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The Male Bias of Tuberculosis in India: A Qualitative and Quantitative Analysis

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by Arthur Lenahan
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Abstract

This thesis uses statistical and narrative techniques to analyze the unusually high male to female gender ratio of tuberculosis (TB) prevalence in modern India, drawing on a series of surveys conducted in 2006. After highlighting the persistence of structural violence through the history of TB and its research, statistical models for both male and female tuberculosis positivity are developed and compared. A likely reporting issue is identified among women over the age of 35, forming the basis of a critique of current World Health Organization surveying methodology and TB treatment policy. The use of active, rather than passive, case-finding techniques is argued to be a crucial step in reducing problems of underreporting in India, particularly for women.

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[1] http://dl.dropbox.com/u/40570298/Appendix%20C%20(DHS%20Frequencies%20and%20Regressions).pdf

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[3] http://dl.dropbox.com/u/40570298/DHS%20India%20Individual%20Records.SAV

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Prologue: Contact

It happened one dusty April afternoon in a village near Jamkhed, on the open arid plateaus of Maharashtra, India. I was volunteering on a hypertension and diabetes survey with the Comprehensive Rural Health Project (CRHP), traveling from hamlet to hamlet on the plains, giving out basic medical advice and scheduling hospital visits for those who needed them: You have hypertension. Come to the clinic next week. You have diabetes. You need insulin--we'll make a delivery in a week.

There was a long line of men to be surveyed, and I was starting to feel the desert heat as the afternoon wore on. To take someone's blood pressure using the manual system, you first feel inside the crux of their arm to find the pulse. Set the stethoscope there. Then, you strap a BP cuff over the stethoscope. Pump until fastened tight--180 mmHg should do it. Watch the meter as the pressure is slowly vented. When you hear the pulse, make a mark; when it stops again, make another. These are the diastolic and systolic blood pressure values. Record the person's name and some basic information: name, employment, residence. You ask, "Do you have any other problems with your health?" Record these as well. The CRHP is well-organized, and followups can be scheduled. Repeat until there are no more people in line.

Let's take a step back. Hypertension and diabetes are considered diseases of the developed world, not the developing. In India, most surveys do not concern themselves with hypertension and diabetes. The health issues there are more basic, and tend to include tuberculosis, HIV/AIDS, maternal health, and issues of malnutrition. However, the CRHP is a special case: through effective and universal provision of primary care, the incidences of maternal mortality, infant mortality, malnutrition, and a range of tropical diseases have fallen to near those of the developed world. Thus, the communities around the CRHP are beginning to face health issues that mirror those of the developed world, and there came a need for surveys to assess the range of the issue. This is why men are willing to line up for blood pressure and diabetes sampling in these communities: the CRHP provides them with free and comprehensive healthcare, so they in turn are glad to participate in studies it conducts.

Reach out, take an arm in your hand, find the pulse. Marvel for a moment at how leathery the skin often is, how tempered by years of work under the Maharashtran sun. An older man sat down to have his blood pressure taken. My mind was beginning to wander when I noticed the arm I was holding was slightly cracked and torn-looking, the fingers slightly bulbed at the tips. Looking up, I realized that this man wasn’t old at all: though parts of his face were deeply lined and worn, his eyes were young. I recognized it from a poster at the hospital. He had early-stage leprosy.

Having never seen, and certainly never touched, a person suffering from leprosy before, I withdrew my hand--perhaps too quickly--and reached for the clipboard to make a note for followup. He looked ashamed and stood up, pulling his arm back into his cloak. While my back was turned to find a pen, he ducked back out onto the street and was gone before I could record his name.

Leprosy is an easy disease to treat in the modern world, and yet it remains one of the most stigmatized. We both were caught up in the social dimension of leprosy, and because of our failure to cross that divide he likely remains untreated. He did not trust me with his secret, and I was not prepared for it. Because of this failure, I started to wonder: How many are there, out there, just like him? How many suffer from curable diseases and yet do not have access, whether physical, financial, or social, to treatment? In this way, I started to notice that there was a kind of no-man's land between medicine and social forces, in which a complex and dynamic web of power interactions takes place. That day, I began to study epidemiology; I had found a drive, but not yet a direction.

I. Introduction

In that it walks a fine line between the social and biological sciences, epidemiology is a fundamentally interdisciplinary field. It is a science in which the scientific method cannot be used in a simple manner, since diseases and their pathologies do not follow a simple chain of cause and effect. Because they are just as behavioral as they are biological, diseases are in perpetual dialogue with those who suffer from them.

If epidemiology is an unusual science, then the epidemiology of gender is even more nebulous. Reviewing the literature of gender and tuberculosis (TB), the scientific method seems to act as a narrative mechanism. It tries to tell, refine, and retell a story--in this case, the story of how a single cough produces a bacterium that travels through the air and lodges in the mucus membranes of a human being. As of today, that story tells us that the person infected is most likely male, poor and living in a developing country. He is uneducated. He is malnourished. He perhaps smokes more than is healthy. He lives in a highly social and increasingly compact world, where human contact is inevitable and constant.

There is some direct, but in some ways problematic, biological evidence that men are more susceptible to tuberculosis than women. However, the degree of variation between male and female rates of TB on a global scale suggests that something more than biology is at play. Furthermore--whether or not the standing narrative is true--the idea of tuberculosis as a male disease has come about in part through a history of structural exclusion in tuberculosis research. As we will see, the use of a 'purely' scientific method to research the epidemiology of tuberculosis has, in the past, allowed structural and societal inequalities to slip into the peer-review system. Here, I will interrogate the narrative of tuberculosis as a male disease, using both qualitative and quantitative means. From a critical standpoint, I aim to examine the factors that create a gender bias in tuberculosis. I choose India as the setting for my research, since it is one of the highest-burden countries in terms of TB rates (WHO 2010), and since it exhibits a fairly high gender ratio of TB rates: 2.1 men to every one woman. In addition, I have personal experience with Indian culture and conditions of research. The fundamental question of this thesis, then, is this: What are the cofactors and determinants in men's TB prevalence in India, as opposed to women's? What groups are most at risk, and which exhibit high gender ratios? Does this phenomenon arise primarily from sociocultural, biological, economic, or methodological sources?

Underneath this problem lies a deeper, but more general, issue: to what degree can diseases like TB be measured as a function of social and economic indicators? What *are* the inherent problems in researching TB from a broad-scale quantitative standpoint, and how do these problems play out at the level of policymaking? As we will see, methodological considerations and careful, well-directed research design are critical to disease research and policymaking, in direct consequence of the fact that diseases, like people, do not always behave rationally and are difficult to control. A key underlying issue here is the importance of active case-finding, a methodological tool that has been discarded by both national and international TB agencies.

The first part of this thesis will be organized into three main sections. First, I will outline a brief history of tuberculosis research and policymaking, in order to trace knowledge and narratives about tuberculosis from the 18th century to today. In addition, this will help to contextualize current knowledge about TB, and to locate themes of power in TB research.

Second, I will discuss the narratives that have emerged in the last twenty years--those of the Third Epidemiological Transition--to explain the variation in gender ratios in tuberculosis, divided into three academic stances: biological, sociocultural, and methodological. Here I will also explore the ways in which various degrees of scientific 'hardness'--e.g., biology as a 'hard' science and anthropology as a 'soft' science--impact and inform researcher's claims about the disease. Again, this is relevant because epidemiology is neither hard nor soft: it is, instead, amorphous. I will then critique each academic narrative and attempt to locate points of inconsistency between them. Third, I will describe India' current health status, and illuminate its importance in the study of gender and tuberculosis. Ultimately, these introductory sections aim to situate a quantitative interrogation of tuberculosis and gender in the context of these broader, qualitative, and often conflicting narratives.

The second part of this thesis uses quantitative tools to map out the complex landscape of TB as a gendered disease, drawing upon the Indian Demographic and Health Survey (DHS) as its statistical source. A shift in tone will take place here, in order to highlight the academic and stylistic boundaries between qualitative and quantitative research, and the use of the first person will be abandoned. Both individual and comparative models are developed for males and females separately using the DHS data, and a combined logistical model will be created from a combined database. Many trends in the gendering of TB rates have been identified on the small scale, including use of solid fuel in cooking and heating, smoking cigarettes, access to public health systems, and malnutrition. Each of these will be tested on the large scale, both individually and in conjunction with each other, to generate models of TB prevalence in Indian men and women. Qualitative claims will then be teased out from these results. First, however, it is necessary to discuss the complex, short, and difficult history of TB research, in order to illuminate the methodological weaknesses and pitfalls of former TB studies. As a researcher, I can only hope to identify these shortcomings, much less to avoid them.

II. Background: History of Tuberculosis and its Research

The First Epidemiologic Transition

The first known incidence of tuberculosis in a human being can be found in a fossilized vertebra from 8000 BCE, showing signs of corrosion typical of extrapulmonary tuberculosis (Herzog et al. 1998:5). Today, tuberculosis is one of the most prevalent infectious diseases in the world. According to the World Health Organization, it is the number one cause of death by infectious disease for women worldwide, surpassing even HIV (Nsubuga et al. 2002). It is also one of the most economically stratified diseases on the planet, with over 95% of incidence occurring in the developing world (Barrett et al. 1998:260). In this section, I aim to trace tuberculosis and its scientific perceptions from the Neolithic era to today, in order to explore the persistent and ever-evolving role of structural inequality in the so-called 'white plague.'

In their article "Emerging and Reemerging Infectious Diseases: the Third Epidemiologic Transition," a team of medical anthropologists and disease historians led by Ronald Barrett classifies the history of human disease into three stages, or, to use their parlance, 'transitions.'

> *"The first epidemiologic transition was associated with a rise in infectious diseases that accompanied the Neolithic Revolution. The second epidemiologic transition involved the shift from infectious to chronic disease mortality associated with industrialization. The recent resurgence in infectious disease mortality marks a third epidemiologic transition characterized by newly emerging, re-emerging, and anti-biotic resistant pathogens in the context of an accelerated globalization of human disease ecologies. These transitions illustrate recurring sociohistorical and ecological themes in human-disease relationships from the Paleolithic Age to the present day"* (Barrett et al. 1998:247).

The researchers trace issues of class, race, and gender through each transition, highlighting the tendency of diseases to most severely afflict the most structurally disadvantaged members of a given society. This tendency, they argue, has become more striking in each transition. Citing skeletal analysis research carried out by Martin and Armelagos in 1979, Barrett et al. write, "Women, children, and--with development of stratified societies--the lower classes suffered disproportionately from the first epidemiologic transition" (Barrett et al. 1998:253). They also draw upon Van Gerven's work with Neolithic Nubian remains to connect themes of disease prevalence to political organization (Barrett et al. 1998:253; Van Gerven et al. 1990).

The Second Epidemiologic Transition

The early links between economic and health inequality can be seen as the origins of the 'essentialist' mode of disease perception. According to disease historian Nicholas B. King, essentialism is the ideological assignment of poor health to some fundamental or essential quality in a human group demarcated by geographies of difference--gender, class, ethnicity, et cetera. That is, the origin of one group is different from another, therefore, it is fundamentally different in terms of health. King writes, "Essentialist explanations for health disparities have often been expressed as origin narratives . . . Since the early sixteenth century, syphilis has alternatively been known as 'morbus gallicus' (the French pox) in Italy, 'le mal de Naples' (the disease of Naples) in France, 'the Polish disease' in Russia, the 'Russian disease' in Siberia, 'the Portuguese disease' in India and Japan, 'the Castilian disease' in Portugal, and 'the British disease' in Tahiti" (King 2003:41). The perpetual displacement and 'otherization' of disease is thus reflected in cultural narratives.

Barrett et al. write that the Second Epidemiologic Transition "is distinguished by a marked decline in infectious disease mortality within developed countries" (Barrett et al. 1998:254). In this transition, the stratification of disease between nations was paralleled by stratification within them. Tuberculosis in particular flourished along socioeconomic, ethnic, and gender boundaries, which strengthened essentialist narratives about ill health.

A few important events made the Second Epidemiologic Transition possible. First, the industrial revolution permitted mass-scale global trade in never-before-seen ways. Diseases could, for the first time, become global rather than regional or even interregional phenomena. This can be seen in the Spanish flu epidemic of 1918, which killed about 50 million people and infected about 500 million people worldwide, with port cities suffering the brunt of the mortality burden (Taubenger et al. 2006:15).

Second, antibiotics and medications to treat infectious disease were developed during the latter half of the 19th century, during the rise of the medical and pharmaceutical establishments. This had a twin effect, Barrett et al. argue: it caused mortality rates to decelerate worldwide, but also drew socioeconomic factors into health in a stronger way than ever before (Barrett et al. 1998:256). Because treatment for tuberculosis became assigned to a certain monetary value, the stratifying effects of tuberculosis became even more stark.

In 1882, Robert Koch published his text *Die Aetiologie der Tuberculose*, becoming the first researcher to identify the tuberculosis bacterium and, to some degree, its patterns of transmission. He was also able to make the case that TB was caused by a single microbe, defeating the standing notion that several agents could cause ‘consumption’ (Herzog 1998:8). This paved the way for innovations in diagnosis and treatment of TB, beginning with Koch’s invention of the tuberculin skin test, which later won him the Nobel Prize in Medicine in 1905 (Herzog 1998:9).

A direct effect of Koch’s discovery of the *tubercule bacillus* and its aerial transmission patterns can be seen in the rise of the sanatorium system as the primary treatment for TB. Sanatoriums were as much a social phenomenon as a medical one, and at the peak of their popularity could be found all around the world. As Herzog points out, there was little medical evidence that isolation and 'clean air' would actually cure the disease; nonetheless, in the strange period between Koch's discovery and the advent of first-line antibiotics, sanatoriums served as quarantine zones. There is some medical basis for their limited efficacy, it should be noted, since the forced scheduling of eating and sleeping helped restore the immune capacities of patients, allowing some to self-cure (Herzog 1998:10).

However, sanatoriums also helped to strengthen ethnic, gender, and class boundaries in TB transmission. In her history of tuberculosis treatment in Los Angeles from 1890 to 1960, disease historian Emily K. Abel outlines a case study of social inequity in treating tuberculosis. As we will see, the politics of TB treatment in 1920s and 30s California closely parallel the modern situation in the developing world, and will be treated here as a case study. While TB was becoming better and better understood by the medical community, essentialist notions of the disease became institutionalized in several ways. Meanwhile, the developing world would not see therapy options for TB until the late 1960s.

First, the sanatorium system helped to cement the idea that tuberculosis was a disease of the poor and unhygienic in the minds of the public. Legislation was passed to limit tuberculosis patients' ability to seek work and receive health insurance. Employers were allowed to fire TB victims after learning of their diagnosis, and "even former patients could be dismissed once their [medical] histories were revealed" (Abel 2007:58). In addition, insurance companies refused to cover TB, and a 1907 law required doctors to report all cases to state authorities. The net effect of these legislations was to stigmatize TB to the point that sufferers could not openly seek help for fear of losing their livelihoods. Even the act of consulting a private doctor for TB was grounds to lose one's health insurance. This inadvertently caused lower-class TB sufferers to delay treatment for longer and longer periods, to the extent that the sanatorium system could not support them once they were forced to report their illness (Abel 2007:30).

Second, the sanatorium system maintained ethnic undercurrents that limited access to treatment. Due to efforts by the California State Board of Health, TB was advertised as a disease of immigrants (Abel 2007:29). Indeed, immigrants were some of the most susceptible to the disease, because of their poor living conditions, malnutrition, and low access to treatment. The burgeoning Hispanic community was particularly underserved by state programs, which largely aimed at expelling them from the state rather than treating the illness. Abel writes,

"The primary justification for expelling tubercular Mexicans during the 1930s was not that they spread the disease to the white population but rather that, because they remained sick for so long, they overwhelmed public resources by consuming extensive amounts of monetary assistance and medical services" (Abel 2007:4).

These accusations, of course, were not true; Hispanic communities had few public treatment options available to them, due in part to aforementioned legislation. Even among those that sought treatment, noncompliance was common among immigrant communities. Narratives began to emerge that patients who did not fully comply with prescribed regimens were "'ignorant,' 'vicious,' and 'overcome by inertia' . . . [that] they disregarded clinic appointments to pursue 'amusements,' a serious charge at a time when reformers labeled most city pleasures 'evil'" (Abel 2007:53). This was a particularly biting idea, in that treatment in sanatoriums was often long, and recent immigrants could not sacrifice long months in treatment that could be spent supporting their families. Another example of this may be found in the refusal of sanatoriums to serve Hispanic food or to teach nurses to speak Spanish. "All advice," Abel claims, “implied the superiority of white, middle-class culture” (Abel 2007:54). Again, we see essentialist narratives creating selective barriers to treatment.

Lastly, gender played an important role in the structural problems created by the sanatorium system: “Health seeking,” Abel writes, “was clearly an overwhelmingly male enterprise” (Abel 2007:14). Since few women were permitted to work outside the home, or travel without their husbands’ accompaniment, there was financially more at stake for men to remain ill with TB than women. This, I argue, remains an important consideration in surveying for TB in the developing world today. We will return to this theme later.

Let us return tracing the history of TB. Perhaps the most important moment in the Second Transition came in September 1943, when a bacterial researcher at the University of California named Selman Waksman developed the first TB-inhibiting antibiotic: streptomycin. Waksman was awarded the Nobel Prize in 1952 for his findings, which generated a revolution the medical approach to TB treatment. Soon thereafter, a team of researchers proved that streptomycin could be administered in two-week courses over a period of a year and a half to eliminate an infection entirely (Herzog 1998:13). Waksman’s findings provided researchers with the first truly effective measure against TB, a disease that had plagued mankind since prehistory. It was a monumental moment for science.

Unfortunately, the celebration did not last long. It quickly became clear to the medical community that antibiotics created complications. The *tubercule bacillus* adapted much more quickly to streptomycin than researchers expected. As we know today, drug resistance comes about when an agent eliminates most, but not all, of a bacterial population. Since the surviving cells have been artificially selected for their resistance to the drug, they adapt to grow even in its presence. This revelation sparked the development of several second-line drugs to combat resistance: in chronological order, "*p*-aminosalicylic acid (1949), isoniazid (1952), pyrazinamide (1954), cycloserine (1955), ethambutol (1962), and rifampin (rifampicin; 1963)" (Herzog 1998:14). Meanwhile, the phenomenon of drug resistance added new dimensions to TB research and treatment: second-line drugs were often more expensive to produce and thus more difficult to distribute. This is compounded by the fact that "when TB becomes active again in a previously treated patient, there is a high chance the patient will be drug-resistant" (Herzog 1998:14). This raises the stakes on relapse, and can transform a treatable infection into a lethal one. In addition, the drug resistance effect introduced an economic dimension into TB research and treatment, and began to cleave the richer and poorer world spheres in two.

As antibiotics became more and more available in the developed world, tuberculosis became less and less visible to Western researchers. In several ways, the 1970s mark the shift from the Second to Third Epidemiologic Transition. Antibiotics had become relatively cheap and widely accessible, at least in the United States and Europe. Meanwhile, global networks of human and financial movement were expanding rapidly. The era of mass globalization was beginning, and with it a new set of health dynamics and paradigms was emerging.

The Third Epidemiologic Transition

It is somewhat ironic that tuberculosis has retained its moniker, the 'white plague', even as the disease has become concentrated in the non-Western world. This nickname came about in the 19th century, when TB was associated with a clammy pallor of the skin--this, of course, applies mainly to Caucasian skin tones. At the beginning of the 1970s, while TB was reaching pandemic levels in south Asia and Africa, it was becoming extremely rare in the United States and Europe. Antibiotic distribution chains effectively stopped at their shores.

Over the course of the 1970s and 80s, research into TB--along with efforts to fight it--entered an “era of neglect and complacency” (Ogden et al. 2003:182). Researchers were hesitant to begin anti-TB programs in the developing world for fear of mismanagement or limited financial support: the sudden cutoff of the antibiotic supply could, and in some cases did, lead to the outbreak of drug-resistant strains. At the same time, funding was being diverted from TB research and toward problems more immediate in the first world, such as cancer and diabetes. TB , Barrett notes, was “becoming a forgotten disease in the context of overly optimistic predictions for its continued decline” (Barrett et al. 1998:260).

In the early 1970s, a TB researcher named Karel Styblo realized that, despite the problem presented by drug resistance, the only cost-effective means of distributing antibiotics in the developing world was to shorten the time to complete treatment. He started experimenting with short-course variations on TB therapy, searching for a version that took six months, rather than fifteen, to complete. This was important for a few reasons. One, a short-course solution meant that agrarian and working-class TB victims would not need to sacrifice as much time to their cure, cutting down significantly on time spent away from supporting themselves and their families. This was thought to be a reason for high noncompliance rates in many parts of the developing world. Two, short-course therapy would reduce the potential margin for drug shortages, which in turn would decrease the likelihood of drug resistance.

However, Styblo’s research was slow to make an impact on epidemiological policy. Other TB researchers were inclined to retain 18-month models, due to a perceived lower likelihood for drug resistance. Also, Styblo gave his short-course method an in-patient basis, as opposed to the outpatient model recommended by early TB surveys in India. Third, Styblo used cohort analysis to study TB as it related to its risk factors, including HIV. This more complex method of analysis was not yet widely used in TB research, and the peer-review system was hesitant to accept it (Ogden et al. 2003:182).

In addition, Styblo's findings were largely ignored by the international development community. As before mentioned, tuberculosis was increasingly discounted in the developed world. "According to one informant," Ogden alleges, "the neglect of TB at WHO was also partly a product of the personal interests of [WHO director-general] Mahler, whose own experience with TB control in India had been fraught with difficulties. In this period the existing TB programme was cut back to two professional staff in the Geneva headquarters, even fewer people in WHO's regional offices" (Ogden et al. 2003:182). Additionally, the WHO's budget in 1992 and 1993 allotted only $10 million to TB; the Global Programme on AIDS received $160 million.

The sidelining of Styblo's research highlights the structural inequality and essentialist disease narratives that came to dominate TB perception during the Third Epidemiologic Transition. Taking HIV, Barrett et al. write,

"Biological evolution alone does not account for the rampant spread of this disease, nor its unequal distribution within and between populations.Throughout Asia, Africa, and the Americas, high HIV and sexually transmitted disease (STD) prevalence rates have been indices of deeper sociohistorical issues such as neocolonialism, the disintegration of poor families because of seasonal labor migrations, sexual decision-making strategies, and the gendered experience of poverty" (Barrett et al. 1998:257).

HIV is a particularly interesting case study here for a few reasons. One, it is highly stigmatized in Western public perceptions, despite the attention it received from the WHO. Two, HIV-TB co-infection is common in the developing world; the two diseases mesh quite well together, one crushing the immune system, the other preying on individuals with compromised immune systems.

Western public attention to TB returned in the early 1990s, after an unexpected multidrug-resistant TB (MDRTB) outbreak occurred in New York City. Between 1991 and 1994, 1,279 cases of MDRTB were recorded by the New York State Department of Health. The highest incidences were reported among 30 to 44-year old black males. However, the New York outbreak was unusual in that a majority of patients were US-born, rather than recently immigrated (Frieden 1993). Farmer traces 80% of incidence to homeless shelters and prisons (Farmer 1995:120), locating the New York outbreak within larger trends of drug resistance in TB.

Farmer argues that, in general, institutions where poverty is endemic and perpetual, and where health resources are limited (such as homeless shelters and prisons), behave as 'factories' for MDRTB. For instance, a similar but much larger MDRTB outbreak occurred in the Russian prison system in the 1990s, where decades of treatment mismanagement selected for strains that are effectively untreatable by any known method--the first cases of extremely drug-resistant TB (XDRTB) (Farmer 1995:116-7).

It is perhaps no coincidence that, in 1991, around the same time as the New York outbreak, the WHO and World Bank put Styblo's short-course therapy into trial in China. The project was given $50 million dollars--a significant initial investment--and was to act as a definitive large-scale litmus test of short-course therapy in the field (Ogden et al. 2003:183). However, in the interim period between 1991 and 1994, the short-course results remained unknown and the WHO continued to invest very little in TB research. The culmination of

Styblo's research came in 1994, with the publication of the WHO's *Framework for Effective Tuberculosis Control,* a 'cookbook' for Styblo's methods (WHO 1994).

The publication of *Framework* marked an important shift of attention back to tuberculosis on a global scale. This had a few immediate effects. First, TB research in the developing world experienced a sudden influx of funding, most of which came from the WHO and World Bank. Second, the WHO repackaged Styblo's short-course therapy as 'directly observed therapy, short-course' or DOTS, following Styblo's revolutionary ideas about inpatient cohort-style treatment and the six-month timeframe. DOTS was then implemented in newly built clinics across the globe as the central pillar of the WHO's "Stop TB Programme." Third, a wave of research emerged investigating tuberculosis dynamics in the developing world. This long-overdue research filled many of the gaps in the knowledge of TB distribution, but focused primarily on the efficacy of DOTS (Ogden et al. 2003:184). Meanwhile, research on the relationship between TB and power dynamics remained sparse.

The DOTS program involved four specific methodological innovations, all of which were aligned with Styblo's ideas. First, each DOTS clinic would keep careful patient records, in order to facilitate research on TB dynamics and to measure regional and global trends. Second, medical supplies such as antibiotics would be guaranteed by the WHO, if any shortages happened to arise. This was a crucial, if financially difficult, step in preventing the development of drug resistance. Third, as mentioned before, chemotherapy would proceed on an inpatient basis, in order to ensure compliance with drug regimen and quality of antibiotic injection. Fourth, case-finding would be dealt with on a passive basis, allowing patients to self-report symptoms followed by diagnosis via sputum smear microscopy (Obermeyer et al. 2008).

Meanwhile, treatment was to be ostensibly free to the patient. As we will see, these characteristics play an important role in the assumptions about TB that followed its 're-emergence' in the international medical community.

In the years since the early 1990s, DOTS has improved the rates of TB in the developing world significantly, making great strides in case detection, treatment efficacy, and compliance rates. This may be seen in Obermeyer's empirical and quantitative study which definitively claims "DOTS expansion has driven increases in estimated smear-positive detection rate from approximately 40 percent in 1995 to 2000 to 60 percent in 2005--a 50 percent increase in five years" (Obermeyer et al. 2008). Estimated prevalences have also decreased significantly from the late 1990s to today.

However, the reemergence of tuberculosis into disease research was inconsistent and somewhat problematic. Though the WHO has invested a great deal of money in its *Stop TB* program and DOTS clinics, guaranteeing and subsidizing the regular flow of medications, it has not incentivized TB research in the pharmaceutical sector. This, as we will see, has failed to fill certain gaps in treatment. Furthermore, aside from the creation of DOTS-Plus in the mid-2000s to fight MDRTB, the DOTS protocol has been little altered since its inception. This rigidity, I argue, perpetuates certain structural disadvantages in access to TB treatment in the developing world--particularly, as we will see, for women.

Before 1991, the last widely used and available tuberculosis drugs had been developed in the 1960s. Wallace Fox, a TB specialist who worked for years in India, made the case in a 1989 speech that "the pharmaceutical industry is loath to bring promising new antituberculosis medications to the state of clinical trial, although they are badly needed for the third world countries" (Fox 1989:192). Fox appears to be speaking the truth. Since his speech, not a single new TB drug has entered the market, even while existing treatments do not effectively treat the full range of the disease.

There is, of course, a powerful economic cause for the lack of new research into TB drugs. The pharmaceutical industry, oriented as it is around profitability, refers to tuberculosis treatments as 'orphan drugs.' According to Farmer, orphan drugs are those that treat diseases most prevalent in geographic regions that cannot return initial investment in the drug's research and development (R&D) (Farmer 2005:162). Trouiller and Olliaro estimate that "the average cost of bringing a new drug to market is about US$240 million" (Trouiller et al. 1999:164); since sales targets drive what drugs are developed, they say, 'tropical diseases' such as tuberculosis, leprosy and malaria receive very low priority for R&D. If drug companies cannot recover their initial average investment, which they often cannot without subsidy for tropical diseases, they have no incentive to develop them. This problem is a direct effect of the 'health-wealth' correlation, and remains a major point of contention for tropical disease specialists and advocates such as Farmer. He writes, "The ends and purposes of medicine are unique, since they are linked to issues of individual trust and common good" (Farmer 2005:162); therefore, for Farmer, R&D for tropical diseases is a case study for noncommercial approaches to pharmaceutical development.

Meanwhile, there is a well-defined need for new drugs. For instance, thiacetazone, an anti-resistance agent, has been a key part of DOTS regimens since its inception. Thiacetazone is most often combined with rifampicin to prevent the buildup of MDRTB, and is a key player in managing resistance (Rieder et al. 2001). Still, it is considered by many physicians to be an inadequate and indeed harmful tool for HIV-TB coinfection. Since thiacetazone is very cheap and fairly effective, it is widely used in the developing world. However, it is known "to cause severe cutaneous hypersensitivity" in HIV patients (Nunn et al. 1993:578), rendering it useless or even dangerous to treat coinfection with TB. Nunn et al. trace the history of thiacetazone to the early 1940s, pointing out that it has not been used in Europe or the US for several decades. In pre-HIV toxicity studies, the drug was found to have about 20% incidence of drug reactions, and the research team concluded that the "incidence of toxic effects attributable to thiacetazone was acceptably low in East Africa" (Nunn et al. 1993:579). Nunn et al. conclude by recommending that "thiacetazone-free antituberculosis regimens should be the goal for all countries" due to its toxicity, particularly for preventing MDRTB-HIV coinfection (Nunn et al. 1993:580).

The current alternative to thiacetazone is ethambutol, but problems exist with this too. Ethambutol is nearly twice the cost of thiacetazone, rendering it much less financially sustainable and available in the developing world (Nunn et al. 1993:580). Furthermore, ethambutol has been linked to toxicity rivaling that of thiacetazone. Griffith et al. link ethambutol use in treating *Mycobacterium avium*, a similar infection, to ocular toxicity, reporting that 42% of ethambutol recipients sought ophthalmological aid as a result of the drug's effects on vision (Griffith et al. 250). Fox cites several Indian publications connecting ethambutol to "ocular lesions with impaired vision," as well as to renal toxicity in children and the elderly (Fox 1989:198). This leaves behind few cost-effective options for countering drug resistance.

Nonetheless, the WHO remains hesitant to invest in new drug development. Ogden et al. document an exchange between an editorial writer for the *Lancet* and WHO officials regarding the need for new drug development for TB. The WHO's response highlights a need for hesitancy to implement new treatment tools, arguing that "'the global challenge of TB lies in the implementation of old, tired and tested technologies'" (Ogden et al. 2003:184). Nearly twenty years have passed since that letter was sent, but in the interim no drugs have even been sent to trial. Pharmaceutical development, it seems, is a powerful case study in the economic complexity of TB treatment, and in the resistance to change at a policy level.

The unwillingness of the WHO to push for the development of new drugs for TB is an excellent case study in that organization's tendency to equivocate about changing DOTS policy. Ultimately, Ogden et al. suggest, the WHO's approach to DOTS has emphasized branding--that is, the 'marketing' of DOTS as the predominant method to treat TB in the developing world--in policy transfer in such a way that false consensus has been established in the WHO. The intrusion of politics into a field that is normally so defined by technical point-and-counterpoint debate seems to do violence to the scientific method itself. The process of marketing DOTS has ignored the "disagreements between academics, scientists, and program managers at the WHO," they write, and "the main emphasis in the [World Health] Organisation in the mid- to late 1990s was on operations with a strong political approach that focused on advocacy and communications, and targeted donors and policy makers rather than academics and scientists" (Ogden 2003:186). These disagreements are crucial, and serve to strengthen the integrity of the peer-review system; nonetheless, the "top-down, if not coercive, stance taken by international organizations toward the transfer of policy" suppresses dissent. Perhaps this is why so few of DOTS' original assumptions have been challenged or reformed effectively.

Nonetheless, the presence of dissent, however subtle, in the academic community at large and of anomalies in the survey data force reassessment and constant testing of TB treatment, policy, and surveying methods. If they go unchallenged, the notion of TB as a ‘disease of the poor’ implies a risk of essentialist narratives about transmission. Having challenged the development of the DOTS drug regimen, let us examine the other methodological ‘innovations’ presented by DOTS: the practice of directly observed inpatient treatment and the practice of passive surveillance.

The direct observation tactic, and its problems, can be characterized by a 2005 survey in which researchers compared treatment outcomes and patient adherence using both qualitative and quantitative methods in a rural Pakistani community. They found that, while the direct observation method was more effective than indirect, respondents were alienated by too-rigid observation schemes. This view, they report, reflects the importance of indirect factors when designing treatment policy, since adherence to treatment was in many cases contingent upon “time, travel costs, ill health, and need to pursue their occupation” (Khan M.A. et al. 2005:354). The researchers call for flexibility in observation schedules, stressing the importance of conformation to patient’s work schedules.

In this way, treatment outcomes--and demographic data--are dependent upon sociocultural factors. The relevance of these factors highlights the importance of actively pursuing and investigating cultural trends that might negatively impact a person’s ability to seek treatment, and in doing so to be represented in statistical form. Though it is often resistant to change in TB policymaking, the WHO relies on academic research, such as the work of Karel Styblo during the 1970s and 80s. It listens, but is slow to change. Thus, to some degree, epidemiological research precedes and informs policymaking and policy transfer, rendering these statistics an important point of entry into international health narratives. One can see how, given the dogmatic approach of the WHO to TB and its tendency to attack those who already lack social capital, essentialist notions might invade inclusion in surveys and clinic reports, and thereby pass undetected. In this way, themes of social power pervade TB research, and narratives surrounding them must be tested.

The second issue with DOTS' methodological assumptions deals with active versus passive case-finding. As mentioned above, DOTS relies essentially on sputum smear microscopy of patients who present themselves to a clinic. This is referred to as 'passive' case-finding, and has drawn criticism for its tendency to make certain assumptions about target populations. Critics like S. den Boon argue that passive case-finding assumes that individuals know enough about tuberculosis to seek treatment for it. This is compounded by the fact that early TB symptoms are subtle, yet victims are still contagious at early stages (den Boon et al. 2008:1342). In this same study, den Boon et al. compare active vs. passive case-finding within a single community, comparing the results of these methods. They find significant differences between the active and passive methods. One of the most interesting, for my purposes, is that active case-finding yields about a .93:1 male:female ratio of tuberculosis prevalence whereas the passive method yields about a .70:1 male:female ratio. Interestingly, the active method yields more evenly distributed results--this will become much more important later. In addition, the researchers find that passive case-finding "may lead to delay in diagnosis and treatment and thus contribute to the transmission of TB" (den Boon et al. 2008:1347). They acknowledge, however, that active case-finding is time-consuming and expensive, rendering the tactic less cost-effective on a policy scale. However, the benefits of active case-finding are strong: a study in rural Malawi finds nine times as many cases of TB with active as opposed to passive case-finding (Zachariah et al. 2003:033).

In conjunction with this study, a comparative survey of the history of active case finding (ACF) in TB research found that prevalence rates under ACF differ significantly from studies in the same region conducted using passive methods (Golub et al. 2005). Furthermore, comprehensive mathematical modeling and projections conducted by Murray and Salomon found that, if DOTS undertook active case-finding accompanied by mass miniature radiography (MMR; an X-ray screening technique) would increase mortality prevention by 11% with a single-cycle MMR, and up to 22% with continuous MMR (Murray et al. 1998:13884). In addition, Golub et al. find that this effect is most significant in areas with high prevalence and poor health systems coverage, recommending strongly that ACF be used in these cases (Golub 2005:1198).

Interestingly, active case-finding has also been found to impact gender rates in TB surveys and studies. Thorson points to a classic study in Bangalore in which active surveying yielded much higher numbers of unreported women than men, compared to a slightly earlier passive survey in the same district (Olakowski et al. 1973; Thorson 2001). The issue of women's access to healthcare is again called into question by a study in eastern Nepal that found a gender ratio of 2.6:1 males to females when using passive case-finding and a ratio of 1.2:1 males to females when using active case-finding. This strongly suggests an issue of access for women, at least in some areas (Cassels et al. 1982).

Lastly, a study by Satyanarayana et al. found significant differences in both TB prevalence and gender ratio between DOTS/RNTCP (Revised National Tuberculosis Control

Programme) data and their own. The DOTS data was collected by self-referral to a clinic, a passive method, whereas the Satyanarayana data was collected by active household survey and self-reporting. The study had two significant findings. One, people who could or would not use public health resources such as DOTS to treat their TB tended to be poorer and were more likely to be from rural areas than those who used the DOTS programme. Importantly, they also felt obliged to pay for their treatment at private clinics, where care was often found to be substandard. Since free TB treatment is included under India's universal health system, this is no small irony. Second, the gender ratio differed significantly between the active and passive data: among citizens not covered by DOTS in the Satyanarayana data, the M:F ratio was about 1.50:1, whereas in the official DOTS data the reported ratio was about 2.0:1 (Satyanarayana et al. 2011).

There are two main problems in the DOTS method that can be drawn from the Satyanarayana study: one, that free coverage often does not reach the structurally disadvantaged TB sufferers, and two, that the official DOTS policy and procedure are shaped by some degree of methodological bias. These assumptions will be tested using DHS data, which come entirely from actively collected household surveys. The use of actively collected data, while problematic, is an important factor in reducing structural barriers to access for women, if any are found to exist. With these methodological and policy-level issues in mind, let us now outline the ways in which TB is discussed in TB research, as well as the ways in which questions about TB are formulated in the research community.

III: Narrating Gender in Tuberculosis Research

It is a well-established and often-stated idea, in the field of TB research, that men are more likely to catch tuberculosis than women across the developing world (Salim et al. 2004; WHO 2010; Holmes 1998; Neyrolles 2009; et cetera). In this section, I will attempt to isolate three standing narratives to explain this difference, and to navigate them from a gender standpoint. These three schools of thought are biological (that immunological factors primarily determine male-to-female prevalence ratios), sociocultural (that behavior patterns are the primary determinant, but nevertheless that the established ratio is real), and methodological (that women are structurally inhibited from seeking TB treatment, and consequently that the established ratio is in many cases false). I will discuss each of these narratives in terms of the prominent studies and ideas that support them, following up with a critical analysis of each. The purpose of this, again, is to situate the current academic debate over why TB prevalence is so much higher in men.

Biological Narrative

The biological school of thought holds most firmly the idea that men have certain genetic and/or immunological traits that renders them more susceptible to TB infection. This claim finds its historical roots in a 1929 paper by Bakwin citing higher infant mortality in males than females (Bakwin 1929). In 1965, a definitive report by Washburn et al. found that male children are more susceptible to many kinds of infections, including but not limited to *E. coli*, meningococcus, salmonella, pneumococcus, and staphylococcus (Washburn 1965:59). Washburn speculates that the resistance mechanism is genetic, and asserts that the X chromosome contributes to disease resistance. Since females have two X chromosomes and males only one, he theorizes that males are weaker to infection (Washburn 1965:57). Of course, his theory and methodology would be considered crude by today's standards; 1960s-era genetics was not equipped to reliably or thoroughly explain such differences.

Modern immunologists have built significantly upon Washburn's theory. It should be noted that almost every modern study on TB immunology uses animal models, due to the ethical issues involved in such testing of humans--this is an imperfect biological analogy, and criticisms might be levied against the lack of supporting evident in humans. Nonetheless, Drs. Neyrolles and Quintana-Murci conducted a survey of available biological and epidemiological data, making the case that men are biologically more susceptible to TB than women despite confounding cultural factors. Acknowledging that women often face structural barriers in seeking treatment for TB, the researchers find that male to female prevalence ratios are about 2:1 worldwide, based on WHO data (Neyrolles et al. 2009:3). They argue that this is consistent with current knowledge about immunological differences in TB response between men and women. For instance, sex steroids seem to play an important role; they write, "these results illustrate the general, but probably simplistic perception of estradiol [a hormone common in females] as an immunity-sustaining or immunity-enhancing mediator, and of testosterone as a mediator inhibiting the immune response" (Neyrolles et al. 2009:2). They also support the idea that genetic architecture determines resistance to infection, and also speculate that anemia and higher fat reserves in the body may act as resistance amplifiers, though these claims have not been widely tested (Neyrolles et al. 2009:4).

This study draws epidemiological support from a 2004 study in Bangladesh which sought to determine whether differential access to care or sex differences drive male sex bias in TB in the developing world. The approach was two-fold, using both active and passive case finding: first, researchers used passive case-finding from rural clinics using sputum smear microscopy, and second they conducted door-to-door surveys to collect sputum samples from household members reporting a "cough of at least three weeks' duration" (Salim et al. 2004:953). The study concludes: "The gender difference observed in routine tuberculosis diagnosis is real, and is not due to lesser accessibility of women to the health services" (Salim et al. 2004:952).

However, both of these studies are problematic for the same reason: they do not account for cultural barriers to diagnosis and treatment. Again, they both use primarily passive methods for diagnosis. The Neyrolles study relies on WHO data, which in turn is aggregated from DOTS data, which in turn is collected based on those individuals that actively seek out the clinic. Though the Salim study attempts to use both active and passive case finding, its active approach involves two points of difficulty in its reliance on collecting sputum *in absentia* and on using family members as reliable respondents--on sputum collection, they write, "A sputum container was left for all suspects, present or absent, with a request to collect a single early morning sputum" (Salim et al. 2004:953). This container would then be retrieved or delivered to the clinic for smear testing. Let us look at a few problematic aspects of this methodology.

One, it is well-documented that tuberculosis is a source of social stigma in South Asia, particularly in rural areas (Nair et al. 1997; Atre et al. 2011). This may be especially true for women; Anna Thorson, a medical anthropologist who works largely with TB, writes, *"Because of the gender inequities existing in many societies, where women have less access to power both in the family and in the societal spheres and where women are more dependent on marriage and traditional family structure, women are considered more vulnerable to social stigma than men" (Thorson 2001:57).*

This stigma is known to manifest in several ways. Most notably, Nair cites a strong desire in Indian women to marry a good husband, which is contingent upon a certain threshold of health. Tuberculosis is often seen, in Indian society, as a deal-breaker. This belief may also be prevalent in Bangladesh, where marriage is of equal social importance to women. Salim et al. attempted to control for this, finding only about 2% of women reporting stigma due to TB versus .7% in men. However, women and their families alike may have little to gain in complying with the survey, and much to lose. This may lead also to an underreporting in stigma.

Two, sputum testing for TB in South Asian women is problematized by a cultural resistance to women spitting (Thorson 2001:57; Gordon et al. 2009; Lin et al. 2007). This has led to problems in other studies, and is even cited as a confounding factor by Neyrolles et al., who write "The poor quality of sputum samples from women in some regions may influence the sex bias observed in patients with TB" (Neyrolles et al. 2009:1). Salim et al. attempt to control for this as well, employing double or triple analyses on borderline results. Still, little research exists on biological differences between TB in male versus female sputum environments, for reasons already mentioned.

There is a clear biological case that men are somewhat more susceptible to TB than women; despite its flaws, this seems an inevitable conclusion. The expected male to female ratio from the Bangladesh study is only about 3:1, and from the Neyrolles report about 2:1. However, these are high estimates even by WHO standards, and do not explain the global variation in the male to female gender ratio (heretofore marked M:F GR). For instance, parts of the Eastern

Mediterranean region claim, on average, more--or at least as many--women as men that seek treatment for TB every year, such as Afghanistan (.5:1), Lebanon (.7:1), and Iran (1:1). (WHO 2010:135). Interestingly, higher overall rates of TB tend to translate into a lower ratio overall, such as in the case of Pakistan (1:1). Pakistan is the highest-prevalence country in the region, and yet displays equal numbers of men and women seeking treatment. Clearly, there is more at play than pure biology in the TB sex ratio, whether due to methodological problems in research or some cultural or behavioral practice.

Cultural Narrative

The cultural narrative is not necessarily the alternative to the biological; instead, it builds upon it, providing explanations for variation in the existing data. We have already seen a few examples of this, such as the difficulty of collecting sputum samples from women in south Asia. More generally, the rationale for the cultural model of TB generally tends to hold that men's bodies are more public than women's. It is an often-made point that women's mobility in the developing world is more restricted than men's, particularly in Muslim cultures such as Pakistan. This is a claim many researchers make by their own intuition, and an excellent example of unwillingness to challenge standing assumptions. It is problematic in several ways.

First, it is very difficult to make the case that, across the developing world, men unilaterally socialize more than women. There is a great degree of variability in women's exposure to the public, even within south Asia. As I have mentioned, Muslim women are generally more confined to the private sphere than Hindu women, but Pakistan (a Muslim majority) shows higher rates of TB among women than India (a Hindu majority) in national surveys. To date, there is no valid research that shows that south Asian men socialize more than women in any meaningful way.

Second, as Thorson points out, tuberculosis spreads more easily in indoor than outdoor environments. Even if we take for granted that most women spend time within their household, the lack of ventilation and the presence of an infected husband should cause a wife to become infected, particularly if over a long period of time. This should show, at most, a 1:1 male:female ratio. In addition, several studies have linked biomass cooking fuels with higher tuberculosis prevalences, due to their capacity to weaken the pulmonary immune system (Gordon et al. 2009; Kolappan et al. 2009). If this is the case, women should exhibit higher rates of TB than men in areas of the world where women predominantly cook indoors, such as India. This is not reflected in the existing data.

Other cultural factors pertain to differences in knowledge about TB, including but not limited to knowledge of its mode of transmission, risk factors such as malnutrition, beliefs about cost of treatment, and/or whether or not it can be cured. Furthermore, misconceptions exist about all of the above. This knowledge is poorly disseminated in many parts of the developing world, particularly in rural areas, creating a self-limiting aspect of treatment despite efforts to emphasize the lack of direct cost to DOTS treatment (Salim et al. 2004:956). These factors also vary between men and women. Men are, on average, more likely to worry about time taken from work and lost potential income, while women are worried about stigma and social isolation (Nair et al. 1997:80).

Methodological Narrative

There is, then, a fundamental question remaining: how many women have tuberculosis, but are not seeking treatment? In other words, how well does the cultural narrative explain the male to female ratio in developing nations? There are several factors that would seem to influence rates among women, but are anomalously reflected in available survey data. For instance, why would Pakistan's M:F ratio be 1:1, while just over the border in India the ratio is over 2:1? Andrew Codlin, a medical anthropologist and epidemiologist, demonstrates that the bulk of this discrepancy appears in women between the ages of 35 to 65, showing a more normal curve in Pakistan than India (Codlin et al. 2011:515). We will return to this in a moment.

As mentioned before, there are discrepancies in men's and women's exposure to biomass fuels, which would seem to primarily map onto higher rates of TB in women than men (Gordon et al. 2009; Kolappan et al. 2009). Unfortunately, these surveys are not disaggregated by sex. Other factors include women's generally higher stigma toward TB in south Asia, lower levels of knowledge about the disease or where to seek treatment, and ability to seek treatment at all without a male escort (Salim et al. 2004; Nair et al. 1997). These all create structural barriers to treatment that are specific to women.

Some researchers extend this claim to all levels of TB treatment. A study by Karim et al. set in rural Bangladesh found that fewer women than men sought treatment upon suspicion of symptoms and that those who participated in active surveys were less willing to submit sputum samples. They write, "[The study] implies lower representation of females at the different clinical steps for TB management using DOTS at community level" (Karim et al. 2011:1337). In addition, their results vary significantly from the Salim study, though a similar region of

Bangladesh was surveyed. A related study in Vietnam found that, while women there seek treatment about as often as men, their diagnosis was delayed longer by an average of two weeks (Long et al. 1999:389).

In addition, the methods commonly used to test for TB often contain certain biases. The tuberculin skin test (TST), first developed by TB bacillus discoverer Robert Koch is still widely used today. According to the Centers for Disease Control (CDC), tuberculin is a 'purified protein derivative' (PPD) that has been extracted from dead tuberculosis bacilli. This test involves injection of .1 mL of tuberculin just under the skin, followed by observation over a 72-hour period. If the skin appears *indured* (hardened) at the point of injection, it may be inferred that specialized immune agents known as T-cells have responded to an already-encountered threat, and that the patient has contracted TB, whether it is latent or active.

Though the tuberculin test is the second most commonly used method of diagnosis today next to sputum smear microscopy, some researchers have suggested that sex may influence the skin test results. For instance, a study of senior schoolchildren in Kuwait found that children who had been immunized against TB with the Bacillus Calmette-Guerin (BCG) vaccination found larger indurations in girls than boys, but that boys exhibited larger indurations with every other type of skin test (Gilvin, Gordonin, Xenopin, Flavescin, Chitin, and Leprosin A) (Shaaban et al. 1990). Furthermore, a Japanese study showed "that more male than female patients--that is, people who had progressed to TB disease--had a positive tuberculin reaction" (Thorson 2001:60). These factors both suggest differential responses to skin testing between men and women, and call into question its efficiency at diagnosis.

Sputum smear microscopy, the most common method of TB diagnosis in the world today, is similarly problematic. This test involves analysis by fluorescence microscopy on a saliva sample, searching for the bacilli themselves on a culture. However, as Thorson points out, 'the production of a sputum sample may be culturally sensitive in some settings and especially so for women, since women in some cultures, such as Pakistan and Bangladesh, are not allowed to spit" (Thorson 2001:65). Most surveys that use sputum testing do not comment on this. In addition, Thorson points to the differential development of pulmonary lesions on men as opposed to women, making the case that women's samples have a lower likelihood of containing mycobacteria.

If we look at TB research in light of its problematic history, in conjunction with the differential knowledge and capacity of women to seek treatment for TB and its higher social stigma, it is easy to see the need for constant reevaluation of research narratives at both the large and small scale. At its root, the problem with TB research remains a legacy of disinterest by the Western academic establishment and methodological dogmatism in the WHO's DOTS policy. More research is needed in many aspects of the male-female TB dynamic. Nonetheless, certain factors have emerged that could be tested on the large scale. According to the above research, TB rates in men versus women should map onto, at least to some degree, malnutrition rates, rates of independence in health-seeking for women, levels of knowledge and stigma about TB and its medical consequences, income level, and quality of the medical establishment in a region, among others.

III: Locating the Problem: Geography and Constructions of Health

I have chosen, for my dataset, a survey focused on health, economic and social indices conducted in India between 2003 and 2006. A detailed description of this survey will soon follow in Methods. India is of particular interest to modern TB research in general. Though it is a high-prevalence state, it is also industrializing rapidly. Its class gaps are deeply entrenched, though in the recent past they have begun to loosen. Women are slowly coming to be recognized as important members of communities, and their health and empowerment indicators are improving across the board.

To understand how TB is constructed from an emic Indian perspective, we must try to locate it not only in physical space and time, but in terms of the complex and multifaceted Indian conceptions of disease and pollution. The medical anthropologist Arthur Kleinman's idea of explanatory models of disease is helpful as an interpretive tool for this purpose: he defines explanatory models as "the notions about an episode of sickness and treatment that are employed by all those engaged in the clinical process" (Kleinman 1980:105). These notions, Kleinman argues, interact in fluid and dynamic ways to shape an individual's perceptions and definitions of health and healing, along with the ways in which they relate and react to the physical world around them.

Indian culture is--as is often and loudly said (Luce 2007)--vibrant, expansive, and difficult to define, a melting-pot of languages, ethnicities, and traditions. Even the notion of Hinduism as a unified religious structure is somewhat disingenuous, since the word Hindu was coined by Arabic invaders in reference to India's location across the Indus river, which runs through modern-day Pakistan. It has been for a long time a habit of foreigners to generalize about Indian culture, and thereby fail to do justice to the wide diaspora of beliefs there. This is a trap I will try to avoid.

Having said that, it is necessary for the purposes of anthropological perspective to draw out some common threads of Indian views on health and purity. The first recorded mentions of tuberculosis in Indian sources appear in the Vedic *Rigveda* and *Manu Smriti*, written around 1500 BCE. In the *Manu Smriti*, Herzog writes, "consumption is attributed to excessive fatigue, worries, hunger, pregnancy, and chest wounds." Herzog also establishes its pollutive quality, reporting that "no Brahman was permitted at that time to marry into a family that harbored consumption" (Herzog 1998:5). The pollution of TB was not only an individual, but *familial* phenomenon; the infection of one person reduced the social capital of the entire lineage. As treatment developed under the Ayurvedic system, these notions of pollution were at least partially retained.

Since TB is, in the words of Paul Farmer, the 'disease of the poor' (Farmer 2005), and in that it targets those already disadvantaged in life, TB continues to bear a particular stigma in the minds of many Indians. Interestingly, this stigma can be described along gendered lines. A study in urban Mumbai found that women often felt more was at stake for them to catch TB: for unmarried women, that their marriageability would be decreased, and for married women, that their wage-earning capacity would be impacted. This wage-earning effect stems from the fact that men are more often self-employed, whereas women depend on others for work in fields like domestic labor and factory work. Meanwhile, men were found to be more fearful of loss of overall income and physical weakness/death (Nair et al. 1997).

The Indian federal government not only recognizes four-year medical degrees in allopathic (Western) medicine, but also in the homeopathic schools of Ayurveda, Unani, Tibeta, and general homeopathic practice (Barrett 2005:20). For Indian Hindus -- a label that describes about 73.6% of men and 72.3% of women -- there is a strong bond between metaphysical and physical health. This bond is described well by the established religious texts; medical anthropologist Ron Barrett writes, “In the Caraka Samhita, the principal text of Ayurvedic medicine, the human body is a homunculus embodying greater cosmological principles” (Barrett 2005:29).

In addition, the bond between religious purity and health has, for many Indian Hindus, a geophysical center: the Ganga river. This bond is renewed via certain ceremonial festivals such as Kumbh, a four-year pilgrimage to the banks of the Ganges for ritual bathing at the ghats (wide steps that hedge the river). The purpose of this, for many sects of Hinduism, is to cleanse the body and soul of infection (Barrett 2005:29). There is also a social undertone in the ritual purity of the Ganges: “The prevalent model of ritual pollution in India combines ideas of dirt and morality,” Barrett argues, “in a way that discriminates against people and justifies their lesser standing within a social hierarchy” (Barrett 2005:25). Thus, the relationship between health and wealth in the secular world is extended into the spiritual world, for many Indian Hindus. Disease is seen by many as an intersection of spiritual and physical malaise.

This bond is particularly strong in tribal communities, a group to which special attention will be paid later. S.P. Gupta, a medical anthropologist specializing in Indian tribes, writes,

“The usual theory of disease in tribal society is that it is caused by the breach of some taboo or by hostile spirits, the ghosts or the dead. Sickness is the routine punishment for every lapse and crime meted out to them by the spirits. Accordingly, they have taboos and prayers. The pahan *(villlage priest), in addition to his religious functions acts [sic] as the mediator between the people and the mystical powers” (Chaudhuri 1986:161).*

However, this ‘magico-religious treatment’ is not the *only* type of healthcare sought in most tribal communities; Bandyopadhyay and MacPherson point out that health systems in tribal communities are most often pluralistic. That is, while homeopathic solutions are popular as a first-line defense in rural Indian communities--only 10% of men and 9% of women try allopathic solutions first, in one case study--allopathic treatment is commonly sought for major ailments. Both are valid solutions, for most households. Nonetheless, it is interesting that, in some villages surveyed, “women of [these] villages have more faith in homeopathic treatment” (Bandyopadhyay et al. 1998:73). One wonders how this affects their treatment pathways.

It is clear that men and women have differing disease trajectories when they are infected with TB: the stakes for men and women are different, as are their knowledge about the disease, capacity to be treated, and biological resistance. Though the DOTS methodology is an effective large-scale means of treating TB in the developing world, it is far from perfect. The use of passive data collection is highly problematic, as we have seen, and poses the risk of creating a circular problem at the policy level--if women do not self-report, it suggests, they do not need treatment. Is DOTS capable of penetrating to and treating both men and women in Indian society using its current methods? If not, how do men and women differ in their disease trajectories?

We will now turn to a discussion on the methods used in this study, and the ways in which past inconsistencies in research and gender dynamics will be tested using broad-scale modeling techniques. As mentioned in the Introduction, the writing style will now shift in tone to a style more conventional of scientific writing, using the passive voice and the third, rather than first, person. Again, I do this in order to emulate the tension within epidemiological claims between qualitative and quantitative sources, and to highlight their unhappy marriage in this research.

V. Methods

A: Tested Variables

The following variables have been selected for analysis from the Demographic and Health Surveys. Each has been shown to covary with tuberculosis rates in some context. The levels of measurement and disaggregation categories are summarized in Appendix D. DHS data are available as ‘positive’ or ‘negative’ responses, unless otherwise stated. Each variable is also described by an expected ‘risk state’, which in the datasets is represented by a value of 1, whereas ‘null’ states have a value of 0.

Age: Older individuals have been shown to have a greater susceptibility to TB than younger people. The critical age past which the rate of TB begins to climb is 35 years for both men and women: the average prevalence of TB under the age of 35 is 378 per 100,000 in men and 370 per 100,000 in women, whereas the average prevalence over the age of 35 is 989 per 100,000 for men and 454 per 100,000 for women (See Appendix DA). This is also a crucial factor in the gender discrepancy in TB rates, since the gender ratio (GR) under the age of 35 is about 1.02 whereas the GR over the age of 35 climbs to 2.17. These findings are supported by a number of studies (Borgdoff et al. 2000, Holmes et al. 1998). Accordingly, the over-35 years age dataset from the DHS has been set aside for logistic regression analysis for both males and females. Thus, age over 35 is expected to positively predict TB (age over 35 = 1, age under 35 = 0).

Prevalence of TB: TB prevalence is the primary measure of this survey, and is used to calculate gender ratio by dividing men’s TB prevalence by women’s. Case-finding took place on an active basis. Prevalence is calculated at an interval level using x persons out of 100,000 who suffered from TB at the time of survey. 596 out of 100,000 men and 379 out of 100,000 women suffer from TB in all categories across India, suggesting an average gender ratio of 1.57 TB-positive men to every one TB-positive woman (DHS 2006).

Gender: As mentioned in much detail above, male gender is expected to be a positive predictor for TB (male = 1, female = 0). It should be noted that the descriptive statistics for gender will be weighted toward female, since roughly twice as many women as men were surveyed.

TB Transmission: Transmission refers to the respondent's ability to correctly identify the primary mode of transmission for pulmonary tuberculosis, i.e., via coughing and sneezing. Knowledge of transmission is a key factor in determining the respondent's behavior when confronted with a TB-positive person. For instance, if the respondent knows it is transmitted by coughing, they are more likely to take care around people with a chronic cough. If they are not educated about TB transmission, they might increase their risk for infection. An average of 56.3% of Indian men and 48.2% of women believe that TB is transmitted via coughing or sneezing (DHS 2006). Knowledge of TB transmission is expected to negatively predict TB (ignorance about TB = 1, knowledge about TB = 0).

TB Misconceptions: Misconceptions represent the incorrect identification of TB transmission vectors, such as sexual transmission, touching a person with TB, mosquito bites, sharing utensils, or consumption of food prepared by someone who has TB. The presence of misconceptions increases a person's likelihood of transmission just as in 'TB Transmission'. However, the two cannot be treated as converse indicators, since a person who does not know anything about TB transmission would not be counted in either indicator. Approximately 54.8%

of Indian men and 50.8% of women have misconceptions about TB transmission, according to NFHS data (NFHS 2006). Having misconceptions about TB is expected to positively predict TB (misconceptions about TB = 1, no misconceptions = 0).

TB Cure: This is a measure of the respondent's opinions on whether or not TB can be cured using any technique, whether allopathic or homeopathic. It is included here as an indicator of degree of education about TB, since presumably a person who does not believe TB can be cured will not invest time and money in seeking treatment. Approximately 79.5% of men and 71.4% of women believe that TB can be cured in India (DHS 2006). It is not known whether knowledge about TB curability will have a positive or negative effect on TB--though a lack of education generally maps onto a state of poverty, and thus TB, it may be the case that infected individuals may seek to learn more about the disease. For now, the 'risk state' will be treated as the lack of knowledge about TB curability (TB cannot be cured = 1, TB can be cured = 0).

TB Discretion: Discretion describes a respondent's desire to keep TB infection of themselves or someone in their family a secret from neighbors and other members of their community. In qualitative surveys, the desire for privacy has been shown to be a strong indicator for social stigma around TB as a disease, since it often negatively impacts a person's cultural capital. The stakes of this are often higher for women than men. For instance, a qualitative study in Mumbai showed that women are more likely than men to worry about marriageability and the loss of employment after contracting TB, particularly if they are young (Nair et al. 1997). An estimated 16.8% of Indian men and 17% of women say they would consider keeping their TB, or a family member infected with TB, secret from their community (DHS 2006). Desire for discretion about TB also has an uncertain effect on TB positivity, since it may actually *prevent* some individuals from being forthcoming about their infection to the surveyor. It will be assumed, nonetheless, that desire for discretion is a positive predictor of TB positivity (desire for discretion = 1, no desire for discretion = 0).

Use of solid fuel for cooking/heating: Some studies, including one that used DHS data, indicate a relationship between high TB prevalence and usage of solid fuels in cooking, such as wood, dung, coal, charcoal, lignite, and plant material such as grass, shrubs, and straw (Mishra et al. 1999, Gordon et al. 2009). A study by Mishra et al concluded that the use of biomass cooking fuel increased the prevalence of TB by a factor of 3.6, citing previous studies linking the prevalence of acute respiratory infection to biomass smoke inhalation. The effect was found to differ by sex: for women, risk was increased by a factor of 2.7 versus 2.4 in men, "controlling for 10 possibly confounding variables (Mishra et al. 1999). This is supported by the fact that women suffer much greater exposure than do men in the Indian context. However, the link between solid fuel use and TB prevalence has been challenged by other studies that point out the strong link between solid fuel use and poverty, stating that the apparent statistical link between TB and solid fuel use is driven by poverty, where "low socio-economic status, smoky rooms, location of the kitchen, ventilation, and associated respiratory symptoms during cooking are likely to be important contributors" (Behera et al. 2010). Mishra et al. do not state whether these were counted among the possible 'confounding factors.' Nonetheless, the Mishra theory is supported by a meta-analysis by Lin et al. connecting the effects of tobacco with biomass smoke in terms of their impact on the respiratory system (Lin et al. 2007). Though the effect of solid fuel use on TB susceptibility is controversial, it has been established as a possible agent and will be included in the regression analyses. Solid fuel use will be tested in each case while controlling for other measures of poverty, in order to reduce the risk of autoregression. The use of solid fuels in cooking is expected to be a positive predictor of TB prevalence (use of primarily solid fuel = 1, use of primarily other fuels = 0).

Prevalence of Smoking Tobacco: The link between smoking tobacco and TB susceptibility is well documented (Behera et al. 2010, Mishra et al. 1999, Lin et al. 2007, Lienhardt et al. 2005, Leung et al. 2010, den Boon et al. 2005). Smoking has been demonstrated to cause "histological changes in the lower respiratory tract" leading to "decreased clearance of inhaled substances, and abnormal vascular and epithelial permeability" (Lienhardt et al. 2005:920). The patho-physiological basis for tobacco smoking and solid fuels inhalation is very similar. Prevalence of smoking tobacco was included in the logistic regression analyses of the DHS dataset, but is problematized by the fact that very few Indian women smoke compared to men. Nonetheless, since cigarette smoking is much more prevalent in Indian men than women, it is a suspected factor in determining the TB gender discrepancy. The use of tobacco is expected to be a positive predictor of TB (smoker = 1, nonsmoker = 0).

Literacy: Literacy is used here simply as a measure of education. The ability to read determines a person's ability to engage with the body of official information surrounding TB, ability to read pamphlets and information sheets on where to seek treatment, and ability to self-identify for the presence of TB. Additionally, crosstabulation of DHS data show a strong bias toward total illiteracy in TB sufferers, though this may be simply a cofactor of poverty. In each analysis, other measures of poverty will be controlled in order to limit the risk of autocorrelation. Approximately 17.6% of men and 35.3% of women are fully illiterate in India. Illiteracy is expected to be a positive predictor of TB (illiteracy = 1, any literacy = 0).

Wealth Index: The DHS datasets register the wealth index of the respondent in five classes: lowest, second, middle, fourth, and highest. These were assigned based on the income level of the household using an unstated formula. The wealth index is the most direct indicator of relative poverty, and is a highly relevant cofactor of TB prevalence. Though there is a strong correlation between them, there is no causal relationship between wealth and TB--thus, wealth was in many cases used simply as a categorical or controlled variable. Lower wealth status is expected to be a positive predictor for TB (lowest wealth index = 1, middle/high wealth index = 0).

Anaemia: Certain studies point to a positive relationship between high anaemia rates and high tuberculosis rates (Lienhardt et al. 2005, Sim et al. 2010). It has been suggested that this correlation is due to a vitamin D deficiency in anaemic individuals, which in turn is linked to impaired cellular immunity to infection (Sim et al. 2010, Davies 1985). Dr. P.D.O. Davies, who researched TB among recent Indian, Pakistani and Bangladeshi immigrants to the UK, suggests that this takes place at three levels: "first by interfering with the division and differentiation of monocyte/macrophage development, secondly, by decreasing macrophage fusion and activation, and thirdly, by impairing differentiation of B and T lymphocytes" (Davies 1985:303-4). In other words, the absence of vitamin D weakens the ability of the immune system to produce antibodies to fight off TB infection. Secondly, anaemia is in many cases a cofactor of general malnutrition, which is considered a strong risk factor for TB (Macallan et al. 1999). However, as Macallan et al. point out, there are methodological difficulties in studying the mechanism further since "the wasting phase is rarely observed by the investigator . . . because of the clinical imperative to commence treatment once a diagnosis has been made" (Macallan et al. 1999:154). Here, both moderate and severe anaemia levels are analyzed as possible determinants, where moderate anaemia is identified as 7.0-9.9 g/dL of haemoglobin and severe anaemia as less than 7.0 g/dL haemoglobin. Lastly, it should be noted that women suffer from anaemia at about twice the rate of men. Approximately 8.3% of men and 8.3% of women suffer from significant anaemia in the DHS dataset (Appendix CA). Anaemia is expected to be a positive predictor of TB (anaemic = 1, nonanaemic = 0).

Body Mass Index (BMI): Similar to anaemia, BMI is also an indicator of malnutrition (Macallan et al. 1999, Habibullah et al. 1999). BMI is calculated in kilograms per square meters by finding the ratio between an individual's weight and height. Here, the cutoff for a low BMI is 18.50 kg/m^2. It should be noted that, while anaemia is found more commonly in women, low BMI is more endemic to men in India. Nonetheless, both serve as accurate covariants of malnutrition, and thereby the degree to which the immune system is compromised. About 26.6% of men and 27.7% of women have a low body mass index (kg/m^2 < 18.5) (Appendix CA). Low BMI is expected to be a positive predictor of TB (low BMI = 1, normal BMI = 0).

Gross Domestic Product (GDP) per Capita in United States Dollars (USD): GDP per capita is a standard economic indicator wherein the yearly sum market value of all goods and services within an economy (here, aggregated to the state level) are divided by the resident population of that economy (here, the number of residents per state). Though this does not indicate individual wealth or poverty, GDP per capita can be seen as a measure of standard-of-living for all the citizens within a state. GDP per capita data were obtained from the Press Information Bureau of India (PIB 2012). Lower GDP per capita is expected to be a positive predictor of TB (scale-level data; no categorical assignment).

Type of Caste or Tribe: Four caste/tribe classes were identified in the DHS data: scheduled castes, scheduled tribes, other backward castes (OBCs), and other. Scheduled castes and tribes have been identified in the Indian Constitution as groups of people that have been historically disadvantaged. Though members of these castes and tribes receive special Constitutional protections and rights, they tend to have worse economic, social, and health indicators than ‘normal’ castes. There are hundreds of scheduled castes, and a complete list may be found through the Indian Ministry of Social Empowerment and Justice[5]. Scheduled tribes refer to groups of indigenous peoples that exist outside of the formal caste system, and have similar development and health indices to scheduled and other backward tribes. A full list of these may be found through the Census of India[6]. The prevalences and gender ratios of TB in scheduled castes, tribes, and OBCs by sex is given in Results. It should be noted that TB is most endemic in scheduled tribes, where the male prevalence is 965 per 100,000 and the female prevalence 694 per 100,000, at an average gender ratio of 1.39 (Appendix DA). Scheduled caste and tribe membership status is expected to be a positive predictor of TB (scheduled caste/tribe membership = 1, no scheduled caste/tribe membership = 0).

Ability to Seek Healthcare: The ability to seek healthcare is subdivided into the following variables, which indicate whether each factor would be a problem for seeking healthcare: getting permission from a husband or father to go, procuring the necessary funds for transportation and/or treatment, traveling a long distance, needing to take public transportation, not wanting to go alone, concern about the lack of a female health provider, concern about the lack of a provider at all, and concern about whether enough pharmaceuticals would be available

[5] http://socialjustice.nic.in/sclist.php

[6] http://censusindia.gov.in/Tables_Published/SCST/ST%20Lists.pdf

for them on arrival. These data are provided only for women, for whom physical mobility is much more conditional than men. Accordingly, whether or not the respondent had final say on seeking healthcare was also measured, as well as ability to travel alone. Each of these responses was indicated by one of two responses: ‘Not a big problem,’ and ‘Big problem.’ The frequency data for each of these may be found in Appendix DA. Again, since this is a methodological factor, it is unclear whether the effect of access to healthcare will have a positive or negative effect on TB, but it will be assumed for now that the effect is negative (need for permission/lack of funds/lack of final say on own healthcare = 1, no need for permission/funds/has final say on own healthcare = 0).

Reasons for Not Using Public Health Resources: The DHS dataset aggregates certain responses in households, in order to measure residents’ reasons for refusing public sector healthcare. The Indian healthcare system is, in theory, designed around a universal coverage model, of which the DOTS programme is a part. All citizens are, in theory, able to receive free or inexpensive healthcare as part of a network implemented and maintained by the state government. However, coverage is inconsistent in many areas, and many sick people turn to privately owned clinics or traditional/homeopathic medicine (See Public or Private Healthcare). Respondents reported poor quality of service, long distance to public facility, and long wait time at facility as their primary reasons for refusing public treatment. 16% of women interviewed for the DHS dataset responded that procuring enough money for seeking healthcare was a ‘big problem,’ whether for transportation or for treatment at a private facility; this highlights the weaknesses of the universal coverage plan (Appendix DA). It was assumed that men did not need permission to seek healthcare, and that men would not have trouble procuring funds for treatment; these data were provided for women only in the DHS. Disuse of public health resources is expected to be a positive predictor of TB, since this implies fewer options for effective treatment (refusal of public sector = 1, use of public sector = 0).

Public or Private Healthcare: As mentioned, there is a crucial difference between access to public and private health systems in India, and complete coverage of the population by the universal system has yet to be achieved. A recent study by Satyanarayana et al. drawing on data from across the Indian subcontinent found that "large proportions of patients who are accessing treatment 'outside DOTS/RNTCP' [Revised National Tuberculosis Control Programme, the Indian national anti-TB agency] are illiterate, live in very low income households, [sic] in rural areas and have to pay for their treatment" (Satyanarayana et al. 2011). The study concludes that a structural lack of access to public care persists among some of the most disadvantaged TB victims, and that public treatment tends to favor second- or middle-class citizens over the very poor. It should be noted that these data come from self-reported sources not counted by DOTS/RNTCP, suggesting to the researchers that there is a severe problem of under-notification and a need for more active case-finding. The DHS found that 17.7% of men and 22% of women use private health systems in India.

Furthermore, evidence from rural communities in West Bengal suggests that private treatment is preferred over public, even though the latter provides free consultation and prescriptions. Bandyopadhyay and MacPherson write that, though an overwhelming percentage of men and women in these communities (97%) were aware of the services provided by public institutions, they were more likely to consult private sources for any major illness, including tuberculosis. With regard to a local Block Primary Health Centre (BPHC), they write, "More than three quarters of the population surveyed (85%) faced some difficulties and problems in seeking treatment from the BPHC. The most common problem was that medicines were never available at the BPHC" (Bandyopadhyay et al. 1998:73). Nonetheless, the use of public health systems is assumed to be a positive predictor of TB, since such clinics are most available to lower-income families who are more likely to catch TB (public sector care = 1, private sector care = 0).

Nonetheless, some variables are more important than others. The following fifteen independent variables were given priority in the models based on their importance to prior studies, and are thus included where relevant:

1. Gender
2. Age over 35
3. Literacy
4. WI
5. Public facility use
6. Smokes tobacco
7. Transmission knowledge
8. Discretion
9. Tribe membership
10. BMI
11. Anaemia
12. Solid fuel use
13. Need for permission to seek treatment
14. Trouble procuring funds
15. Final say on own health care

Null values were assumed for males on variables 12-15, since these questions were included only on the women's survey in the original DHS data.

<u>B: Analyses</u>

The DHS dataset was analyzed using a logistic regression modeling process. Since the most important dependent variable, TB positivity, is disaggregated into 'positive' and 'negative' responses from individuals, it can at most be treated as binomial data. The logistic regression technique is capable of predicting a binomial response using a series of independent traits, so this technique was the strongest possible analysis. Secondary models were made by filtering the DHS dataset for respondents who would desire discretion about having TB (see Included Variables), and for those over the age of 35 since this category expresses the entirety of the gender discrepancy.

First, a general model was developed to predict TB positivity, where gender was included as a variable. This was obtained by combining all of the independent variables listed in the Tested Variables section. However, since some variables proved highly insignificant, the list was pared down such that only the strongest variables were left in the final analysis. For each final model, the following criteria were met: each variable was at least 95% significant, each chi-square was at least 95% significant, and a maximum of 50 iterations were used to allow for convergence. The individual (male vs. female) logistic regression models were obtained in a similar fashion, but in this case categorical dependent variables were set, as described above.

Lastly, a series of comparative DHS models were created using the maximum set of independent variables to predict TB positivity for each of the following categories: total men, total women, men over the age of 35, women over the age of 35, men who desired discretion about TB infection, and women who desired discretion about TB infection. These models provide ß coefficients that can be compared at the scale level, and thus present a powerful measure of relative variance in TB trends between men and women. It should be noted that confidence intervals of $p>.05$ were permitted for the sake of calculation, but each violation is noted in a footnote.

VI: Results

A: Descriptive Statistics

Fig. 1:
Male to Female Gender Ratio in TB Prevalence
by Indian State

Jammu Kashmir	1.61
Himachal Pradesh	2.03
Punjab	1.86
Uttarakhand	1.99
Haryana	1.31
Uttar Pradesh	1.72
Delhi Territory	1.15
Rajasthan	2.42
Gujarat	1.36
Madhya Pradesh	2.10
Bihar	1.21
West Bengal	1.68
Jharkhand	2.82
Chhattisgarh	1.76
Orissa	1.60
Maharashtra	1.60
Goa	3.98
Karnataka	1.47
Andhra Pradesh	1.70
Tamil Nadu	2.12
Kerala	1.57

Fig. 2: Descriptive Statistics for Included Variables: Men and Women[7]

Variable	μ	Std. Deviation	N	% Positive
TB Positivity	0.0048	0.06896	191464	0.5
Gender	0.3742	0.48391	198754	37.4
Age Over 35	0.3377	0.47292	198754	33.8
Literacy	0.2866	0.45219	198754	28.7
Low Wealth Index	0.2470	0.43127	198754	24.7
Public Sector Care	0.1203	0.32534	198754	12.0
Smoker	0.1300	0.33800	198706	13.1
TB Transmission Knowledge	0.5600	0.49700	183345	51.2
Desire for Discretion	0.2479	0.43181	190883	24.8
Scheduled Tribe	0.1283	0.33446	198754	12.8
Low BMI	0.2730	0.44549	198754	27.3
Anaemia	0.1652	0.37138	99770	16.5
Solid Fuel Use	0.3505	0.47711	198754	35.0
Need for Permission to Seek Healthcare	0.0335	0.17998	198720	3.40
Trouble Procuring Funds for Treatment	0.0999	0.29989	198721	10.0
Final Say on Own Healthcare (Women)	0.1789	0.38328	162226	17.9
Belief that TB is Spread by Touching	0.1200	0.32900	183345	12.3
Belief that TB Can be Cured	0.9232	0.26620	160260	92.3

[7] μ values take place on a scale of 0 to 1, since every variable is binary. Thus, weighting toward 1 indicates weighting toward the 'risk state'. Meanwhile, '% Positive' represents the percentage of "1" responses, and is found by multiplying μ by 100.

Fig. 3: Descriptive Statistics for Included Variables: Men Only

Variable	μ	Std. Deviation	N	% Positive
TB Positivity	0.0061	0.07787	72607	0.60
Age Over 35	0.3766	0.48455	74369	37.7
Literacy	0.1757	0.38059	74369	17.6
Low Wealth Index	0.2335	0.42304	74369	23.4
Public Sector Care	0.0925	0.28979	74369	9.25
Smoker	0.3300	0.46900	74357	33.0
TB Transmission Knowledge	0.5600	0.49600	74346	56.0
Desire for Discretion	0.1617	0.36814	66498	16.2
Scheduled Tribe	0.1206	0.32568	74369	12.1
Low BMI	0.2663	0.44201	74369	26.6
Anaemia	0.0829	0.27579	74369	8.29
Belief that TB is Spread by Touching	0.1200	0.32300	74346	12.0
Belief that TB Can be Cured	0.9378	0.24146	63073	93.8

Fig. 4: Descriptive Statistics for Included Variables (Women Only)

Variable	μ	Std. Deviation	N	% Positive
TB Positivity	0.0040	0.06289	118857	0.400
Age Over 35	0.3144	0.46427	124385	31.4
Literacy	0.3529	0.47789	124385	35.3
Low Wealth Index	0.2551	0.43591	124385	25.5
Public Sector Care	0.1369	0.34377	124385	13.7
Smoker	0.0100	0.12000	124349	1.00
TB Transmission Knowledge	0.5500	0.49700	108999	55.0
Desire for Discretion	0.2940	0.45561	124385	29.4
Scheduled Tribe	0.1330	0.33952	124385	13.3
Low BMI	0.2770	0.44751	124385	27.7
Anaemia	0.4061	0.49112	25401	40.6
Solid Fuel Use	0.5600	0.49639	124385	56.0
Need for Permission to Seek Healthcare	0.0536	0.22514	124351	5.36
Trouble Procuring Funds for Treatment	0.1597	0.36630	124352	16.0
Final Say on Own Healthcare (Women)	0.3304	0.47035	87857	33.0
Belief that TB is Spread by Touching	0.1300	0.33300	108999	13.0
Belief that TB Can be Cured	0.9138	0.28068	97187	91.4

B: DHS Frequency Tables

All frequency data from the DHS may be found in Appendices BA (for females) and BB (for males). They have been broken down into the following categories: age less than 35, age greater than 35, Hindu, Muslim, scheduled caste, scheduled tribe, other backward castes (OBCs), lower wealth index, and middle/higher wealth index. TB prevalence is distributed as follows, where prevalence refers to number of active cases per 100,000 people:

Category	Male	Female	Gender Ratio (M:F)
Age > 35	989	454	2.17
Age < 35	378	370	1.02
Hindu	581	350	1.66
Muslim	672	476	1.41
Scheduled Caste	742	493	1.50
Scheduled Tribe	965	694	1.39
OBC	528	359	1.47
Wealth Index: Lower	1159	645	1.78
Wealth Index: Middle/High	443	312	1.42
Total	596	379	1.57

C: DHS Frequency Results and Discussion

The frequency tables created from the DHS individual-level data yielded several interesting results. Gender disparity in TB prevalence was found to vary greatly between categories of age, religion, caste/tribe status, and wealth index. Prevalence itself was also found to vary between these categories. The purpose of these tables was to highlight disparities in both prevalence and gender ratio, and in doing so suggest trends in TB distribution. These will be discussed individually.

Total (All Men and Women Surveyed): Men's average TB prevalence was found to be 596 overall, as opposed to women's prevalence of 379. Meanwhile, the gender ratio for all men and women was found to be 1.57. It should be noted that the overall prevalence values obtained differed significantly from the WHO estimates from 2008. The WHO calculated an overall TB prevalence of about 299 per 100,000 population, whereas the DHS survey has clearly projected a higher value (between 400 and 500, depending on weighting). This difference is most likely explained by the passive vs. active case-finding methods--as has been stated, the WHO DOTS data-collection relies on passive self-reporting, while the DHS method is an active household survey. This dynamic supports the claims of studies advocating active case-finding as a more accurate collection methodology (den Boon et al. 2008, Zachariah et al. 2003, Golub et al. 2005, Murray et al. 1998, Olakowski et al. 1973, Thorson et al. 2001, Cassels et al. 1982, Satyanarayana et al. 2011). Active vs. passive case-finding methodology will become a recurring motif in attempting to explain these findings.

Age Greater Than/Less Than 35: The age of 35 was observed to be a threshold value, not only for raw prevalences but for the gender ratio. The observed male bias effect appears to appear only in individuals over the age of 35, where the gender ratio skyrockets from 1.02 (under 35) to 2.17 (over 35). There are likely three forces at play in this finding. One, the effect of biological immunity forces may increase significantly as an individual ages, as suggested by Neyrolles (Neyrolles et al. 2009) and Washburn (Washburn 1965)--that is, sex-differentiated steroid production may continue to protect women over the age of 35, while men are left susceptible as they age.

The second effect is social in nature. Women over the age of 35 that were included in this survey, which was conducted between 2005 and 2006, were born at the latest in the year 1971. The early 1970s were a pivotal period in the nation's history. Children born in 1971, or before, would have lived in a more conservative India, one untouched by Indira Gandhi's Emergency Era or the Green Revolution or the liberalization of the economy. More traditional religious and social values may be stronger in older individuals, and this trend may drive older women to desire more discretion about TB infections.

The third possible effect is that of access to reliable and well-equipped DOTS/RNTCP facilities. The inability of the public healthcare system to treat certain structurally disadvantaged TB victims has been documented here (Satyanarayana et al. 2011). It may be the case that older women who live far from public TB treatment facilities are not able to travel alone, or to travel at all, to these facilities. Thus, they may be missed in official data collection. More research on the effect of age and gender on TB prevalence is needed.

Hindu/Muslim: Aside from Hindu and Muslim, respondents also reported belief structures ranging from Buddhism to Jainism, Sikhism, Christianity, Judaism, Zoroastrianism, Donyi Polo, and atheism. These were not included as categorical variables in this study due to their relative low frequency of occurrence. Nonetheless, religion was not found to have a significant impact on TB prevalence or gender ratio of TB, though Muslims reported slightly higher rates in both genders and a slightly lower gender ratio of TB.

Type of Caste or Tribe: Scheduled castes, other backward castes, and scheduled tribes were found to have higher than average prevalences in both sexes and lower than average gender ratios. Scheduled tribes were found to have the highest TB prevalence of the three categories with a male rate of 965 per 100,000 and a female rate of 694 per 100,000. Interestingly, this also constitutes the lowest gender ratio of the three at 1.39 men for every one woman. These results are not surprising since--as has been mentioned in Methods--the scheduled tribes and castes are highly underserved by public health apparatuses.

Wealth Index: Wealth index was the best categorical indicator of TB prevalence, particularly for men: men of higher wealth indices reported TB prevalences around 443 per 100,000, while among lower wealth indices the prevalence skyrocketed to 1159 per 100,000. This finding closely fits with the idea of TB as a disease of the poor.

D: DHS General Logistic Regression Models

The formulae below represent an overall model to predict TB positivity using as many of the above variables as possible. Two models are presented. In the former, all of the variables above are included; in the latter, variables in which $p > .05$ were removed to see if a more powerful prediction could be made. Descriptive statistics are provided above in Fig. 2 for reference, where μ represents weighting between 0 and 1. Accordingly, a value for overall predictability of TB is included for both models. For this predictive function, it was necessary to have values for as many variables as possible, and so a roughly representative subsample of 66,475 men and 76,300 women were selected based on the criteria of at most one value missing. In cases where values were missing, a series mean was assumed for the sake of computation. The function was computed to solve for p by the formula $p = (10^y)/(1+10^y)$, and the mean of p for TB-positive individuals was found (μ_p). This latter mean represents the ability for the model to predict TB positivity, since models are more powerful as μ_p approaches 1 (TB-positive = 1, TB-negative = 0). This may be compared to the value μ_t, which represents the mean of p for TB-negative individuals. Accordingly, this value is more powerful as μ_t approaches 0.

Each model is presented in the following form:

Dependent Variable [y] = $\log(p/1-p)$ = Y-Intercept [$\propto$] + Coefficient [$ß]_1 x_1 + ß_2 x_2 \ldots + ß_n x_n$

Parenthesized values represent confidence levels, where the maximum permitted level for the latter model is $p<.05$. Pearson goodness-of-fit (GoF) values are also taken for each model; their significance level is represented below each. The maximum permitted confidence level for Pearson is $p<.05$ for the latter model, and the maximum permitted number of iterations was 100. Variables in this section are indexed as the following:

x_1 = Gender
x_2 = Age greater than 35
x_3 = Literacy: literate vs. illiterate
x_4 = Wealth index: middle/high vs. low
x_5 = Use of public healthcare
x_6 = Smokes cigarettes
x_7 = Knowledge of TB transmission
x_8 = Desire for discretion about TB infection
x_9 = Membership in a scheduled tribe
x_{10} = Body mass index: normal vs. low
x_{11} = Anaemia level: normal vs. anaemic
x_{12} = Use of solid fuels in the household
x_{13} = Need for permission to seek healthcare
x_{14} = Trouble procuring funds for medical treatment
x_{15} = Final say on own healthcare (women only)

Inclusive General Model

$$y = \log(p/1\text{-}p) = -7.789 + 1.024x_1 + .858x_2 + .710x_3 + .526x_4 + .988x_5 - .184x_6 + .551x_7 - .283x_8 + .424x_9 + 1.203x_{10} + .508x_{11} + .191x_{12} - .919x_{13} + .497x_{14} + .273x_{15}$$

Number of Iterations = 63
Pearson GoF Significance = .000
μ_p = .0008
μ_t = .0001

Reduced General Model

$$y = \log(p/1\text{-}p) = -7.558 + .748x_1 + .823x_2 + .704x_3 + .523x_4 + .990x_5 + .552x_7 - .294x_8 + .404x_9 + 1.206x_{10} + .515x_{11} + .451x_{14}$$

Number of Iterations = 53
Pearson GoF Significance = .000
μ_p = .0005
μ_t = .0000

E: DHS General Logistic Regression Models Results and Discussion

The findings of these overall models are interesting for a few reasons. First, and perhaps most importantly, male gender is confirmed to be a strong risk factor for TB. Though this finding is not in itself surprising, it heavily supports the idea that the observed male bias is true. This, of course, does not preclude the possibility that women either have not been *diagnosed* with TB, or that they hide their TB from the surveyor for one reason or another. Nonetheless, it justifies the division of male from female into categories for separate analysis, as is done below.

Second, low body mass index was also found to be a highly important predictor of TB. This result is also unsurprising, since BMI is an effective measure of malnutrition. This, combined with age older than 35 as a risk factor, confirms many of the notions about age and malnutrition presented in previous studies (see Tested Variables).

Third, tobacco smoking and solid fuel use were found to have a relatively small, or even negative, effect. This casts doubt on the effect of solid fuel use and tobacco smoking on TB positivity, though the lack of male data on solid fuel use may distort its true effect. In addition, tobacco smoking was ruled out altogether in the reduced general model due to its low confidence level.

Fourth, it should be noted--conditionally--that the need to ask permission to seek healthcare is a highly *negative* predictor of TB. This likely emerges as an effect of the lack of need for men to ask permission, for whom every case was assumed to be negative. A look at the women's models below may shed more light on its relevance for women as opposed to men.

Lastly, it is interesting that the mean *p* values for TB-positive (μ_p) and TB-negative cases (μ_t) are so small for both the inclusive and reduced general models. There is a significant difference between the values for both models, suggesting that the p value is roughly eight times higher for TB-positive than TB-negative persons in the former case. The latter case cannot be accurately measured, since zero is an infinitely small value. In sum, these models are able to predict to a small degree whether a person will have TB or not based on the above fifteen variables, though in most cases the difference is quite small.

F: DHS Individual Logistic Regression Models

The following formulae represent logistic regression modeling for men's and women's TB positivity for each of the following categories: total, age over 35, and desire for discretion about TB. All supplementary materials may be found in Appendix DC. In each variable, the expected TB-predicting option is registered as value = 1, and the null option as value = 0, e.g. for anaemia 1 = anaemic and 0 = not anaemic. A maximum of 50 iterations was permitted to find an optimal solution; models were rejected if they exceeded this processing time. These models are built upon the same criteria, and are presented in the same format, as those above. Again, μ_p and μ_t are provided to give a measure for power of prediction.

Men's Prevalence of TB (No Filter)

$$y = \log(p/1-p) = -9.121 + .392x_1 + .018x_2 + .179x_3 + .293x_4 + .211x_5 + .142x_6 + .352x_7 + .494x_8 + .252x_9 + .187x_{10} - .093x_{11}$$

x_1 = Use of public healthcare (.000)
x_2 = Current age of respondent (.000)
x_3 = Knowledge of TB transmission (.000)
x_4 = Literacy: literate vs. illiterate (.000)
x_5 = Wealth index: middle/high vs. low (.000)
x_6 = Belief that TB is spread by touching a person with TB (.004)
x_7 = Belief that TB can be cured: yes vs. no (.000)
x_8 = Body mass index: normal vs. low (.000)
x_9 = Membership in a scheduled tribe (.000)
x_{10} = Anaemia level: normal vs. anaemic (.001)
x_{11} = Smokes cigarettes (.022)

Pearson Goodness of Fit (GoF) Test = .000
μ_p = 1.67e-8
μ_t = 5.69e-9

Men's Prevalence of TB (Filter: Age > 35)

$$y = \log(p/1\text{-}p) = -7.142 + .744x_1 + .652x_2 + .912x_3 - .459x_4 + .796x_5 + .412x_6 + 1.041x_7 + 1.814x_8 - .497x_9$$

x_1 = Literacy: literate vs. illiterate (.000)
x_2 = Wealth index: Middle/high vs. low (.000)
x_3 = Use of public healthcare (.000)
x_4 = Smokes cigarettes (.001)
x_5 = Knowledge of TB transmission (.000)
x_6 = Belief that TB is spread by touching a person with TB (.010)
x_7 = Belief that TB can be cured (.008)
x_8 = Body mass index: normal vs. low (.000)
x_9 = Desire for discretion if family member has TB (.015)

Pearson GoF = .040
μ_p = .000
μ_t = 2.25e-4

Men's Prevalence of TB (Filter: Desire for Discretion About TB)

$$y = \log(p/1\text{-}p) = -6.902 + 1.142x_1 + 1.380x_2 + .710x_3 + .765x_4$$

x_1 = Use of public healthcare (.000)
x_2 = Literacy: literate vs. illiterate (.000)
x_3 = Body mass index: normal vs. low (.007)
x_4 = Anaemia: normal vs. anaemic (.016)

Pearson GoF = .007
μ_p = 6.66e-5
μ_t = 6.91e-6

Women's Prevalence of TB (No Filter)

$$y = \log(p/1\text{-}p) = -7.056 + .932x_1 + .411x_2 + .747x_3 + .608x_4 + .022x_5$$

x_1 = Body mass index (.000)
x_2 = Trouble procuring funds for medical treatment (.000)
x_3 = Use of public healthcare (.000)
x_4 = Literacy: literate vs. illiterate (.000)
x_5 = Current age of respondent (.000)

Pearson GoF = .000
$\mu_p = 2.38e\text{-}5$
$\mu_t = 6.91e\text{-}6$

Women's Prevalence of TB (Filter: Age > 35)

$$y = \log(p/1\text{-}p) = -6.294 + 1.104x_1 - .375x_2 + .868x_3 + .673x_4$$

x_1 = Body mass index: normal vs. low (.000)
x_2 = Desire for discretion about TB infection (.032)
x_3 = Literacy: literate vs. illiterate (.000)
x_4 = Use of public healthcare (.000)

Pearson GoF = .002
$\mu_p = 3.20e\text{-}5$
$\mu_t = 9.69e\text{-}6$

Women's Prevalence of TB (Filter: Desire for Discretion About TB)

$$y = \log(p/1\text{-}p) = -6.727 + .683x_1 + .441x_2 + .970x_3 + 1.022x_4 + .659x_5$$

x_1 = Body mass index: normal vs. low (.001)
x_2 = Trouble procuring funds for medical treatment (.049)
x_3 = Use of public healthcare (.000)
x_4 = Smokes cigarettes (.018)
x_5 = Current age > 35 (.000)

Pearson GoF = .000
$\mu_p = 2.00e\text{-}5$
$\mu_t = 3.22e\text{-}6$

G: DHS Individual Logistic Regression Results and Discussion

Each of the following dependent variables was modeled using logistic regression, for both men and women: overall TB positivity, positivity over the age of 35, and positivity in those who desire discretion about TB infection. The age category was selected as a followup based on results from DHS frequency tables showing that the primary gender ratio appears in Indian respondents over the age of 35 (See Results). However, it should be noted that some variables were available only for women, such as use of solid fuels and ability to seek healthcare. All frequency data may be found in Appendices DA and DB, and all logistic regression details are available in Appendix DC. Also, it should be noted that in almost every case μ_p was found to be larger than μ_t roughly by a factor of ten, suggesting some degree of efficacy in predicting TB positivity based on these models.

Total Men's Prevalence of TB: The most important factors in determining men's TB prevalence were the choice of a public rather than private health facility, illiteracy, low wealth index, disbelief that TB can be cured, low body mass index, anaemia, and membership in a scheduled tribe. Less important factors included smoking cigarettes, correct knowledge of TB transmission, higher age, and belief that TB can be spread by touching. Each of these responses was found to increase the respondent's chances of having TB, with the highly notable exception of cigarette smoking--this slightly *lowered* the respondent's chances of TB.

These findings support some previous assertions about the epidemiology of TB prevalence among men, but challenge others. The finding that TB sufferers are more likely to use public, rather than private, health sources indicates that, for men, the overwhelming use of private health resources is not an issue, though it is clear that some populations remain underserved. Meanwhile, it is interesting that illiteracy is a significant determinant of TB in men, though this may be a symptom of general poverty--no direct causal connection can be made between TB positivity and illiteracy.

Second, this model supports the notion that anaemia and low body mass index weaken the immune system to TB infection in men. Since these are both measures of malnutrition, these findings are unsurprising, along with the finding that low wealth index is a determinant for TB.

Third, the finding that belief that TB cannot be cured maps onto TB positivity suggests that men may feel fatalistic about their infection, which may in turn lead them to noncompliance with treatment. This is an issue that needs to be addressed at the level of public health education.

Two covariates in this analysis are somewhat unexpected: the *negative* effect of smoking on TB positivity, and the *positive* effect of knowledge about transmission. These results suggest that smoking is not a good indicator of TB prevalence--indeed, smokers seem to catch TB *less often*. Instead, knowledge about TB transmission appears to correlate with TB positivity. This may be the case because of personal relevance, since having TB encourages one to learn about TB.

Men's Prevalence of TB, Age > 35: Many of the relevant variables from the Total Men's Prevalence of TB model are also represented here, with one important exception: desire for discretion about TB infection. In men who said they would want discretion, the likelihood of having TB was significantly lower. This indicates that older men may be hiding TB positivity, since a desire for discretion maps onto a higher social cost for having TB, and heavily supports the notion that stigmatization of TB may drive inaccuracy in reported prevalence statistics. Lastly, it is remarkable that this category presents the only outlier in terms of power of prediction, since μ_p is actually smaller than μ_t. It is uncertain why this is the case.

Men's Prevalence of TB, Desire for Discretion: Interestingly, this filter causes many of the determinants identified in the Total Men's analysis to disappear, leaving only the use of a public rather than private facility, illiteracy, low body mass index, and anaemia. These are the most 'baseline' indicators, since they deal with measures of poverty and biological symptoms alone. For these men, none of the TB knowledge categories (cure, transmission, misconceptions) proved significant, along with age and tribal status. Little can be inferred from these results, since the absence of significance does not imply reverse causality. Nonetheless, the absence of significant results is itself interesting, largely because the social stigma for reporting them may be higher. More research is needed here.

Total Women's Prevalence of TB: Many of the variables affecting men's TB positivity were also found to affect women's rates of TB positivity, including low body mass index, use of public health facilities, illiteracy, and advanced age. Body mass index was found to be twice as strong a factor for women than men, along with use of public facilities and illiteracy. The effect of age was similar, but remained small (<.02). However, the knowledge determinants--namely, belief in a cure and TB transmission knowledge--did not prove significant, along with scheduled tribe status or anaemia.

Interestingly, women's positivity was predicted by an inability to seek healthcare due to financial restraints (this variable was not available for men). This supports the idea that certain populations remain underserved by the universal TB treatment system (DOTS), which is in theory free of charge. The bulk of the burden, then, either derives from the cost of transportation or cost of treatment at private facilities--more research is needed to tease out these distinctions.

Women's Prevalence of TB, Age > 35: For women over the age of 35, low body mass index, illiteracy, and use of public health facilities are all important determinants of TB positivity, while literacy and body mass index are stronger indicators for women over the age of 35 than in all age categories. In addition, desire for discretion about TB becomes an important factor here, in a manner similar to men over the age of 35 ($ß_{female} = -.375$, $ß_{male} = -.497$). The implications of this will be discussed in Synthesis. For now, it is also notable that women over the age of 35 do not have trouble seeking healthcare due to financial constraints--this may stem from a possible trend toward financial stability with age.

Women's Prevalence of TB, Desire for Discretion: This model proved to be highly similar to the women's overall regression. It is notable that illiteracy was *not* found to be a significant cofactor, but cigarette smoking was found to be highly important ($ß = 1.022$). This is the only category in which cigarette smoking correlated with TB positivity, though the implications of this finding are not clear. Secondly, women who stated they were older than 35 were found to be significantly more likely to be positive for TB.

H: DHS Comparative Logistical Regression Models

In this analysis, logistical models were constructed from the male and female DHS datasets with all of the significant variable candidates included. These models permit cross-comparison of variable coefficients between categories, e.g. 'Women's Prevalence of TB (No Filter)' to 'Women's Prevalence of TB (Filter: Age > 35)'. The dependent variable for TB positivity was used in each model. Since the category 'Men's Prevalence of TB (No Filter)' yielded the most significant dependent variables, all of these independent variables were included for cross-comparison. A value for 'number of iterations' was included since some models were very complicated, and thus required a long processing time.

x_1 = Type of health facility last visited: public
x_2 = Current age of respondent
x_3 = Knowledge of TB transmission
x_4 = Literacy: literate vs. illiterate
x_5 = Wealth index: middle/high vs. low
x_6 = Belief that TB is spread by touching a person with TB
x_7 = Belief that TB can be cured: yes vs. no
x_8 = Body mass index: normal vs. low
x_9 = Membership in a scheduled tribe
x_{10} = Anaemia level: normal vs. anaemic
x_{11} = Smokes cigarettes
x_{12} = Desire for discretion about TB infection
x_{13} = Trouble procuring funds for medical treatment (women only)

Men's Prevalence of TB (No Filter)

$$y = \log(p/1\text{-}p) = -9.052 + 1.039x_1 + .050x_2 + .508x_3 + .791x_4 + .563x_5 + .407x_6 + .958x_7 + 1.378x_8 + .538x_9 + .464x_{10} - .309x_{11} - .247x_{12}$$ [8]

Number of Iterations: 43
Pearson GoF = .000
μ_p = .000
μ_t = 8.92e-5

[8] p = .094; p>.05

Men's Prevalence of TB (Filter: Age > 35)

$y = \log(p/1-p) = -8.168 + .912x_1 + .000x_2$[9] $+ .814x_3 + .738x_4 + .619x_5 + .403x_6 + 1.058x_7 +$
$1.786x_8 + .232x_9$[10] $+ .397x_{10} - .458x_{11} - .499x_{12}$

Number of Iterations = 28
Pearson GoF = .564
$\mu_p = 4.68e\text{-}4$
$\mu_t = 2.80e\text{-}5$

Men's Prevalence of TB (Filter: Desire for Discretion About TB)

$y = \log(p/1-p) = -8.046 + 1.241x_1 + .019x_2$[11] $+ .406x_3$[12] $+ 1.187x_4 + .560x_5$[13] $+ .248x_6$[14] $+ .841x_7$[15] $+$
$.718x_8 + .205x_9$[16] $+ .611x_{10}$[17] $+ .125x_{11}$[18] $+ .000x_{12}$[19]

Number of Iterations = 47
Pearson GoF = .000
$\mu_p = 9.61e\text{-}4$
$\mu_t = 4.86e\text{-}5$

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[9] Age was not included, since this is a categorical constant.

[10] p = .214; p>.05

[11] p = .152; p>.05

[12] p = .168; p>.05

[13] p = .064; p>.05

[14] p = .484; p>.05

[15] p = .113; p>.05

[16] p = .645; p>.05

[17] p = .076; p>.05

[18] p = .662; p>.05

[19] Desire for discretion was not included, since this is a categorical constant.

Women's Prevalence of TB (No Filter)

$$y = \log(p/1-p) = -7.447 + .742x_1 + .020x_2{}^{20} + .375x_3{}^{21} + .717x_4 + .463x_5 + .219x_6{}^{22} - .262x_7{}^{23} + .822x_8 + .261x_9{}^{24} + .374x_{10}{}^{25} - .022x_{11}{}^{26} - .391x_{12}{}^{27} + .514x_{13}$$

Number of Iterations = 45
Pearson GoF = 1.000
$\mu_p = 2.33e\text{-}5$
$\mu_t = 5.73e\text{-}6$

Women's Prevalence of TB (Filter: Age > 35)

[20] p = .231; p>.05

[21] p = .069; p>.05

[22] p = .427; p>.05

[23] p = .481; p>.05

[24] p = .310; p>.05

[25] p = .063; p>.05

[26] p = .970; p>.05

[27] p = .177; p>.05

$$y = \log(p/1\text{-}p) = -14.752 + 2.127x_1 + .000x_2{}^{28} + .008x_3{}^{29} + 1.135x_4{}^{30} - .123x_5{}^{31} + .809x_6{}^{32} - 29.518x_7{}^{33} + 1.061x_8{}^{34} + .594x_9{}^{35} + 1.318x_{10} - .680x_{11}{}^{36} + .941x_{12}{}^{37} - .124x_{13}{}^{38}$$

Number of Iterations = 85
Pearson GoF = .564
$\mu_p = 2.84e\text{-}14$
$\mu_t = 5.23e\text{-}13$

Women's Prevalence of TB (Filter: Desire for Discretion About TB)

$$y = \log(p/1\text{-}p) = -9.835 + 1.064x_1{}^{39} + .073x_2{}^{40} + .082x_3{}^{41} + .750x_4{}^{42} - .540x_5{}^{43} + .732x_6{}^{44}$$

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[28] Age was not included, since this is a categorical constant.

[29] p = .990; p>.05

[30] p = .191; p>.05

[31] p = .858; p>.05

[32] p = .260; p>.05

[33] p = 1.000; p>.05

[34] p = .104; p>.05

[35] p = .429; p>.05

[36] p = .429; p>.05

[37] p = .138; p>.05

[38] p = .866; p>.05

[39] p = .054; p>.05

[40] p = .103; p>.05

[41] p = .887; p>.05

[42] p = .242; p>.05

[43] p = .397; p>.05

[44] p = .281; p>.05

$$- 29.779x_7 + 1.994x_8 + .309x_9 + .396x_{10} + .552x_{11} + .000x_{12} + .838x_{13}$$
[45] [46] [47] [48] [49] [50]

Number of Iterations = 156
Pearson GoF = .000
μ_p = 8.81e-5
μ_t = 9.36e-6

I: DHS Comparative Logistical Results and Discussion

The above models attempt to present a unified scale by which to mathematically compare TB cofactors. The included independent variables were drawn from a list of all significant variables across all categories, with the notable exception of "Trouble procuring funds for medical treatment"--this variable was available only in the women's dataset. In almost every category, the power of prediction for the models was found to be about ten times higher for TB-positive individuals than TB-negative, mirroring the above results. The only exception to this was the unfiltered men's category, which is discussed in more detail below. For now, it should be noted that the comparative approach to logistical modeling was somewhat problematic.

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[45] p = 1.000; p>.05

[46] p = .695; p>.05

[47] p = .476; p>.05

[48] p = .619; p>.05

[49] Desire for discretion was not included, since this is a categorical constant.

[50] p = .164; p>.05

Logistical modeling is a tricky procedure, in that it forces variables to interact in reflexive, complex, and unpredictable ways. The addition of one variable would often cause other significant variables to become insignificant; this is why so many variables listed as significant ($p<.05$) in the DHS Individual Logistical Models section became insignificant in the DHS Comparative Logistical Models section. Accordingly, the former section was aimed at creating the most exhaustive, significant, and optimally iterated models, whereas the latter concerned simple comparison *at the sake of* statistical significance. This may help to explain why μ_p for the unfiltered men's category is smaller than μ_t. Furthermore, the parameter for permitted iterations to find an optimal solution was expanded from 50 to 200, since up to 156 were required for optimal solutions to be found with all variables included.

This section is organized by independent variables rather than categories, for comparison's sake.

Public Facility Use: The use of public facilities for treatment is sensical in TB sufferers since DOTS does not charge for care, creating an incentive among TB-positive respondents to use public rather than private resources. Among men, public facility healthcare was found to be a stronger indicator for TB in those who desired discretion about infection (ß = 1.241), and weakest among men over the age of 35 (ß = .912). Meanwhile, public facility healthcare was found to be strongest for women over the age of 35 (ß = 2.127) and weakest for the unfiltered women's sample (ß = .742). In this way, divergent trends are observed in public care use between men and women, particularly when age is taken into account.

Current Age: Age cannot be used as a variable when filtering for respondents over the age of 35, since this creates a potentially confounding effect. Nonetheless, age was maintained throughout the remaining models because it is an interval-level measurement, and thus helps to prevent problems created by the use of only categorical variables. Advanced age was found to be a relatively strong determinant for TB among the unfiltered male set (ß = .050) and among women who desire discretion about TB use (ß = .073), though neither of these coefficients is high compared to the other included variables.

Knowledge About TB Transmission: Knowledge that TB could be spread through the air via coughing or sneezing is useful for preventative measures, and in this way might help to lower the rate of transmission. Transmission knowledge was found to be twice as strong an indicator of TB positivity among men men over the age of 35 (ß = .814) as among men who desire discretion about TB infection (ß = .406). Among women, on the other hand, transmission knowledge was overall a weaker indicator than among men, where TB positivity among the unfiltered female dataset was best predicted (ß = .375) and positivity among women over the age of 35 was worst predicted (ß = .008).

Literacy: It is not fully clear why illiteracy is a strong indicator for TB positivity among men and women--more research is needed here. It is possible that illiteracy is a cofactor of poverty, which might lend it false correlation to TB positivity. Nonetheless, illiteracy was found to be a 50% stronger determinant of TB positivity among men who desire discretion about TB (ß = 1.187) as opposed to men over the age of 35 (ß = .738) or the unfiltered male set (ß = .791). Among women, on the other hand, illiteracy was a better predictor of TB positivity among women over the age of 35 (ß = 1.135) than among the unfiltered female set (ß = .717) or among women who desire discretion about infection (ß = .750).

Wealth Index: TB has often been described as a disease of the poor. Accordingly, it is fitting that poverty is a strong indicator for most cases of TB. For men, there was little variability in the TB positivity coefficient (.560 < ß < .619). However, for women, an interesting effect was observed: low wealth index was found to be a determinant for TB positivity among the unfiltered female dataset (ß = .463), but *middle/high* wealth index was found to determine TB positivity among both women over the age of 35 (ß = -.123) and women who desire discretion about TB infection (ß = -.540). These findings are somewhat unexpected, but may stem from the fact that low confidence levels were found for the latter two categories (p = .858 and p = .397, respectively).

Belief that TB is Spread via Touching: The belief that physical contact transmits TB is a case study in slight misconceptions about TB, and could be contrived as a measure of stigmatization. Among men, this belief was twice as strong a determinant for TB positivity among unfiltered men and men over the age of 35 (ß = .407 and .403, respectively) as among men who desire discretion about TB (ß = .248). Among women, on the other hand, this belief was a stronger determinant for those over the age of 35 (ß = .809) and those who desire discretion about infection (ß = .732) than among the unfiltered set (ß = .219). In addition, women seem to exhibit stronger determinacy from this belief than men.

Belief that TB Can Be Cured: The belief that TB is curable is an important factor in a victim's willingness to invest time and resources in procuring treatment. For men, there is little variability between the categorical filters for strength of determinacy (.841 < ß < 1.058). For women, meanwhile, little can be said about the belief that TB can be cured, since none of the female dataset categories yielded a confidence level of less than p = .481--both filtered sets had confidence levels of p = 1.00.

Body Mass Index: As a measure of malnutrition, low BMI proved to be a strong determinant for TB positivity in every dataset. Among men, BMI was most predictive of TB positivity for those over the age of 35 (ß = 1.786) and weakest for men who desire discretion about TB infection (ß = .718). For women, on the other hand, low BMI was over twice as strong an indicator for women who desire discretion about TB infection (ß = 1.994) as for the unfiltered female dataset (ß = .822).

Scheduled Tribe Membership: As has been discussed, scheduled tribes constitute a severely underserved community in India, and tuberculosis rates there are among the highest in the world. Accordingly, membership in them represents a risk factor for TB in the context of this study, though it is not a *strong* risk factor for any category. For men, tribal membership proved to be twice as strong a determinant for the unfiltered male set (ß = .538) as for either of the filtered sets (ß = .232 and .205). For women, TB positivity was twice as strongly predicted by tribal membership in individuals over the age of 35 (ß = .594) as for the unfiltered female set and those who desire discretion about infection (ß = .261 and .309, respectively).

Anaemia: Like BMI, anaemia is a cofactor of malnutrition, which has in turn been linked to a weakening of the immune system to TB infection. For men, there is not substantial variability between the categories in the relationship between anaemia and TB positivity (ß = .397, .464, and .611) with the strongest category being men who desire discretion about TB infection. However, women over the age of 35 exhibit twice as strong a relationship as the latter male group (ß = 1.318), while the other two female categories are similar to male levels (ß = .396 and .374).

Tobacco Smoking: As has been discussed in detail, cigarette or bidi smoking constitutes a potential risk factor for TB susceptibility. However, in four out of six categories (unfiltered male, unfiltered female, men over 35, and women over 35), tobacco use was found to *negatively* predict TB positivity--that is, smoking *reduced* the chances of TB infection (ß = -.309, -.022, -.458, and -.680, respectively). This finding is surprising, and will be discussed in more detail below. Meanwhile, cigarette smoking was a positive indicator for TB among both men and women who desired discretion about TB infection (ß = .125 and .552, respectively), with smoking women being much more strongly susceptible.

Desire for Discretion: Again, the desire for discretion about infection constitutes a categorical constant in some cases, so it is relevant only to the 'unfiltered' and 'over 35' categories. As predicted by the individual DHS logistical models, the desire for discretion is much more strongly indicative of TB *negativity* in men over the age of 35 (ß = -.499) as for the unfiltered male set (ß = -.247). For women, on the other hand, the picture is more problematic. Women over the age of 35 exhibited strongly positive determinacy for TB positivity (ß = .941), whereas the unfiltered female set exhibited negative determinacy similar to men (ß = -.391). This problem will be discussed in greater detail below, but for now it should be noted that the 'over 35' women's ß coefficient was not significant under the confidence level $p<.05$.

Trouble Procuring Funds for Treatment: As mentioned above, this variable applied only to the women's categories. Interestingly, a wide range of positive and negative determinacy for TB was found between the three women's categories. Women who desired discretion about

TB infection and worried about procuring funds for treatment exhibited strong positive determinacy for TB infection (ß = .838). This effect was substantially weaker for the unfiltered female dataset (ß = .514). Meanwhile, trouble procuring funds exhibited negative determinacy for TB infection among women over the age of 35--that is, they were *less likely* to have TB if they had trouble paying for treatment. This result was fascinating and unexpected.

VII: Synthesis

The purpose of this section is to attempt to form a coherent picture out of the above results, such that clear conclusions may be taken from them. This is not a simple task, since neither the cultural nor biological nor methodological narratives can be applied in a clear and simple way. These findings support some assumptions about TB differentiation between genders, but challenge others. It is clear, most of all, that gender and tuberculosis interact in complex ways, and that the epidemiological process is fraught with difficulties that must be recognized and addressed before solid research can take place. In this way, the findings of this study may serve to highlight the structural issues within TB research. I will now discuss a few general themes in these results, and attempt to integrate them.

First, it appears that the male bias presents itself in these results as a real and powerful risk factor, second only to a low body mass index. Assuming the data used here are accurate, this provides strong support for a biological explanation for the gender bias, having shown a reduced importance of cultural factors such as education, knowledge about how TB is transmitted, and scheduled tribe membership. Interestingly, the methodological factor of a woman's lack of control over her health trajectory also proved to be relatively low-priority predictor of the presence or lack of TB. However, this does not preclude the existence of *other* methodological factors such as the desire for discretion about TB, which will be discussed in more detail below. However, there is only circumstantial evidence for this claim.

Second, it is highly important that the gender discrepancy in TB rates is concentrated almost entirely in male and female respondents over the age of 35. As discussed earlier, the male:female gender ratio in respondents under 35 is about 1:1, whereas the ratio among those over 35 is over 2:1. This appears to be a highly critical age interval for a study of gender and TB, though it is a domain in which little research has been conducted. It is also a domain in which much more research is needed, since there may be biological confounding factors that better explain the susceptibility of males in this interval. Nonetheless, it is for this reason that I set aside this group in the logistic analysis, in hopes that social or behavioral cofactors might emerge.

The fact that a desire for discretion emerges in the older age categories for the DHS individual models--and that this has a negative impact on TB prevalence--suggests that significant stigma persists among older Indian populations with regard to TB. This also calls into question the passively collected DOTS/RNTCP prevalence data, which as of today continues to shape TB policy. Since treatment takes at least six months of antibiotic chemotherapy under the short-course protocol, it is likely difficult for respondents who desire discretion to seek treatment without staking social capital. At a policy level, this is a problem of education and expansion of coverage; meanwhile, at a socioeconomic level, it is an issue of worker's rights. As detailed in certain TB perception studies (Nair et al. 1997, Atre et al. 2004), TB is stigmatized in young women because marriageability is at stake, whereas among older women potential loss of work and financial stability drive stigmatization. Ideas of purity and fear of illness and death cause both groups to worry about catching and treating TB. Because the gender ratio begins to diverge after the age of 35, it is clear that marriage is not at stake. Instead, since women are more likely than men to be employed under another person, they must take time off to get treatment and may lose their job security in the interim. This may drive an underreporting trend among older women.

It should be noted, however, that the results of the DHS models complicate this theory somewhat. The comparative DHS results show that desire for discretion about TB is positively related to TB infection, whereas the individual DHS results show that women over the age of 35 are *less likely* to have TB if they desire discretion about it. In other words, women over the age of 35 said they would like more discretion about TB if they were infected (though they were willing to tell the surveyor about these seemingly conflicting stances). In this way, women over 35 seem to exhibit both positive and negative determinacy of desire for discretion toward TB infection. Interestingly, both the individual and comparative models yield mean *p*-values that are higher among TB-positive than TB-negative individuals by about a factor of 10, a difference that persists in almost every model found.

Third, the findings that were *not* significant are often as important as those that are. For instance, smoking tobacco proved to be a nonsignificant determinant in all of the male analyses and in only one of the female analyses (Filter: Desire for Discretion About TB Infection). The findings from the DHS data indirectly challenge certain theories about TB susceptibility and tobacco use, as described in Methods and various cited studies (Behera et al. 2010, Mishra et al. 1999, Lin et al. 2007, Lienhardt et al. 2005, Leung et al. 2010, den Boon et al. 2005)--that is, that men smoke at a much higher rate than women, so they catch TB at a much higher rate (1.5% of women smoke, as opposed to 32.6% of men). Perhaps a controlled small-scale case-study comparison of two communities would further test this hypothesis, though there remains little direct evidence of its veracity.

Interestingly, the DHS comparative models (which included all potential variables) showed a *negative* relationship in several cases between TB positivity and smoking, suggesting that smokers are less likely to contract TB. Again, these comparative models do not have the same strength of significance as the individual DHS models, but their findings are interesting from a relative standpoint. Most fascinatingly, they found that the only positive relationship between TB and smoking applied to men and women who desired discretion about TB infection. It is uncertain why this is the case, and further research is clearly needed.

Similarly, the findings described above do not support the solid fuel hypothesis, which holds that men and women living in households that cook or heat using biomass fuels are significantly more susceptible to TB (Mishra et al. 1999, Behera et al. 2010, Lin et al. 2007).

Instead, since wealth index is controlled for in several models, it seems more likely that solid fuel use is only an indicator of poverty. Furthermore, solid fuel use was not found to be a significant determinant among women, even when wealth index was controlled--this strengthens the claim that solid fuel does not have a direct causal link with TB.

Fourth, problems of education about, and consistency within, treatment options persist in modern India. These limit treatment in a variety of ways. The comparative DHS models found that older men are relatively less likely to seek treatment at public facilities than older women, suggesting a potential underreporting problem for older *men* in national DOTS/RNTCP statistics. At the same time, older women with TB infections are relatively less likely to know about TB transmission patterns than older men, suggesting that there is a problem in women's capability to protect themselves from infection; this is supported by the higher determinacy of illiteracy for TB infection in older women than men. It should be noted that illiteracy is used here as an effective measure of education level, and was a persistently strong indicator for TB infection across all categories in both the comparative and individual DHS models.

Fifth, and in conjunction with this, it is possible that active case-finding helps to uncover trends and determinants in TB prevalence and gender differentiation that do not emerge under self-reporting, passive conditions. Though this was not tested for in this study, several prior quantitative and qualitative case studies exist to support it, as listed below. This problem also highlights the tension between the public and private spheres in health treatment in India. Shortcomings in universal public treatment, as has been argued, tend to create demand for a private market in which data are not recorded on infectious disease rates. Because of this, the landscape of tuberculosis prevalence is often ill represented by DOTS/RNTCP resources.

In light of this, official DOTS/RNTCP data seem to account only for those who fit the following conditions:

1. Respondent lives in close physical proximity to a DOTS clinic, or can afford travel.

2. Nearby DOTS/RNTCP clinics are well-staffed, efficient, capable of providing adequate drug regimens, clean, and not over-burdened.

3. Respondent is capable of taking time off work.

4. It is not cheaper or more convenient for the respondent to seek private treatment for TB.

5. Respondent is permitted to seek treatment by cultural and religious rules.

6. Respondent does not fear loss of social capital, such as marriageability, in seeking treatment.

7. For female respondents, it is conditional that childcare has been established in advance.

8. Respondent believes that TB can be cured by allopathic medicine, and is willing to make a significant financial and temporal commitment to get better.

If these conditions are not fully met, it is difficult for many respondents to seek treatment and, indeed, to be accounted for in statistical surveys. Since DOTS/RNTCP data drive TB policymaking in India, the stakes for this are quite high. Furthermore, as has been established (Appendices and DA, Satyanarayana et al. 2011, den Boon et al. 2008, Zachariah et al. 2003, Golub et al. 2005, Murray et al. 1998, Olakowski et al. 1973, Thorson 2001, Cassels 1982), TB targets the most structurally compromised members of Indian society.

Interestingly, 29.4% of women in the DHS survey responded that they would possibly want to keep TB a secret if infected, as opposed to 14.5% of men. The fact that men desire discretion at about half the rate of women, yet exhibit double the prevalence of tuberculosis, is itself remarkable, particularly in light of the structural issues in data collection revealed using the active case-finding method. To be clear, there is no direct evidence that women are being underreported in the DHS data, since they too relied on self-reporting, and therefore on the honesty of the respondents, who have social and financial incentives to be discreet about TB infection. Nonetheless, the DHS penetrated to many communities DOTS/RNTCP could not, and therefore reduced the likelihood of physical distance or financial barriers to treatment.

In any case, it is likely that the most important and basic aspect of this research is the tension between correlation and causation in epidemiological research. As we have seen, there is no simple cause-and-effect in TB. A more scientific approach would perhaps perform a more case-controlled analysis, looking at small-scale communities and controlling for all but one variable, meticulously, until cofactors have been significantly identified.

However, it is certain that epidemiological research can rarely ascertain this degree of control. It is impossible to account for all variables in a dynamic and open social system, and consequently it is highly difficult to sort out correlation from causation. This is true of almost any epidemiological enterprise, applying even to John Snow, the father of modern disease studies. Snow famously solved an outbreak of cholera in 19th-century London by mapping new incidences of cholera and finding that they radiated outward from public water sources like the Broad Street Pump. Shutting down the pump reduced new cases of cholera tenfold, and Snow was celebrated for his findings. It is important to remember, within this, that Snow's hypothesis was proven true by action and retrospection: he could not have ruled out all of the other confounding factors involved, and in spite of this he found a compelling relationship and acted on it.

Similarly, there is no causal claim in this research, though a causal claim was sought. There is only a complex web of relationships. Categorical and descriptive claims can be made, such as that the gender ratio is concentrated in individuals over the age of 35, and that such individuals who suffer from TB also tend to desire discretion about it, but there is no causal evidence that older Indian men and women are so stigmatized by TB that there remain significant barriers to treatment. This web of relationships can only be tested by action at a policy level, just as Snow's hypothesis could only be truly tested by shutting off the pump. Perhaps if there were some change to TB policy on a broad and institutional level a causal claim could be made.

For now, this research is intended to stand as a testament to the complexity and ambiguity inherent in epidemiological work. Each variable tested was included because of its significance to TB rates in one or more small-scale studies, and even still most of them were set aside as too insignificant on a nationwide level. This has been, it seems, more an exercise in *disproving* than validating. Despite the messiness of this research from a statistical and analytical standpoint, its importance is clear: assumptions about health must be interrogated and assessed thoroughly, particularly when social stigma is at stake.

Appendix A: Sources of Error

Epidemiological research is never a perfect science, largely because social forces and factors do not follow rigid rules, as they do in physics or biochemistry. Error is a perpetual possibility, particularly when using national-scale data, and every one of these findings should be further tested using small-scale controlled case studies. The most likely sources of error are the following: lack of controlled variables, inaccuracy or dishonesty in survey responses, type 1 ($\propto$) error, and human error in data entry or calculation.

A central problem in conducting a nation-wide analysis, particularly in a country so diverse as India, is the inability to control for every variable. India contains over a billion people who practice a wide array of cultural traditions, and thus even the most carefully executed large-scale analysis must admit to some degree of uncertainty. The lack of homoscedasticity in certain models implies that certain unaccounted-for variables are at play--more research is needed to identify these.

Second, certain regions behave strongly as outliers and may distort the results presented here. For instance, the state of Goa exhibits a male:female gender ratio of TB rates at about 3.98:1--this is the highest ratio in all of India, and indeed would be considered unusually high anywhere in the developing world. This may be the case due to Goa's history as a Portuguese colony, its relatively high GDP, or its divergent genetic population. In any case, more research is needed into Goa and states like it to understand this difference, which may well provide insight into the nature of the male bias.

Third, the DHS data rely on self-reporting for all responses except for blood haemoglobin content and body mass index. Thus, it is possible in some cases that respondents mistakenly diagnosed themselves with TB or were unaware that they had TB at all, in addition to misrepresentation in any of the other variables. Future research might account for this by taking sputum smear samples from TB candidates and testing them, though this would dramatically increase the cost of broad-scale surveying.

Fourth, as is true for all statistical analysis, it is possible that coincidental trends might be mistakenly identified as significant. The confidence level for all tests used in this study was $p<.05$ with two-tailed analysis; thus, there is a 5% chance in either a positive or negative direction that a false positive was found. $p<.05$ was chosen as the permitted confidence level in this study in light of its nature as a social/behavioral analysis.

This selected confidence level was violated at many points by the DHS comparative models, and each violation has been documented. The statistically insignificant variables were retained for two reasons. One, since each part of the logistical model behaves as part of a system, it was necessary to retain insignificant variables such that the models could be compared on a similar scale. Two, scientific honesty is a central goal of this research, and it is as important to show insignificance as significance in the name of transparency. The effect of this is that the DHS comparative models are less statistically sound than their counterparts and should be taken ‘with a grain of salt,’ though the findings therein are still relevant.

Appendix B: Future Research

Above all else, it is clear that more research is needed into the variation in TB gender ratios across the states of India. As described in the Introduction, the history of modern TB research is young and, consequently, has yet to interrogate many of its assumptions about underlying social forces. The most modest goal of this research is to detect inconsistencies and structural issues in the gendering of TB rates in India, in order to outline a plan for future research and investigation.

One topic that is clearly in need of further research is the social context of TB infection among older populations. Why do they feel a desire for discretion about infection? Does this, in practice, impede them from seeking treatment? How capable are they of self-diagnosing for TB? In their view, how does DOTS treatment differ from private care? What is the connection between tobacco use and the desire for discretion? Too little is currently known about stigmatization and treatment-seeking behavior to make policy-level decisions and adjustments, just as too little has been done to adjust for social context in DOTS implementation.

Another topic in need of further research is with regard to groups relying on private treatment for TB infection. Since the goal of DOTS/RNTCP is to provide free and universal treatment for TB, why do these groups continue to pay for service? Is this primarily an issue of distance or of quality of treatment? In light of Satyanarayana et al.'s findings, along with the degree of discrepancy between actively and passively collected statistics, there is a clear need for accountability of private care providers to national standards and for integration of record-keeping. An accurate picture of TB in India is possible, it seems, only through cooperation between the public and private spheres.

Third, the prevalence and spoligotype strain distribution of drug-resistant TB in India, particularly among lower-income families, is in need of further research. There are hundreds of known genetic strains of TB spread across India, though their physical distribution has not been discussed thoroughly (Kulkarni 2005). The geography of drug resistance could be used to create a map of transmission patterns, from which in turn researchers could identify underserved communities.

Fourth, certain states that exhibit extremely high male:female prevalence ratios need to be researched in much greater detail. Why, for instance, is the gender ratio of Goa nearly 4:1? Is this an issue of overexposure of TB to men, or of underreporting of infected women? A focused case study in TB gendering in state boundary communities--for instance, in towns near and within Karnataka (GR = 1.47:1) or Maharashtra (GR = 1.60:1)--would illuminate this problem.

Lastly, there is a great need for more research on the scheduled tribes of India, and the disease trajectories of these communities. As can be seen in the DHS Frequency Tables, men and women in scheduled tribes exhibit the highest prevalences of TB of any tested group in this survey. "Poor economic condition, nutritional deficiency, [and] lack of knowledge in respect of health and hygiene" (Chaudhuri 1986:128) are endemic in tribal communities, M.K. Chowdhuri writes, and more research is needed on the small scale in these places to develop a better idea of the problem.

Appendix C: Survey Background and Statistical Tools

This analysis utilizes the Demographic and Health Surveys of India (DHS) as its primary sources. A regression analysis was performed on each survey, and the results were compared. Each has certain strengths and weaknesses which factored into its selection--this will be discussed below. First, however, it is important describe each survey in its scope, timeframe, and collected indicators.

The dataset used in this study was requested from the MEASURE Demographic and Health Surveys Project, an international organization funded by USAID which has conducted over 240 surveys in 85 countries since 1984 (USAID 2006). The most recent DHS India project, the DHS V, was completed in 2006, and its data were aggregated into the NFHS III. All of the aforementioned indicators are also present here. However, these data are available on a case-by-case basis, allowing for more disaggregated and thorough analysis. The survey is divided into a male and female dataset. The men's survey includes 75,000 case studies and the women's includes 124,000, each represented by approximately 800 indicators. The male and female surveys were acquired by submitting a formal request to MEASURE DHS.

The DHS is the source dataset from which the NFHS was extrapolated, and thus uses the same methodology and parameters. Since it has an individuated basis, the DHS data about TB and its cofactors are available at a nominal level for many indicators, and at an interval level at others. Since the goal of this research is to find determinants in men's and women's TB prevalences, the dependent variable in regression analysis is TB positivity--a nominal variable, which can be represented as a 'positive' or 'negative' response. Thus, nominal-level regression techniques such as logistic regression are required, though they are weaker than standard linear regression. We will return to this later. A second problem with the DHS data is that it represents males and females separately, though they have been combined to calculate the General Logistic Regression Models. This, in addition to the fact that the women's dataset is nearly twice as large, renders the calculation of an accurate gender ratio impossible at any level. Furthermore, a gender ratio cannot be inferred from any other source, since an accurate regression in which a gender ratio serves as the dependent variable would require data from both male and female respondents. The datasets are incommensurable in some ways without a carefully executed aggregation, which is beyond the scope of this study. Accordingly, the DHS data will be useful insofar as providing a model for how male and female TB prevalences vary independent of one another.

Still, the DHS data have certain strengths. One, its individuated basis provides a very high n-value, which permits a high degree of certainty in many analysis. Two, it provides frequency data and other descriptive statistics, and thus can give an accurate prevalence for TB and its cofactors. Three, the DHS is capable of providing insight on the factors influencing TB positivity on an individual scale, and permits the researcher to qualitatively compare models between men and women.

Type of Analytic Software Used

SPSS by IBM© was selected as the analytic software for this study. The program is commonly used for social, economic, and epidemiological statistics, and is relatively easy and versatile to use. Furthermore, the DHS dataset was available in a format easily read by SPSS. The NFHS dataset, on the other hand, was available only in text form and was entered manually.