall
Female respondent	0.413	0.389	0.403	0.405	0.400
	(0.036)	(0.016)	(0.016)	(0.015)	(0.009)
Hindu respondent	0.840	0.834	0.821	0.833	0.830
	(0.027)	(0.012)	(0.012)	(0.012)	(0.007)
Muslim respondent	0.155	0.128	0.155	0.152	0.146
	(0.027)	(0.011)	(0.012)	(0.011)	(0.006)
Respondent has some literacy	0.688	0.669	0.703	0.701	0.691
	(0.034)	(0.015)	(0.015)	(0.014)	(0.008)
Respondent has secondary education	0.307	0.293	0.288	0.310	0.298
	(0.034)	(0.015)	(0.014)	(0.014)	(0.008)
Asset index	0.134	-0.102	0.022	-0.110	-0.052
	(0.079)	(0.036)	(0.039)	(0.029)	(0.019)
Respondent has bank account	0.640	0.587	0.633	0.613	0.613
	(0.035)	(0.016)	(0.015)	(0.015)	(0.009)
Number of social contacts	3.087	2.666	2.249	2.671	2.564
	(0.425)	(0.208)	(0.139)	(0.205)	(0.105)
Previously treated for TB	0.159	0.174	0.185	0.167	0.174
	(0.027)	(0.012)	(0.012)	(0.012)	(0.007)
Tested within 1 month of symptoms	0.878	0.852	0.794	0.816	0.824
	(0.024)	(0.011)	(0.013)	(0.012)	(0.007)
Observations	189	974	992	1027	3182

Table 2: Summary statistics, by outreach type

	(1) Control	(2) Peer outreach	(3) Anonymous contact tracing	(4) Identified contact tracing	(5) Overall
Female respondent	0.413	0.412	0.371	0.411	0.400
	(0.036)	(0.016)	(0.016)	(0.015)	(0.009)
Hindu respondent	0.840	0.836	0.818	0.832	0.830
	(0.027)	(0.012)	(0.013)	(0.011)	(0.007)
Muslim respondent	0.155	0.142	0.161	0.134	0.146
	(0.027)	(0.011)	(0.012)	(0.010)	(0.006)
Respondent has some literacy	0.688	0.676	0.682	0.713	0.691
	(0.034)	(0.015)	(0.015)	(0.014)	(0.008)
Respondent has secondary education	0.307	0.282	0.285	0.320	0.298
	(0.034)	(0.014)	(0.015)	(0.014)	(0.008)
Asset index	0.134	-0.104	-0.034	-0.053	-0.052
	(0.079)	(0.035)	(0.039)	(0.031)	(0.019)
Respondent has bank account	0.640	0.594	0.630	0.612	0.613
	(0.035)	(0.016)	(0.016)	(0.015)	(0.009)
Number of social contacts	3.087	2.605	2.441	2.543	2.564
	(0.425)	(0.192)	(0.182)	(0.186)	(0.105)
Previously treated for TB	0.159	0.165	0.169	0.189	0.174
	(0.027)	(0.012)	(0.012)	(0.012)	(0.007)
Tested within 1 month of symptoms	0.878	0.811	0.825	0.825	0.824
	(0.024)	(0.013)	(0.012)	(0.012)	(0.007)
Observations	189	977	927	1089	3182

Table 3: Effects of financial incentives on TB detection

	(1) Patients screened	(2) Tests recommended	(3) Patients tested	(4) Positive tests
Encouragement	0.044**	0.030**	0.024*	0.003
	(0.018)	(0.015)	(0.014)	(0.003)
	[0.0009]	[0.0041]	[0.0257]	[0.1093]
Unconditional incentive	0.096***	0.080***	0.056***	0.013**
	(0.024)	(0.020)	(0.015)	(0.006)
	[0.0009]	[0.0130]	[0.0257]	[0.4088]
Conditional incentive	0.102**	0.078**	0.059**	0.005
	(0.031)	(0.027)	(0.021)	(0.006)
	[0.0010]	[0.0138]	[0.0646]	[0.4088]
Observations	3182	3182	3182	3182
R-squared	0.02	0.03	0.03	0.02
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: treatments jointly 0	0.00	0.00	0.00	0.07
P-value: Encouragement = Conditional	0.09	0.13	0.12	0.76
P-value: Encouragement = Unconditional	0.03	0.01	0.02	0.09
P-value: Conditional = Unconditional	0.84	0.93	0.90	0.30

"Patients screened" (column 1) is the number new of suspects who meet with an Operation ASHA counselor after receiving referral card. "Tests recommended" (column 2) is the number of new suspects who are observed by Operation ASHA counselors to have symptoms of active TB and are therefore told to report to a government center for testing. "Patients tested" is the number of new suspects who obtain a test at a government testing center. "Positive tests" is the number of new suspects who have a positive sputum test result. The unit of observation is the current patient. Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level and reported in parens. The sample includes all current patients. The omitted category is patients in pure control clinics. * $p<0.10$, ** $p<0.05$, *** $p<0.001$ False discovery rate corrected p-values (based on Benjamini and Hochberg (1995)) in square brackets.

Table 4: Effects of outreach type on TB detection

	(1) Patients screened	(2) Tests recommended	(3) Patients tested	(4) Positive tests
Peer outreach	0.124***	0.092***	0.058**	0.010**
	(0.030)	(0.025)	(0.018)	(0.004)
	[0.0007]	[0.0018]	[0.0038]	[0.0374]
Identified contact tracing	0.054**	0.042**	0.035**	0.005
	(0.016)	(0.014)	(0.013)	(0.004)
	[0.0038]	[0.0060]	[0.0157]	[0.2461]
Anonymous contact tracing	0.056**	0.049**	0.043**	0.005
	(0.020)	(0.019)	(0.018)	(0.005)
	[0.0113]	[0.0157]	[0.0207]	[0.3172]
Observations	3182	3182	3182	3182
R-squared	0.02	0.03	0.03	0.02
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: treatments jointly 0	0.00	0.00	0.01	0.09
P-value: Peer = Identified	0.01	0.03	0.11	0.46
P-value: Peer = Anonymous	0.03	0.12	0.44	0.47
P-value: Identified = Anonymous	0.89	0.67	0.56	0.99

"Patients screened" (column 1) is the number new of suspects who meet with an Operation ASHA counselor after receiving referral card. "Tests recommended" (column 2) is the number of new suspects who are observed by Operation ASHA counselors to have symptoms of active TB and are therefore told to report to a government center for testing. "Patients tested" is the number of new suspects who obtain a test at a government testing center. "Positive tests" is the number of new suspects who have a positive sputum test result. The unit of observation is the current patient. Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level and reported in parens. The sample includes all current patients. The omitted category is patients in pure control clinics. * $p<0.10$, ** $p<0.05$, *** $p<0.001$ False discovery rate corrected p-values (based on Benjamini and Hochberg (1995)) in square brackets.

Table 5: Complementarities between peer outreach and financial incentives on TB detection

	(1) Patients screened	(2) Tests recommended	(3) Patients tested	(4) Positive tests
Peer outreach, no financial incentive	0.036	0.023	0.017	-0.001
	(0.023)	(0.020)	(0.017)	(0.003)
	[0.1738]	[0.3237]	[0.3322]	[0.8523]
Contact tracing, no financial incentive	0.048**	0.034**	0.028*	0.005
	(0.020)	(0.017)	(0.016)	(0.004)
	[0.0384]	[0.0845]	[0.1283]	[0.3322]
Peer outreach, financial incentive	0.178***	0.134***	0.083**	0.016**
	(0.044)	(0.038)	(0.026)	(0.007)
	[0.0012]	[0.0028]	[0.0047]	[0.0574]
Contact tracing, financial incentive	0.063***	0.054***	0.046**	0.006
	(0.017)	(0.016)	(0.015)	(0.004)
	[0.0028]	[0.0032]	[0.0067]	[0.1738]
Observations	3182	3182	3182	3182
R-squared	0.03	0.03	0.03	0.02
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value:	0.01	0.02	0.04	0.06
Peer encouragement = Peer incentives				
P-value:	0.39	0.23	0.23	0.79
Contact tracing encouragement = Contact tracing incentives				
P-value:	0.64	0.62	0.50	0.30
Contact tracing encouragement = Peer encouragement				
P-value:	0.01	0.03	0.11	0.21
Contact tracing incentives = Peer incentives				

"Patients screened" (column 1) is the number new of suspects who meet with an Operation ASHA counselor after receiving referral card. "Tests recommended" (column 2) is the number of new suspects who are observed by Operation ASHA counselors to have symptoms of active TB and are therefore told to report to a government center for testing. "Patients tested" is the number of new suspects who obtain a test at a government testing center. "Positive tests" is the number of new suspects who have a positive sputum test result. Contact tracing includes both identified and anonymous contact tracing. Financial incentives includes both conditional and unconditional incentives. The unit of observation is the current patient. Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level and reported in parens. The sample includes all current patients. The omitted category is patients in pure control clinics.
* p<0.10, ** p<0.05, *** p<0.001 False discovery rate corrected p-values based on Benjamini and Hochberg (1995)) in square brackets.

Table 6: Heterogeneous effects of financial incentives on the number of referrals

	(1)	(2)	(3)	(4)	(5)
Outcome:	**Patients screened**				
Heterogeneity by:	Asset ownership	Social contacts	No treatment delay	Intensive phase	Female
Above median	0.001	0.023*	-0.007	0.004	-0.001
	(0.007)	(0.012)	(0.013)	(0.007)	(0.014)
Encouragement	0.062**	0.064**	0.014	0.046**	0.040**
	(0.022)	(0.023)	(0.024)	(0.022)	(0.018)
Unconditional incentive	0.107***	0.099***	0.091**	0.084***	0.091***
	(0.028)	(0.025)	(0.030)	(0.020)	(0.026)
Conditional incentive	0.103**	0.090**	0.119**	0.111**	0.113**
	(0.033)	(0.028)	(0.048)	(0.046)	(0.035)
Above median * Encouragement	-0.037*	-0.034	0.037**	-0.005	0.012
	(0.020)	(0.023)	(0.017)	(0.019)	(0.026)
Above median * Unconditional incentive	-0.023	-0.006	0.005	0.029	0.009
	(0.022)	(0.023)	(0.033)	(0.034)	(0.034)
Above median * Conditional incentive	-0.001	0.017	-0.020	-0.023	-0.041
	(0.043)	(0.030)	(0.061)	(0.047)	(0.063)
Observations	3182	3052	3173	3182	3053
R-squared	0.02	0.02	0.02	0.02	0.02

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The sample includes all current patients. The omitted category is patients in pure control clinics. "Above median" is an indicator set to 1 for patients with above-median asset scores (column 1); above-median social contacts (column 2); who did not delay seeking treatment for their own symptoms of TB (column 3); in the first two months of treatment (column 5); and who are female (column 6). * p<0.10, ** p<0.05, *** p<0.001

Table 7: Heterogeneous effects of outreach strategies on the number of referrals

	(1)	(2)	(3)	(4)	(5)
Outcome:			**Patients screened**		
Heterogeneity by:	Asset ownership	Social contacts	No treatment delay	Intensive phase	Female
Above median	-0.001	0.021*	-0.006	0.005	0.001
	(0.006)	(0.012)	(0.013)	(0.006)	(0.013)
Peer outreach	0.126***	0.118***	0.078**	0.120**	0.126***
	(0.030)	(0.030)	(0.039)	(0.038)	(0.034)
Identified contact tracing	0.054**	0.054**	0.063**	0.052**	0.057**
	(0.020)	(0.018)	(0.031)	(0.018)	(0.017)
Anonymous contact tracing	0.082**	0.076**	0.056*	0.065**	0.054**
	(0.028)	(0.024)	(0.032)	(0.024)	(0.021)
Above median * Peer	-0.003	0.011	0.056	0.010	-0.005
	(0.045)	(0.037)	(0.054)	(0.049)	(0.065)
Above median * Identified	0.000	-0.003	-0.011	0.004	-0.022
	(0.020)	(0.020)	(0.032)	(0.021)	(0.024)
Above median * Anonymous	-0.050**	-0.028	-0.001	-0.023	0.001
	(0.023)	(0.022)	(0.024)	(0.018)	(0.026)
Observations	3182	3052	3173	3182	3053
R-squared	0.02	0.03	0.02	0.02	0.02

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The sample includes all current patients. The omitted category is patients in pure control clinics. "Above median" is an indicator set to 1 for patients with above-median asset scores (column 1); above-median social contacts (column 2); who did not delay seeking treatment for their own symptoms of TB (column 3); in the first two months of treatment (column 5); and who are female (column 6). * p<0.10, ** p<0.05, *** p<0.001

Table 8: Comparison of current patients and new symptomatics

	(1) Current patients	(2) New symptomatics	(3) Difference	(4) P-value (1) = (2)
Female	0.400	0.366	0.034	0.378
	(0.009)	(0.037)	(0.038)	
Some literacy	0.691	0.448	0.243	0.000
	(0.008)	(0.038)	(0.036)	
Asset Index	0.031	-0.144	0.175	0.426
	(0.051)	(0.124)	(0.219)	
Social contacts	2.564	1.413	1.152	0.010
	(0.105)	(0.266)	(0.445)	
Observations	3182	172	3354	

Table 9: Effects of financial incentives on characteristics of referred patients

	(1) Female	(2) Some literacy	(3) Asset index	(4) Social contacts
Unconditional incentive	0.041	-0.003	-0.808**	-0.643
	(0.104)	(0.103)	(0.335)	(0.652)
Conditional incentive	-0.065	0.054	-0.515	0.320
	(0.103)	(0.098)	(0.346)	(0.813)
Observations	172	172	172	172
R-squared	0.13	0.15	0.18	0.08
Mean of dep. var. in encouragement group	0.39	0.71	0.02	2.05
P-value: jointly 0	0.60	0.82	0.06	0.51
P-value: Conditional incentive=Unconditional incentive	0.32	0.59	0.35	0.30

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The sample includes new patients who were screened because of a referral. The omitted category is new patients referred under the encouragement incentive condition.

Table 10: Effects of outreach type on characteristics of referred patients

	(1) Female	(2) Some literacy	(3) Asset index	(4) Social contacts
Anonymous contact tracing	-0.079	0.177	0.354	1.491**
	(0.108)	(0.121)	(0.408)	(0.656)
Identified contact tracing	-0.120	0.169	0.151	2.165
	(0.119)	(0.105)	(0.406)	(1.521)
Observations	172	172	172	172
R-squared	0.13	0.17	0.16	0.11
Mean of dep. var. in peer outreach group	0.37	0.68	-0.06	1.96
P-value: jointly 0	0.58	0.23	0.67	0.07
P-value: Identified=Anonymous	0.72	0.94	0.56	0.64

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The sample includes new patients who were screened because of a referral. The omitted category is new patients referred via peer outreach.

Table 11: Cost of detection

Panel A: Costs by Incentive Type

	Encouragement		Conditional		Unconditional	
	Cost per current patient	Total cost	Cost per current patient	Total cost	Cost per current patient	Total cost
Incentive payments	n/a	n/a	11	10500	12	12600
Referral card printing	30	29880	31	30000	21	21656
Training of current patients	14	13542	14	13542	13	13542
Payments to health workers	144	143200	147	143200	139	143200
Total cost		186622		197242		190998
Cost per symptomatic screened	4552		2055		2247	
Cost per TB case detected	31104		15172		11235	
Cost per symptomatic screened ($US)	70		32		35	
Cost per TB case detected ($US)	479		233		173	

Panel B: Costs by Outreach Type

	Peer to Peer		Identified Contact Tracing		Anonymous Contact Tracing	
	Cost per current patient	Total cost	Cost per current patient	Total cost	Cost per current patient	Total cost
Incentive payments	13	12400	5	5300	6	5400
Referral card printing	80	78160	1	1408	2	1968
Training of current patients	14	13542	12	13542	15	13542
Payments to health workers	n/a	n/a	197	214800	239	214800
Total cost		104102		235050		235710
Cost per symptomatic screened	860		4797		4533	
Cost per TB case detected	6506		29381		19642	
Cost per symptomatic screened ($US)	13		74		70	
Cost per TB case detected ($US)	100		452		302	

Panel A: Estimated number of detections correspond to outcome variables in Table 3, columns (1) and (4).
Panel B: Estimated number of detections correspond to outcome variables in Table 4, columns (1) and (4).
All costs in Indian rupees, except where indicated. Exchange rate is Rs. 65 to $US 1.

Appendix

Table A1: P-values for pairwise omnibus balance tests

	Control	Unconditional incentive	Conditional incentive
Encouragement	0.130	0.217	0.000
Unconditional incentive	0.076		0.044
Conditional incentive	0.361		

	Control	Identified contact tracing	Anonymous contact tracing
Peer to peer	0.287	0.198	0.592
Identified contact tracing	0.187		0.350
Anonymous contact tracing	0.497		

Each cell reports the p-value of the F-test that the coefficients on the variables listed in Table 1 are jointly zero, in a LPM specification where the sample includes respondents in the respective pairs of treatment conditions, and the outcome is a binary for assignment to one of the treatment conditions instead of the other. Each specification includes city fixed effects.

Table A2: Number of referrals named by current patients

		Incentive type		
N. names given	Overall	Encouragement	Unconditional	Conditional
None	2881 (90.71%)	906 (91.33%)	910 (88.87%)	881 (90.73%)
1 name	186 (5.86%)	54 (5.44%)	70 (6.84%)	57 (5.87%)
2 names	62 (1.95%)	23 (2.32%)	23 (2.25%)	16 (1.65%)
3 names	23 (0.72%)	6 (0.6%)	9 (0.88%)	8 (0.82%)
4 names	11 (0.35%)	2 (0.2%)	5 (0.49%)	4 (0.41%)
5 names	9 (0.28%)	0 (0%)	4 (0.39%)	5 (0.51%)
6 names	4 (0.13%)	1 (0.1%)	3 (0.29%)	0 (0%)
			Outreach type	
N. names given		Peer-to-peer	Identified CT	Anonymous CT
None		910 (93.53%)	981 (90.17)	806 (87.04)
1 name		49 (5.04%)	71 (6.53)	61 (6.59)
2 names		10 (1.03%)	17 (1.56)	35 (3.78)
3 names		2 (0.21%)	13 (1.19)	8 (0.86)
4 names		0 (0%)	3 (0.28)	8 (0.86)
5 names		2 (0.21%)	2 (0.18)	5 (0.54)
6 names		0 (0%)	1 (0.09)	3 (0.32)

Distribution of current patients according to the number of names given to the enumerators, overall and by experimental condition.

Table A3: Effects of financial incentives on TB detection (including baseline covariates)

	(1) Patients screened	(2) Tests recommended	(3) Patients tested	(4) Positive tests
Encouragement	0.043**	0.032**	0.025*	0.003
	(0.018)	(0.014)	(0.014)	(0.003)
Unconditional incentive	0.095***	0.078***	0.054***	0.010**
	(0.026)	(0.020)	(0.014)	(0.004)
Conditional incentive	0.098**	0.073**	0.056**	0.003
	(0.030)	(0.025)	(0.020)	(0.004)
Observations	3009	3009	3009	3009
R-squared	0.03	0.03	0.04	0.03
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: treatments jointly 0	0.00	0.00	0.00	0.10
P-value: encouragement=conditional	0.08	0.12	0.13	0.94
P-value: encouragement=unconditional	0.04	0.02	0.03	0.18
P-value: conditional=unconditional	0.92	0.84	0.90	0.23

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The sample includes all current patients. The omitted category is patients in pure control clinics. Includes all covariates from Table 1.

Table A4: Effects of outreach strategies on TB detection (including baseline covariates)

	(1) Patients screened	(2) Tests recommended	(3) Patients tested	(4) Positive tests
Peer outreach	0.122***	0.090***	0.057**	0.007**
	(0.031)	(0.024)	(0.017)	(0.003)
Identified contact tracing	0.048**	0.037**	0.030**	0.002
	(0.016)	(0.013)	(0.013)	(0.003)
Anonymous contact tracing	0.060**	0.052**	0.046**	0.006
	(0.020)	(0.018)	(0.017)	(0.004)
Observations	3009	3009	3009	3009
R-squared	0.03	0.03	0.04	0.03
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: treatments jointly 0	0.00	0.00	0.01	0.08
P-value: peer=identified	0.01	0.02	0.04	0.17
P-value: peer=anonymous	0.05	0.15	0.55	0.84
P-value: identified=anonymous	0.48	0.33	0.24	0.43

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The sample includes all current patients. The omitted category is patients in pure control clinics. Includes all covariates from Table 1.

Table A5: Effects of financial incentives on TB detection (clinic level specification)

	(1) Patients screened	(2) Tests recommended	(3) Patients tested	(4) Positive tests
Encouragement	0.045	0.033	0.027	0.004
	(0.054)	(0.046)	(0.034)	(0.011)
Unconditional incentive	0.097*	0.080*	0.055	0.011
	(0.055)	(0.046)	(0.034)	(0.011)
Conditional incentive	0.099*	0.074	0.057*	0.004
	(0.055)	(0.046)	(0.034)	(0.011)
Observations	128	128	128	128
R-squared	0.19	0.22	0.27	0.28
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: treatments jointly 0	0.11	0.13	0.18	0.54
P-value: Encouragement = Conditional	0.09	0.13	0.13	0.96
P-value: Encouragement = Unconditional	0.10	0.07	0.14	0.26
P-value: Conditional = Unconditional	0.93	0.81	0.94	0.24

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The unit of analysis is the clinic; outcomes are averages of current patient level outcomes within clinic. The omitted category is pure control clinics. Regressions weighted by clinic population using Stata's aweight command.

Table A6: Effects of outreach strategies on TB detection (clinic level specification)

	(1) Patients screened	(2) Tests recommended	(3) Patients tested	(4) Positive tests
Peer outreach	0.124**	0.091**	0.058*	0.008
	(0.054)	(0.046)	(0.034)	(0.011)
Identified contact tracing	0.050	0.039	0.032	0.003
	(0.054)	(0.046)	(0.034)	(0.011)
Anonymous contact tracing	0.061	0.053	0.047	0.007
	(0.054)	(0.046)	(0.035)	(0.011)
Observations	128	128	128	128
R-squared	0.21	0.22	0.27	0.28
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: treatments jointly 0	0.03	0.10	0.27	0.74
P-value: Peer = Identified	0.02	0.04	0.17	0.38
P-value: Peer = Anonymous	0.05	0.16	0.59	0.89
P-value: Identified = Anonymous	0.72	0.57	0.42	0.46

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The unit of analysis is the clinic; outcomes are averages of current patient level outcomes within clinic. The omitted category is pure control clinics. Regressions weighted by clinic population using Stata's aweight command.

Table A7: Complementarities between peer outreach and financial incentives on TB detection (clinic level specification)

	(1) Patients screened	(2) Tests recommended	(3) Patients tested	(4) Positive tests
Peer outreach, no financial incentive	0.033	0.024	0.018	-0.001
	(0.059)	(0.050)	(0.038)	(0.012)
Contact tracing, no financial incentive	0.051	0.038	0.032	0.007
	(0.054)	(0.046)	(0.035)	(0.011)
Peer outreach, financial incentive	0.181**	0.134**	0.084**	0.014
	(0.055)	(0.047)	(0.036)	(0.011)
Contact tracing, financial incentive	0.062	0.053	0.045	0.004
	(0.051)	(0.044)	(0.033)	(0.011)
Observations	128	128	128	128
R-squared	0.28	0.27	0.30	0.29
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: Peer encouragement = Peer incentives	0.00	0.01	0.03	0.11
P-value: Contact tracing encouragement = Contact tracing incentives	0.71	0.58	0.52	0.76
P-value: Contact tracing encouragement = Peer encouragement	0.69	0.71	0.63	0.40
P-value: Contact tracing incentives = Peer incentives	0.00	0.00	0.06	0.16

Linear models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The unit of analysis is the clinic; outcomes are averages of current patient level outcomes within clinic. The omitted category is pure control clinics. Regressions weighted by clinic population using Stata's aweight command.

Table A8: Effects of financial incentives on the probability of TB detection

Indicator:	(1) Any patients screened	(2) Any tests recommended	(3) Any patients tested	(4) Any positive tests
Encouragement	0.038***	0.029***	0.022**	0.004
	(0.010)	(0.008)	(0.009)	(0.003)
Unconditional incentive	0.061***	0.054***	0.041***	0.012**
	(0.013)	(0.012)	(0.010)	(0.005)
Conditional incentive	0.049***	0.042***	0.035**	0.004
	(0.013)	(0.012)	(0.012)	(0.004)
Observations	3182	3182	3182	3182
R-squared	0.06	0.06	0.06	0.02
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: treatments jointly 0	0.00	0.00	0.00	0.05
P-value: Encouragement = Conditional	0.37	0.26	0.22	0.99
P-value: Encouragement = Unconditional	0.08	0.04	0.05	0.12
P-value: Conditional = Unconditional	0.44	0.41	0.55	0.18

Linear probability models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The sample includes all current patients. The omitted category is patients in pure control clinics. * p<0.10, ** p<0.05, *** p<0.001

Table A9: Effects of outreach strategies on the probability of TB detection

Indicator:	(1) Any patients screened	(2) Any tests recommended	(3) Any patients tested	(4) Any positive tests
Peer outreach	0.065***	0.053***	0.038***	0.009**
	(0.012)	(0.011)	(0.009)	(0.003)
Identified contact tracing	0.035***	0.027***	0.023**	0.004
	(0.010)	(0.008)	(0.009)	(0.003)
Anonymous contact tracing	0.046***	0.043**	0.036**	0.006
	(0.014)	(0.013)	(0.013)	(0.005)
Observations	3182	3182	3182	3182
R-squared	0.06	0.06	0.06	0.02
Mean of dep. var. in control group	0.00	0.00	0.00	0.00
P-value: treatments jointly 0	0.00	0.00	0.00	0.04
P-value: Peer = Identified	0.02	0.03	0.07	0.29
P-value: Peer = Anonymous	0.20	0.47	0.89	0.69
P-value: Identified = Anonymous	0.39	0.21	0.22	0.65

Linear probability models estimated by OLS, including city fixed effects. Standard errors are clustered at the clinic level. The sample includes all current patients. The omitted category is patients in pure control clinics. * p<0.10, ** p<0.05, *** p<0.001

Table A10: Cost of detection: reduced-cost scenario

Panel A: Costs by Incentive Type

	Encouragement		Conditional		Unconditional	
	Cost per current patient	Total cost	Cost per current patient	Total cost	Cost per current patient	Total cost
Incentive payments	n/a	n/a	11	10500	12	12600
Referral card printing	16	15440	16	15520	11	11496
Training of current patients	14	13542	14	13542	13	13542
Payments to health workers	69	68400	70	68400	67	68400
Total cost		97382		107962		106038
Cost per symptomatic screened	2375		1125		1248	
Cost per TB case detected	16230		8305		6238	
Cost per symptomatic screened ($US)	37		17		19	
Cost per TB case detected ($US)	250		128		96	

Panel B: Costs by Outreach Type

	Peer to Peer		Identified Contact Tracing		Anonymous Contact Tracing	
	Cost per current patient	Total cost	Cost per current patient	Total cost	Cost per current patient	Total cost
Incentive payments	13	12400	5	5300	6	5400
Referral card printing	40	39080	1	1408	2	1968
Training of current patients	14	13542	12	13542	15	13542
Payments to health workers	n/a	n/a	94	102600	111	102600
Total cost		65022		122850		123510
Cost per symptomatic screened	537		2507		2375	
Cost per TB case detected	4064		15356		10292	
Cost per symptomatic screened ($US)	8		39		37	
Cost per TB case detected ($US)	63		236		158	

This scenario assumes distribution of 5 cards instead of 10 and reduces health worker stipends by 50%, to Rs. 900/month.
Panel A: Estimated number of detections correspond to outcome variables in Table 3, columns (1) and (4).
Panel B: Estimated number of detections correspond to outcome variables in Table 4, columns (1) and (4).
All costs in Indian rupees, except where indicated. Exchange rate is Rs. 65 to $US 1.