TREATMENT AND TRANSMISSION FACTORS AFFECTING TUBERCULOSIS INCIDENCE IN THE EMERGING ECONOMIES OF THE POST-SOVIET BALTIC REPUBLICS, 1989-2009

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

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And hereby certify that in their opinion it is worthy of acceptance.

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Thank you to my parents and my incredible life partner Paul for all their support and encouragement.

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TREATMENT AND TRANSMISSION FACTORS AFFECTING TUBERCULOSIS INCIDENCE IN THE EMERGING ECONOMIES OF THE POST-SOVIET BALTIC REPUBLICS, 1989-2009

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ABSTRACT

Tuberculosis (TB) has re-emerged as a global public threat since the 1980s, rising in incidence throughout the world, coinciding with the rise of HIV. Political instability and economic depression exacerbate the effects of a communicable disease epidemic, which poses a threat to current developing countries as well as faltering industrialized nations. Tracking the emergence of tuberculosis in the Baltic republics (Estonia, Latvia, and Lithuania) from their split from the Soviet Union to their current state allows patterns affecting TB's incidence and mortality rates to be delineated. TB in the Baltic region does not have a linear correlation with HIV incidence, but it is significantly correlated with the presence of physicians. Healthcare workers properly trained in the WHO's DOTS strategy for controlling TB have a significant effect on controlling the spread of the disease. Many types of data that would further describe the epidemic in the Baltic region are not available. Social and behavioral information is notably absent, and it is recommended that data collection in these areas for developing countries be the focus for future infectious disease epidemiology and control.

CHAPTER 1 – INTRODUCTION

Tuberculosis, once thought to be a near-extinct disease, has recently re-emerged as a global public health threat. Its history of infecting humans dates back many thousands of years, its effects seen in both written and bioarchaeological records (Dormandy 1999; Daniel 2006). A deadly bacterium, *Mycobacterium tuberculosis* is an airborne pathogen commonly transmitted through the coughing and sneezing of an infected individual. The bacteria can lay dormant in its host, with most people never manifesting symptoms of the disease. Yet the clinical disease may develop at any time in a person's lifespan, often emerging during physically stressful periods when the immune system is weakest. Upon showing symptoms the infected person becomes infectious to others and may spread the disease.

In the mid-20th century, tuberculosis was assumed to be a problem of the past. Receding on its own, particularly in developed countries, the advent of antibiotics aided the disease's decline. Coinciding with the rise of human-immunodeficiency virus (HIV) infections, tuberculosis incidence surged anew in the 1990s and soon became a leading cause of morbidity and mortality throughout the world (Zaman 2010). A highly resistant bacterium, tuberculosis treatment requires many months and sometimes years of treatment with multiple antibiotics to cure a single case. This stringent regimen proves difficult to effectively follow and many lapses occur in treatment, particularly among the poverty-stricken who lack education, money, and access to healthcare. Antibiotics

create a selective pressure on the bacteria and the lapses in treatment allow multiplication of resistant strains. This has led to the appearance of multiple antibiotic resistant strains, requiring more extensive and rigorous treatment. These drug-resistant strains have exacerbated the global re-emergence of tuberculosis and strained attempts at controlling its spread.

Since the surge of the 1990s, tuberculosis incidence has slowed, but prevalence remains high. Globally, over 9 million people develop active cases, and 2 million people die from the disease each year (Stop TB 2011). Many of those reported as new cases were previously infected and have recently emerged from the disease's latent state. It is estimated that roughly one-third of the world's people currently have a latent tuberculosis infection (Stop TB 2011). The current threat is particularly great in developing countries, where poverty is rampant and socio-political unrest disrupts funding for and access to healthcare (Romaniuk & Crawford 2011). Malnutrition, physical stress, and exposure to crowded and unhealthy living circumstances are all high risk factors for both the emergence of a latent infection and the transmission of the bacterium. Other risk factors include smoking, alcohol and drug use, diabetes mellitus, and HIV infection (Lonnroth et al. 2009; Murray 2009).

The crux of the tuberculosis problem is treatment; once emerged from latency the bacteria can be transmitted to susceptible individuals. If proper precautions and treatments are executed for an infectious individual, transmission to others is less likely. Unfortunately, adhering to the arduous course of treatment provides an additional

complication. While the recent problems of tuberculosis have been attributed to HIV, poverty-worn areas in developing countries are the focal point of insufficient treatment, resulting in both drug-resistance and continued transmission. In the modern era, infectious disease transmission is not limited by geography. Therefore the transmission of a disease easily transcends political borders and class divisions through advanced transportation services. Tourism, migration, and foreign aid workers all assist in allowing tuberculosis in all its forms to infect humans across the globe. Through this, a disease like tuberculosis becomes not just a threat to the poor and marginalized, but to humans everywhere.

Since poverty and economic disruption promote the transmission of tuberculosis, this disease may become a more dangerous threat in the future. Economic crises result in an increase of all causes of mortality, but they also raise mortality from major specific causes (Falagas et al. 2009). Since 2008 the world economy has been dramatically damaged compared to its 1990s glory. Industrialized, powerhouse nations have faltered financially while unemployment and poverty proportionally amplify. A global depression runs the risk of increased communicable disease transmission as well as greater difficulties in managing a pandemic (Suhrcke et al. 2011). Because of the perception of tuberculosis as a disease of poverty in Third World countries, lack of attention to, and funding for, preventive practices have left most individuals in First World countries unvaccinated and highly susceptible to contracting tuberculosis (Suk et al. 2009; Maher 2010). Reflective study of the emergence and decline of a

communicable disease in a susceptible area sheds light on the patterns that most affect transmission and effective treatment.

In an effort to examine the arc of an epidemic in a developing country, I investigated global disease trends to find a suitable case study for the relationship between economic development and tuberculosis rates. The first criterion was that the chosen region must have recently surfaced as an industrialized, modern economy in the world market. This would ensure that as of the year 2010, their social and economic configuration were on par with other First-World countries. The second criterion was that it had significant tuberculosis rates and moderate HIV rates. Because HIV is inextricably linked with the re-emergence of tuberculosis, it must be included in a modern analysis, but it is not the focus of this research. Third, it should be an area with limited tourism. Although no society can be considered an impervious microcosm (Galton's problem), choosing an area with limited international movement would somewhat control for the introduction or re-introduction of bacterial strains. Fourth, the region's developmental milestones must be recent and easily marked. The idea of a country's 'development' is somewhat abstract, but certain indicators of social and fiscal strength may be delineated as it transitions from disorganization to a structured economy.

Using the above criteria I chose not one, but three countries for this project: Estonia, Latvia, and Lithuania. Collectively these countries are referred to as the Baltic republics. They are intertwined both in demographic composition and history; sharing

geographic borders with each other and the Baltic Sea (see Figure 1.1). Their historical convergence includes having been annexed to the Soviet Union in the early 20th century, and achieving independence from the same in 1991.

The Soviet Union was a self-sustaining nation through much of the mid-to-late 1900s, socially and economically detached from the rest of the world. Its communist regime advocated self-sufficiency and executed this goal through specializing regions in specific types of industry. The Baltic States were relegated to agricultural work, with

Figure 1.1: The Baltic Region
Source: www.worldatlas.com

little processing or finishing skills sustained in the region. Therefore when they declared independence in 1991, they were as close to an untouched economy as could be found within my criteria's parameters. All three countries built their economies in the 1990s, and were accepted into NATO and the European Union in 2004, a signal of their independent strength as nations.

Record keeping within the Soviet Union was highly secretive and unreliable, and population data in the region prior to the 1990s are only rough estimates. Therefore the starting date for my research is 1989, at the beginning of the Baltic revolutions against the USSR. Because they were accepted into two internationally recognized partnerships in 2004, I extended my data to 2009. This allows several years to visualize disease trends after their stabilization. It was important to include all three countries because their composition and history is so similar, yet their independent development may reveal some differences which could affect their disease trends.

A number of tuberculosis studies have been previously conducted in the Baltic area; not only in Latvia, Lithuania, and Estonia, but in the surrounding Scandinavian and former Soviet countries as well. Finland and other Scandinavian countries have been exempt from the onslaught of HIV and tuberculosis incidence experienced in Eastern Europe. A few researchers have examined the threat of drug-resistant tuberculosis strains in Finland, finding that transmission of these severe strains is rare (Marttila et al. 2008; Ruutu et al. 2010). The increasing trend of drug-resistant tuberculosis cases dominates current research throughout Eurasia. Bacterial isolates from Russia (Stepanshina et al. 1999; Toungoussova et al. 2002) and the Baltic States (Kruuner et al. 2001; Bakonyte et al. 2003; Tracevska et al. 2003) have been analyzed to determine the molecular epidemiology of multi-drug resistant strains, often finding that drug-resistant strains are easily transmitted.

In addition to the molecular research, studies in Russia extend to their health practices and its reverberating effects in former-Soviet countries (Toungoussova et al. 2006). Russian epidemiological research has been found to be nearly non-existent (Vlassov 2000) which exacerbates the tuberculosis and HIV burden in Russia and the former Soviet Union (Perelman 2000; Honneland & Rowe 2005). In turn, there is a great concern that inclusion of former-Soviet countries into the European Union will threaten public wellfare through increased cross-border communicable disease transmission, particularly of tuberculosis (Coker et al. 2004; Brand et al. 2000; McKee & Maclehose 2000; Bernitz 2008; Fears et al. 2010). Therefore most of the research in the Baltic region and the surrounding area has focused on the genotypes of multi-drug resistant strains and the possible consequences for the greater European Union.

Another body of research is concerned with the efficacy of treatment in the Baltic Republics (Alban & Kutzin 2006; Leimane & Leimans 2006; Leimane 2007) as well as the whole European Union (Sterling et al. 2003; Lang et al. 2010). Many of these studies emphasize the use of vaccination and the creation of new antibiotics to control tuberculosis. A small amount of published literature has focused on the relationship between poverty and tuberculosis in the region (Suk et al. 2009), but most current research does not focus on one particular behavioral risk factor. There are currently very few researchers who focus on social factors affecting current transmission in the Baltic States and their neighbors. Therefore, I chose to look back upon the past twenty years of tuberculosis in the Baltic republics by keeping in mind not only treatment, but behavioral transmission and susceptibility factors as well.

Executing this study required several steps. Chapters 2 and 3 establish context for the study: Chapter 2 discusses the Baltic republics, particularly in terms of their history and current position. The disease itself is discussed in Chapter 3 to explain its biological and pathological characteristics, as well as its association with human populations. Chapter 4 explains the common methodology used when studying the transmission of tuberculosis. Numerous researchers identified the important risk factors (previously listed) as well as the markers of development (Dye et al. 2008; Dye et al. 2009; Aspler et al. 2010; Dye & Williams 2010; Kliiman & Altraja 2009). From this literature search, I draw five main hypotheses regarding tuberculosis in the Baltic region, and proceed to test each. Population-level data were available from numerous sources, including the World Health Organization, the World Bank, and each individual country's government websites. Chapter 4 analyzes these data and the support for my hypotheses, and Chapter 5 succinctly concludes the study.

Much of this project focuses specifically on the Baltic republics, but the intention is to consider this area's experience with tuberculosis in light of greater disease trends. Unfortunately much of the necessary data for a full picture of the situation are not available, as is the case for most developing countries. Public health efforts to combat tuberculosis and its drug-resistant strains must focus on encouraging collecting the appropriate data for proper observation of disease trends. The threat of tuberculosis to the world is not over, and indeed the treatment efforts to eliminate it are faulty in some areas, as will be seen in Lithuania. This thesis supports the World Health Organization's

Stop TB strategy, but also illuminates some areas of necessary improvement for combatting the global issue of tuberculosis.

CHAPTER 2 – THE BALTIC REPUBLICS

I. Origins of the Region

The Baltic region is located in northern Europe with the Baltic Sea dividing the Scandinavian region from the greater part of the continent, and includes all the countries that border the sea. On the eastern coast of the Baltic Sea lie the current Baltic States: Latvia, Lithuania, and Estonia. For the purpose of this study, the Baltic region refers only to these three Baltic States. The name "Baltic" derives from the languages traditionally spoken in the region, including the living languages Lithuanian and Lettish (Gimbutas 1963). The first human settlers in this region came after the last ice age ended, roughly 11,000 years ago. Archaeologists have found evidence of multiple fishing and hunting settlements along the eastern edge of the Baltic Sea, the evolution of which can be traced throughout the Bronze Age (Selirand & Tonisson 1984). The Iron Age brought a transition to farming in the area, a similar development throughout the Old World at this time, which also fostered trade and a relationship with the Roman Empire (Cary & Scullard 1980). The current inhabitants of the Baltic states are directly descended from tribes that settled the region over 4,000 years ago (von Pistohlkors 1990). Modern Lithuanians and Latvians are considered Indo-European, while Estonians and Livonians (a small tribe with some descendents remaining in Latvia) are Finno-Ugrian, to which their linguistic roots can be traced (Hiden & Salmon 1994).

The Baltic peoples were divided into smaller tribes throughout the first millennium CE, but gradually united into nations during the medieval period. Lithuania

was created as a kingdom in the 1230s, growing over the following century to become the largest country in Europe, incorporating modern day Poland, Belarus, Ukraine, and parts of Russia (Magocsi 1996). Throughout several wars over power, Lithuania became closely tied with Poland, later forming the Polish-Lithuanian Commonwealth in 1569. Despite this union, Lithuania retained a national identity separate from Poland (Stone 2001).

While Lithuania's history parallels that of Poland, Latvia and Estonia are more closely tied to each other. Acquired by the Holy Roman Empire in the 13th century, the Pope sent German crusaders to the area to force the native pagans to convert to Catholicism (successfully, although adherents to Lutheranism have dominated since the 1700s) and acquiesce into the empire (Christiansen 1997). Russian, Danish, and Swedish forces all participated in the attempt to convert the Baltic area, which also included Prussian and Lithuanian tribes. First under Danish rule, then German, the Baltic region was submerged in centuries-long struggles between foreign landowners and Baltic peasants (Christiansen 1997). In the late sixteenth century, what is now Latvia and Estonia were taken into Polish-Lithuanian rule. The Northern Wars between the Swedish and Russian empires in the 16th and 17th centuries ravaged the Baltic region as well as the Polish-Lithuanian Commonwealth. The final Northern War ended with the Treaty of Nystad in 1721, resulting in much of Estonia and Livonia (including Latvia) being acquired by the Russians. Lithuania remained relatively untouched throughout the Northern Wars, strengthened by its alliance with Poland. However the new empires of Europe soon overwhelmed the Polish-Lithuanian Commonwealth dominance. Three

segmentations of the Commonwealth occurred during the eighteenth century, with 1795 marking the final absorption of the region into the Russian Empire (Hiden & Salmon 1994).

Unification under the Russian Empire did not yet bring peace to the region. Under the Russian tsar's rule, Russian was introduced as a compulsory language in government and schools in the Baltic region during the nineteenth century. In Lithuania, authorities seized estates from the wealthy Baltic German nobility and distributed the wealth and land among the peasants (Thaden 1981). Many of these acts of Russification served to weaken the Baltic German influence in Latvia, Estonia, and Lithuania (as Germans largely composed the upper classes in these areas), yet also served to repress local history and culture. The mid-nineteenth century response to the empire's actions involved a cultural awakening of individual national identities, with Russification broadly resisted. The First Latvian National Awakening occurred in the mid-to-late 19th century, with a reemergence of Latvian language and literature (O'Connor 2003). The Estonian Age of Awakening occurred at roughly the same time, culminating in the Russian Revolution of 1905, when political and social movements resulted in widespread revolts against the Russian Empire (Pipes 1996). By 1917, the Russian Revolution was complete and the tsarist rule in St. Petersburg was overthrown by the Bolshevik party led by Vladimir Lenin, who would go on to rebuild the nation (Suny 1998). Latvia, Lithuania, and Estonia all declared independence from Russia in 1918; however, their freedom was short-lived. Lithuania was occupied by German and Polish armies and annexed again to Poland in the 1920s (O'Connor 2003). Germans continued to occupy Latvia and Estonia,

but the countries remained independent for nearly twenty years. In 1922 during the Russian Revolution, the Union of Soviet Socialist Republics (USSR) was created by Lenin, and later continued by his successor Joseph Stalin (Suny 1998). Throughout the period of Baltic independence in the 1920s and 1930s, the Russian-led Soviet Union was built up by Stalin into an industrialized, single-party Communist superpower.

II. Soviet Rule

During World War II, the 1939 German-Soviet Treaty of Non-Aggression secretly divided lands of interest between Russia and Nazi Germany, effectively deciding their agreed areas of conquest in Northern and Eastern Europe (Hiden & Salmon 1994). Soon after this pact was made, German and Russian forces invaded their respective areas of conquest. The German seizure of Poland incited declarations of war from major European nations, marking the beginning of World War II. The non-aggression part of the German-Soviet treaty, however, was not fulfilled and Germany invaded the Soviet Union in 1941. By default, the Baltic region was thrust into World War II conflicts due to their renewed association with the Soviet Union. The Third Reich occupied the Baltic republics in 1941, only a year after the area's invasion by the USSR. The Baltic territory was incorporated into Nazi Germany, but was reclaimed by the Soviet Union in 1944 during the Baltic Offensive operation (O'Connor 2003).

World War II had a devastating impact on Europe, with the Baltic States suffering some of the highest casualty rates. Estonia sustained over 90,000 deaths throughout the

conflict, and over 190,000 Lithuanian Jews were murdered during the Holocaust alone, with nearly six times that number of civilians perishing throughout the war (Raun 2001). Throughout the greater Soviet Union, roughly 27 million people died during the war (Hosking 2006). Despite the large toll, the Soviet Union emerged from World War II as a powerful economic and military force, maintaining its superpower status for nearly 50 years.

Despite Soviet occupation of the Baltic republics, the area still did not stabilize. During the Red Army's occupation, hundreds of thousands of refugees fled their home countries for neighboring Germanic and Scandinavian states (Suny 1998). Those that remained were forced to begin Sovietization to cleanse them of an identity separate from Russia. Some areas resisted, particularly in Lithuania, as guerilla partisans fought against the Soviets throughout Stalin's rule; many of the partisans were killed or deported to Siberian work camps (Courtois et al. 1999). As part of its integration with the Soviet Union, mass deportations were ordered for the Baltic countries, with more than ten percent of the remaining Baltic population removed from their homelands (Courtois et al. 1999). The mass deportation was undertaken through Operation Priboi in 1949, which labeled the native Estonians, Latvians, and Lithuanians as enemies of the Union. These people were taken to labor camps in remote areas of the USSR, upon which they were forced to sign an agreement that declared them not only unable to return to their homelands, but unable to leave their designated settlement under penalty of twenty years' forced labor (Strods & Kott 2002).

The Soviet Union as a state was the world's largest country, covering over 8.6 million square miles and encompassing 15 republics at its height. The capital of the USSR was the city of Moscow, from which the Soviet government held highly centralized control over the expansive Union (Suny 1998). Operation Priboi allowed for the removal of many higher class citizens of the Baltic region, and the subsequent collectivization of the remaining peoples. Stalin's plan for the whole Union involved consolidating land into collective farms, following through on the Communist agenda of shared wealth (Strods & Kott 2002). Agriculture was the focus of the collectivization, presuming that labor on the lands would produce a surplus of food for the Union, but this result was never achieved. Instead, the increased farm size led to decreased agricultural production, which drove Moscow to increase production quotas on Baltic farms (Shen 1994). To compensate for the low number of people remaining in the Baltic states after World War II and Operation Priboi, Moscow also ordered large-scale immigration of industrial workers from other parts of the Soviet Union, particularly from Russia proper (Hiden & Salmon 1994).

Sovietization also involved specialization of regions in types of labor. The 'planned economy' approach Stalin set forth for the USSR centralized all production and distribution of goods, with all implementation decided by the government. The Baltic was marked primarily for agricultural production, but Latvia and Lithuania were also used for power-generation intended to provide electricity for the entire Union (Shen 1994). Without their own imports or mining, Latvia and Lithuania became dependent on Russia for fuel, including oil, natural gas, and coal. Industrialization occurred throughout

the Union, with several plants invested in the Baltic region. These plants centered on production of machinery and parts, metalwork and metallurgical products, precision tools, household appliances, chemical and building materials, timber, and food processing (Shen 1994). Specialization resulted in dependence on other areas within the Union for all supplies; even those materials that were produced in the community were exported and processed in different regions. This resulted in a far-reaching transportation system throughout the Soviet Union, which became one of the most extensively used systems in the world (Hanson 2003). Dependence on the government for distribution of products and supplies forced cooperation with the Communist regime, and maintained the coalition of the Soviet Union until the late 1980s.

III. Independence from the Soviet Union

The 1980s were a divisive time in the Soviet Union. A long war in Afghanistan and the nuclear plant disaster in Chernobyl exacerbated the slowing of the economy. The USSR's currency dropped in value, and competition from Saudi Arabia lowered the demand for Russian oil (Courtois et al. 1999). Despite their planned economic system, Soviet isolation from outside influence resulted in retarded growth in technology, healthcare, and education. By the late 1980s, the Union was no longer the influential powerhouse it had been in previous years. Under the direction of Mikhail Gorbachev, increased democratization and political openness in the USSR re-awakened the independent drive of its oppressed citizens.

The Singing Revolution began in 1987 in Estonia with large demonstrations in Tallinn, its largest city. The demonstrations included singing hymns and songs forbidden by the Soviet government (Thomsen 1992). The resistance in Estonia was born from an ethnic re-awakening of the Estonian people, and soon spread to Latvia and Lithuania. The Latvian people arranged two assemblies in 1988, the Latvian People's Front and the Latvian National Independence Movement, to organize the call for independence from the Soviet regime. One year later, Lithuania began the Sajūdis, their own political and social reform movement (Trapans 1991). The re-awakening of nationalism in the Baltics involved a resurgence of language, literature, and symbols associated with their independent states. In an act of regional solidarity, the People's Fronts from all three Baltic countries held a demonstration on August 23, 1989, the anniversary of the German-Soviet Treaty that decided their fate. During this demonstration, a peaceful 370 mile human chain formed across the three countries as a symbol of severance from the Soviet Union's hold on the region (Thomsen 1992).

Popular fronts from the Baltic republics organized Supreme Council parliamentary systems for each country while still resisting Soviet influence. The elected members adopted each nation's constitution and passed legislation in 1990, and then three leaders from the Supreme Councils acted as heads of state. Lithuania declared independence in March of 1990, Latvia in May 1990, and Estonia did so formally in August of 1991. The Soviet Union was slow to accept their empire's dissolution, and refused to recognize any republic's independence. However in December of 1991, the

presidents of Russian, Ukraine, and Belarus declared the Soviet Union dissolved, and Gorbachev (then president of the USSR) resigned (Shen 1994).

In an attempt to remain an imposing influence in the Baltic region, Russian soldiers were encouraged to maintain occupation for several years, and did not vacate until the early 1990s. The last Soviet troops departed Lithuania in August 1993, but did not leave Latvia or Estonia until late 1994 (Suny 1998). After the break-up of the Soviet Union, the Baltic republics were left to rebuild themselves. But after fifty years of Sovietization and oppression, they were in a much different condition than when they were last sovereign nations. Russia's political and economic control over the Baltics changed the demographics of the region, which did not revert to its previous structure after independence was declared.

IV. After-effects of Independence

The economies of the Baltic republics were severely limited as an effect of Soviet collectivization and industrialization. In 1989, Lithuania's gross national product (GNP), a measure of the sectors that compose the country's overall income, earned 56% from the industrial sector, and 23% from the agricultural sector. In similar trends, Latvia earned 45% GNP from industrial and 25% from agricultural, and Estonia earned 44% GNP from the industrial sector and 25% from agricultural (Shen 1994). The employment ratios in these areas followed the GNP, with the majority of workers skilled only in specific production industries. As an effect of the limited skills and equipment available,

the Baltic was left with an oversupply of industrial products and an undersupply of finished products and consumer goods. State ownership of land had suppressed entrepreneurial development and talents, forcing the new countries into continued dependence on other regions on the former Soviet Union. As an additional detriment, the Soviet Union's isolation left farm productivity and industry lagging behind Western standards, so the Baltic States could not effectively compete in world markets upon reaching independence (Shen 1994).

Demographic indicators of the Soviet Baltic region are uncertain due to lack of reporting, but largely followed the greater Soviet trends. Prior to Soviet rule few foreigners moved into the Baltic, but overall composition of the countries had changed during occupation and by 1990 citizens of Russian descent composed 11% of Lithuania, 30.3% of Estonia, and 34% of Latvia. In addition, military operations, famines, and epidemics under Soviet rule had kept population growth in check for the entire 20th century (Shen 1994). Most basic demographic data were underreported by the Soviet Union; however some studies have estimated trends in the Baltic republics during Russian occupation (e.g. Anderson & Silver 1989a, b, c; 1990a, b). In the 1950s, Baltic life expectancy was greater than in Eastern Europe, but this fell over time as the region increasingly integrated with the USSR. In the 1960s, life expectancy in the USSR declined as a whole, and the 1970s saw a rise in infant mortality (Anderson & Silver 1989a). In the 1980s infant mortality declined somewhat while life expectancy at birth and age-specific mortality rates also declined. Despite this, infant mortality and overall mortality were still higher in the USSR than in other developed countries (Anderson & Silver 1989a).

These trends may be due to the overall deterioration of public health programs in the USSR, but the data provide only estimates over the whole Union, so they cannot be directly quantified. Post-Soviet demographics in the Baltic region alone will be discussed in Chapter 4.

Little is known about trends in the Baltic republics alone during their association with the Soviet Union. It is known, however, that the Baltic republics had the best socio-economic conditions in the USSR through much of their recent history, with Estonia exceeding the income of all other Soviet republics, followed by Latvia and Lithuania (Krumins & Zvidrins 1992). This socio-economic advantage likely resulted in greater life expectancies and lower mortalities than the rest of the USSR. In 1959 the Baltic region had much higher death rates compared to other Soviet republics, but by the 1970s Lithuania had slightly lower than average mortality in the republics (Dutton 1979). This may reflect overall better living conditions and lower mortality in the Baltic republics in the 1970s and 1980s, but without complete data this assumption cannot be confirmed. Information on specific causes of death in the Soviet Union was not made available to the public until 1989, thus only some overall mortality data are available. It is known, however, that there was higher mortality in rural areas than urban in the Baltic republics, and that *rural* mortality increased through the 1970s and then decreased in the 1980s. This trend has been attributed to lower mortality of men at working ages; however, the cause of this cannot be ascertained (Krumins & Zvidrins 1992). And while the greater mortality in rural areas may reflect trends in the republics overall, it cannot be assumed without additional information. The greatest detriment to studying changes

in mortality in the Baltic republics is not just the lack of mortality information, but the lack of cause-specific mortality information. For this reason, 1989, the year in which data became available on cause-specific mortality, has been chosen as the starting point for investigating tuberculosis in the Baltic.

Beyond demographic composition, Soviet rule had several other impacts on the Baltic region. Industrialization imposed ecological damage on the region (Krumins & Zvidrins 1992). Agricultural specialization had depleted the land and, as previously mentioned, there was increased dependence on other countries for products and supplies. The economy was very unstable once the Soviet system was no longer in place, as is often true of newly independent nations (Jones 1997). The challenge for any new country is to first build its government and infrastructure in order to regulate and stabilize the economy. This process can take years or decades, with international recognition of the country's progress often following suit. For the Baltic region this process is still occurring; however, the period of greatest turmoil stretched from their independence in 1991 through their admittance into the European Union in 2004. During this time, each Baltic republic formed a democracy-based government and converted from the Soviet-initiated planned economy to a free market economy.

V. Economic Markers of Development

There is some difficulty in measuring the progress of a country's development, as there are no universally accepted proxies (Mathieson et al. 1996; Spangenberg 2004;

Manuele 2009). The strength of government agencies is reflected in economic reports, but they do not directly correlate with the quality of life of its citizens (Meso et al. 2009). Instead, there are a handful of financial and economic indicators that serve to inform on the progress of a nation as it builds itself into a global power. These financial and economic measures are used as proxies for a base-line indication of overall quality of life and wellbeing of the general population (Spangenberg 2004). Some of the most commonly used indicators include gross national income (GNI), the Human Development Index (HDI) and the amount of lending interest from the International Monetary Fund (IMF).

Gross national income (GNI), also referred to as gross national product (GNP), is the total output value of goods and services plus taxes of all working residents in a country, divided by mid-year population and converted to U.S. dollars with adjustments made for inflation (World Bank 2004). The World Bank considers upper-middle income countries to be those with a GDP of roughly $3000 – $9200. To mark when the Baltic republics are solidly through this threshold, at the near-center of this estimate with $4000 GDP, I consulted data from the European World Health Organization's *Health for All* (HFA) database. These data showed that Estonia passed a GDP of $4000 in the year 2000, while Latvia and Lithuania did so in 2003 (see Appendix Table A.2).

While the GNI estimates economic stability, is does not duly reflect social stability. For this, the Human Development Index (HDI) was created. The HDI measures the average achievements in a country through life span, access to knowledge, and

standard of living. A country is considered well developed when they reach an HDI score of higher than 0.78 (World Bank 2004). However, not all of the Baltic countries have yet surpassed that mark as of 2010. Instead, I used the HFA database to determine when they each reached closest, at 0.77 HDI. Estonia did so in 2001 with an HDI of 0.772; Lithuania in 2005 with 0.775 HDI; and Latvia in 2006 with a 0.771 HDI (see Appendix Table A.3).

A third economic indicator is the lending interest rate from the International Monetary Fund (IMF). The lending interest is the rate charged by banks on loans to prime customers (IMF 2011). There is no standard threshold that marks the progress of a country, however the United States and the United Kingdom are both considered strong, reliable economies. These countries both keep average lending interest rates below 10%, so this will serve as an economic milestone for the Baltic as well. While after independence all three countries had lending rates well over 20%, Estonia's lending rate broke below 10% in the year 2000, at 7.43%. Lithuania achieved a 9.63% lending rate in the year 2001, and Latvia reached below 10% (at 7.97%) in 2002 (IMF 2011).

The above data give some measure of the Baltic's economic and social progress, but there are also some qualitative factors to consider. Admittance into the European Union is a significant marker in the development of sovereign nations, as the criteria for admittance are extensive. The European Union was created after World War II in order to bolster economic cooperation on the continent, and it has since become a symbol of social and economic modernity for those nations who gain admittance. The 1993

Copenhagen European Council established several criteria for membership within the European Union, including democracy and human rights for all citizens of the country, a functioning and globally competitive market economy, and the ability to adhere to the political and economic standards of the EU (European Commission 2010). Later requirements adopted at the Madrid European Council of 1995 required adjustment of national legislation to ensure that EU protocol is implemented in each country (European Commission 2010). Estonia, Latvia and Lithuania were all determined to have met these criteria in 2003, and were officially accepted into the EU in 2004.

Also in 2004, all three Baltic countries joined the North Atlantic Treaty Organization (NATO), a political and military alliance of 28 countries promoting democratic ideals and security for all countries, where an attack on one nation is considered an attack on them all (NATO 2011). Acceptance into NATO ensures not only the Baltic region's security, but their ability to aid other countries. Association with the EU and NATO in 2004 marks the concrete stabilization of the Baltic region.

If 2004 marks the highest achievement of international recognition for the Baltic republics, then where was the turning point between the unrest of the early 1990s and the recognition of the mid-2000s? National development is not a simple bell curve and there is no one date that can be used, but it is necessary to estimate a turning year for the purposes of studying these countries' development in Chapter 4. Therefore I will simply take the average of each country's milestone years listed above for GNI, HDI, IMF lending interest, EU and NATO alliance (see Table 2.1).

Table 2.1: Years of significant post-Soviet economic achievements

	Estonia	Latvia	Lithuania
GNI	2000	2003	2003
HDI	2001	2006	2005
IMF	2000	2002	2001
EU	2004	2004	2004
NATO	2004	2004	2004
average:	2001.8	2003.8	2003.4

Rounding the average years of achievements, Estonia's milestone year of development is 2002, Latvia's is 2004, and Lithuania's is 2003. Quantifying development is a difficult task, as measures are often argued to be weighed differently (Chao et al. 2008). While GNI and HDI are the most common quantitative measures of development, there are also limitations to this methodology (Malul et al. 2009). Given that there is no agreement on the precise methods, I will use the above calculated milestone years as a rough estimate of the Baltic's governmental and infrastructural peak moments of progress with which to contrast the data in Chapter 4.

VI. TB in the USSR

The history and modern development of the Baltic region is important to consider when discussing infectious disease patterns. The central tenet of this thesis is the effect of economic and political turmoil on incidence of tuberculosis. From the independence of the Baltic States in 1991 to their stabilization in 2004, the region was a

highly unstable place, slowly building up infrastructure and in turn, healthcare (Kirk & Silfverberg 2006). Government involvement in providing healthcare to its citizens and implementing internationally-accepted disease control regimes are important components for tracking disease transmission in emerging economies (Smolinski et al. 2003). The contrast between the Soviet approach to healthcare and the post-independence Baltic approach is important to this end, particularly when discussing tuberculosis. The primary differences between the Soviet and Western approaches to tuberculosis will be discussed in the next chapter.

CHAPTER 3 – THE BIOLOGY, EPIDEMIOLOGY, AND HISTORY OF TUBERCULOSIS

In order to fully understand the impact of tuberculosis on the Baltic republics, it is helpful to review its basic biology and pathophysiology, the mode of transmission, its history, and recent studies conducted on risk factors for acquiring the bacterium and expressing the disease. Although the bulk of this paper does not discuss the nature of antibiotic resistance, the re-emergence of tuberculosis in the late twentieth century is a central component of my study, and drug-resistant varieties of tuberculosis relate to this subject. Discussing all of these aspects of the pathogen will assist in identifying and explaining the data discussed in the next chapter.

I. Biology of Tuberculosis

Tuberculosis is caused by a genus of bacteria called *Mycobacterium*. There are four species of this genus which cause disease, and each is loosely restricted by the animals they infect. *Mycobacterium bovis* causes TB in bovine and sometimes humans, *Mycobacterium avium* causes TB in birds and immunosuppressed humans, and *Mycobacterium leprae* causes leprosy in humans. The most common cause of clinical tuberculosis in humans is *Mycobacterium tuberculosis,* which is restricted to human infection (Todar 2011). This last species will be the primary focus, as it is the most common etiologic agent of tuberculosis in humans, especially in recent times.

Mycobacterium tuberculosis is a rod-shaped bacterium 2 - 4 µm long and 0.2 – 0.5 µm wide (Breed et al. 1948). The bacterium has a mycolic acid coat on the surface of its cells, which makes it unreceptive to Gram staining; thus it is neither Gram-positive nor Gram-negative (Ryan & Ray 2004). The mycolic acid coat is unique in its rich lipid layer, which is highly protective and assists in its resistance to permeability from stains and dyes as well as antibiotics, acidic and alkaline substances, and immune system attack. Because it cannot be detected by Gram staining, an acid-fast stain on a sputum sample is used instead to detect a tuberculosis infection under a microscope (Todar 2011). *M. tuberculosis* requires large amounts of oxygen for replication, which occurs relatively slowly; the bacterium divides every 15-20 hours. It is also a resilient bacterium, able to survive for long periods of time without a moist growth environment, and it is resistant to many disinfectants (Murray et al. 2005).

II. Transmission and Pathogenesis

Mycobacterium tuberculosis is an airborne pathogen, transmitted human-to-human through sneezing, speaking, or spitting. Aerosol droplets of sputum are expelled by the tens of thousands into the surrounding area during these activities, with each droplet containing tuberculosis bacteria (Cole & Cook 1998). These droplets can remain airborne for some time, as they are often miniscule. Bacteria within the droplets find a susceptible host and begin the infection process described below. There are several dependent factors for transmission, including the presence of live bacilli in large

numbers in the patient's sputum, sputum becoming airborne, the presence of a susceptible host, and the length of exposure to infected air. Extended close contact with a tuberculosis patient is necessary for infection to occur (Scharer & McAdam 1995). However, only 10% of those who are infected by *M. tuberculosis* manifest the clinical disease. Those who have a latent infection with no symptoms are not capable of transmitting the pathogen (WHO 2006c; Todar 2011).

Initial infection with *M. tuberculosis* begins when air-borne droplet nuclei are inhaled, and travel into the lungs, reaching the pulmonary alveoli. Upon settling into the alveoli, the bacteria are engulfed, but not destroyed, by alveolar macrophages. After 7-21 days, the bacteria begin replicating within the alveolar macrophages (Houben et al. 2006). It is the ability to replicate within macrophages (essential pathogen-destroying white blood cells) that makes *M. tuberculosis* so successful evading destruction within humans. The primary site of infection is usually located in the lower part of the upper lobe of the lung, or the upper part of the lower lobe. The inflammation that occurs in this area is called the Ghon focus, which composes the visible infectious area in a chest x-ray (Kumar et al. 2007). The center of the tubercle formation has a necrotic area where the bacteria can live, but not multiply (Scharer & McAdam 1995).

The process described here is restricted to pulmonary tuberculosis, which accounts for 75% of active cases (Todar 2011). There are numerous other types of infections, as *M. tuberculosis* can affect nearly every organ in the human body. If the bacteria spread to the bronchus, they can then invade other parts of the lung. If they

instead reach the blood supply, then the tubercle bacilli can spread asymptomatically throughout the body until hypersensitivity and cell-mediated immunity develop (Scharer & McAdam 1995). Incidences of bacteremia (where the bacteria ender the bloodstream) often mean that bacteria will reach other organs, and the disease will manifest as a form of extrapulmonary tuberculosis. While incidences of inter-organ spread can affect nearly any area, it is most common in the genitourinary system, bones, lymph nodes, brain, kidneys, and joints (Kumar et al. 2007). When tuberculosis is identified as extrapulmonary, there are two possibilities for the infection's origin. Either the initial infection was pulmonary and then disseminated to other systems through bacteremia, or the initial infection began in an organ separate from the lungs. These extrapulmonary cases are most common in immunosuppressed individuals and young children (Todar 2011).

III. Symptoms and Diagnosis

Ninety per cent of *Mycobacterium tuberculosis* infections are asymptomatic, and a person can remain latent for an entire lifetime. Only 10% of those with latent infections will manifest the disease (Kumar et al. 2007). For those that develop pulmonary tuberculosis, symptoms include chest pain, coughing up blood, and persistent long-term coughing. Symptoms of other tuberculosis infection sites often have a longer latency period before emerging, but upon emergence the signs include fever, chills, night sweats, appetite loss, weight loss, and fatigue (Scharer & McAdam

1995). Infection in certain organs can also manifest unique symptoms, such as meningitis in the central nervous system and Pott's disease in the spine (Golden & Vikram 2005).

Diagnosis of tuberculosis infection is most reliably done with a sputum or pus sample, which is cultured to yield visible colonies. This process using body fluids, however, can take 4-6 weeks. Another method is the BACTEC system where bacterial growth occurs in 9-16 days (Todar 2011). A clinical examination may also include x-rays or scans, particularly to locate the Ghon focus, or a Mantoux test. The Mantoux test is a tuberculin skin test where a test antigen is injected into the patient's skin, and reveals infection through a large lesion 10-15 mm in diameter (Konstantinos 2010). The skin test is positive due to increased lymphocyte concentration from the immune system reaction, leading to tissue hypersensitivity (Scharer & McAdam 1995). A skin test is less reliable that the lengthy sputum test, as it can produce false negatives if the patient is co-infected with some types of disease (Kumar et al. 2007). Due to these complications, there have been newer tuberculosis tests created in recent years, which include polymerase chain reaction assays to detect *M. tuberculosis* DNA and a direct test that amplifies the bacteria to determine its presence (Reddy et al. 2002).

IV. Disease Progression, Treatment and Drug Resistance

The degree to which the disease progresses depends on the bacterial strain, whether the individual has previously been exposed to tuberculosis, whether the

individual has been vaccinated, the dose or load of bacteria in the initial infection, and the immune status of the host (Todar 2011). Upon detection by lymphocytes (other white blood cells), a granuloma of cells forms around the infection site. This granuloma functions to prevent the spread of the bacteria, as well as destroy the infected macrophages (Kumar et al. 2007). This is what composes the necrotic site of the tubercles. This action by the host immune system may eliminate the infection, or it may result in a latency period where an individual has been exposed to the bacteria, but has not (yet) manifested symptoms and cannot transmit the bacteria to others. Latency may turn into a cyclical process of infection, wavering between active and inactive infection.

The sudden onset of tuberculosis symptoms in adulthood is often a consequence of an initial infection occurring when young. This sudden emergence of the disease out of latency occurs when the body is weakened, such as postpartum, during adolescence, in old age, suffering from malnourishment, or in individuals with alcoholism, diabetes, or cancer (Scharer & McAdam 1995). Adult onset often occurs in people who have either not manifested, or overcome, initial infection without the aid of treatment. Those that do not receive treatment for active tuberculosis have a 50% chance of death (Onyebujoh & Rook 2004). If, however, the bacteria disseminate to other areas in the body as in extrapulmonary tuberculosis, untreated cases have a near 100% fatality rate. Effective early treatment results in a reduction to only 10% fatality (Kumar et al. 2007).

Treatment often includes antibiotics. The special structure of the mycobacterial cell wall inhibits many antibiotics, therefore there are a limited number of effective

drugs (Acharya & Goldman 1970). Long term treatment is necessary to ensure total eradication of bacteria from the body, which is much more intense in tuberculosis treatment compared to other bacterial infections. This long course for tuberculosis requires between 6 and 24 months of continuous treatment (Todar 2011). Isoniazid and rifampicin are commonly used; however, due to their common usage these are also the two drugs most commonly causing the emergence of drug resistant strains. Other antibiotics used, in a minimum of two types at a time, include pyrazinamide, ethambutol, and streptomycin. When a four-drug course of treatment is followed, the success in eradicating a tuberculosis infection reaches ninety-five per cent (Todar 2011).

Lapse in treatment regimens and overuse of these basic antibiotics has led to multi-drug resistant strains of tuberculosis (MDR-TB). MDR-TB refers to strains that are resistant to the two most common antibiotics used to combat tuberculosis, rifampicin and isoniazid. Extensively drug resistant strains (XDR-TB) are less common than MDR-TB, but are a rising concern in public health circles. XDR-TB refers to strains that are resistant not only to isoniazid and rifampin, but also any fluotoquinolone and at least one second line injectable drug (WHO 2006c). Both MDR-TB and XDR-TB often result from a failure of patients to properly take their antibiotic regimen for the allotted period of time; however, these strains can also be transmitted person-to-person. Immunocompromised individuals have the largest risk of complications from these strains, as they have little inherent immune system function to assist in resisting the bacilli. These immunocompromised individuals include people who have recently had surgery, are co-morbid (affected by more than one disease), or are elderly, although the

largest risk of MDR-TB and XDR-TB co-infections occurs in individuals infected with HIV (Farmer & Walton 2003; Silversides 2006; Chaisson & Martinson 2008; Getahun et al. 2008; WHO 2009a).

V. Prevention: Vaccines and DOTS

Attempts have been made to develop vaccines that can prevent tuberculosis. The bacille Calmette-Guerin (BCG) vaccine is a widely used vaccine consisting of a live avirulent strain of *Mycobacterium bovis* (Bonah 2005). The vaccine was developed in the early 20th century, and is able to prevent serious forms of tuberculosis in children. This 80% efficacy in children is offset by the more variable protection offered to adults who receive the vaccine, ranging from 0 - 80% prevention (Bannon & Finn 1999). The BCG vaccine does not prevent infection with *M. tuberculosis*, but it does prevent manifestation of the disease (Todar 2011). Therefore the vaccine is limited to childhood inoculation, as it has minimal effects on adult pulmonary tuberculosis. It is also limited in its distribution; although childhood vaccination is common in countries such as South Africa, it is nearly nonexistent in countries with a lower tuberculosis burden, such as the United States (WHO 2006a). Vaccines are part of a worldwide effort to eradicate tuberculosis; however, because tuberculosis is seen as a disease of poverty (Suk et al. 2009; Maher 2010), TB control initiatives do not have much success in extending preventive efforts to developed countries (Stop TB 2011).

Because adult pulmonary tuberculosis contributes greatly to the worldwide prevalence of the disease, other vaccines are being developed to tackle the burden. These new vaccines are based on a variety of methods, and have been promoted through prizes, advance market commitments, and tax incentives from policymakers (Barder et al. 2006). There are seven major contenders, but all of these preventive vaccines are still being developed and are being subjected to further clinical trials before they will be widely available (Beresford & Sadoff 2010).

Other issues of prevention beyond the vaccine deal with behavior and proper planning. Because the pathogen is transmitted via air, crowded conditions with poor ventilation exacerbate transmission of tuberculosis. These conditions occur in a variety of areas, including prisons, poorhouses, hospitals, and other crowded areas. Proper treatment of existing cases, then, is the largest component of strategies to prevent the spread of tuberculosis. Many initiatives have attempted to tackle this dilemma. The World Health Organization (WHO) declared tuberculosis a global health emergency in 1993. After this declaration, the Stop TB Partnership was developed, proposing the Global Plan to Stop Tuberculosis, promoting its eradication by 2015 (WHO 2011). The Stop TB Initiative not only promotes the use and development of vaccines, but it also seeks to increase diagnostics and treatment. A major element of Stop TB is the Directly Observed Treatment Short course (DOTS) strategy. This strategy has five main components: sustained political and financial commitment, diagnosis by sputum-smear microscopy, standardized short-course anti-TB treatment (SCC) given under direct and supportive observation (DOT), a regular supply of high-quality anti-TB drugs, and

standardized recording and reporting (WHO 2006b). It is assumed that this strategy will aid in preventing future epidemics by effectively treating current cases, and therefore limiting the number of infectious individuals in the global population.

Studies have determined that the DOTS strategy was very successful in the 1990s, reducing tuberculosis incidence by 5-10% annually (Sleeman et al. 1998; Sharma & Liu 2006). By 2004, over 83% of the world's population lived in an area covered by the DOTS strategy of control (Blondal 2007). Unfortunately, the rate of tuberculosis decline seen in the 1990s has not been sustained in the new millenium (Dowdy & Chaisson 2009), and the Stop TB Initiative has had to re-evaluate its strategy and expand the DOTS framework (WHO 2002). This re-evaluation of the DOTS strategy became particularly important upon the realization of its impotence in the face of multi-drug resistant strains (Sterling et al. 2003; Espinal & Dye 2005). The WHO introduced DOTS-Plus in 1998, which is structured to focus particularly on MDR-TB and XDR-TB (WHO 2002; WHO 2003). Despite its intent to discourage all strains of TB, DOTS-Plus has not yet proven to be more effective than the original DOTS strategy for controlling transmission (Obermeyer et al. 2008).

VI. Predisposing Factors

Complicating the strategies behind prevention and treatment are increased risk factors and co-morbid diseases with tuberculosis. Risk factors for the expression of tuberculosis symptoms relate to any activities that suppress immune function.

Malnutrition, poverty, alcohol use, smoking, air quality, human immunodeficiency virus (HIV) infection, and access to healthcare all complicate the issues facing tuberculosis eradication (Gandy & Zumla 2003; Lonnroth et al. 2009; Murray 2009). Malnutrition and alcohol use dampen immune function, and poverty can instigate both conditions. Limited access to healthcare can also exacerbate malnourishment and alcohol use, because the damaging effects of poor nourishment or alcohol abuse may go unchecked without medical intervention. Lack of healthcare also delays the treatment of other diseases that may weaken the body and allow tuberculosis to develop. Smoking and poor air quality can weaken the lungs as well as the immune system. Thus, because pulmonary tuberculosis is the most prevalent form of the disease, these conditions increase likelihood of contracting and dying from tuberculosis (Gandy & Zumla 2003; Arcavi & Benowitz 2004).

Chief among these predisposing factors is co-morbidity with HIV infection. As of 2009, there were approximately 33 million people with HIV, and 2.2 billion with *Mycobacterium tuberculosis* (WHO 2009a). HIV patients are 20-37 times more likely to contract tuberculosis than non-HIV cases, and in some areas almost 80% of tuberculosis cases are infected with HIV (Getahun et al. 2009). In 2008, 23% of AIDS-related deaths were attributed to tuberculosis, and that number is expected to rise without treatment (WHO 2009b). Therefore, HIV infection is considered the greatest risk factor for latent or new tuberculosis infection, and has often been implicated in the global re-emergence of tuberculosis in the late twentieth century (Small et al. 1992; Castro 1995; Chaisson & Martinson 2008). The recent re-emergence of tuberculosis as a global issue shows that

the current pandemic has resulted from opportunistic *M. tuberculosis*. The disease expresses itself in those with weakened immune systems, and once it is expressed it can be transmitted to other susceptible individuals. Once thought to be nearly eradicated, tuberculosis cases have been on the rise since 1985, and the presence of HIV is unquestionably the culprit behind this trend (Silversides 2006; Chaisson & Martinson 2008; Dye et al. 2009; Getahun et al. 2009; WHO 2009a).

VII. History

Tuberculosis is an ancient disease. Abscesses characteristic of spinal tuberculosis have been identified on prehistoric skeletons, which allow for the dating of the disease and the presumption that it has been infecting hominins since the origin of *Homo sapien sapiens,* and possibly earlier (Daniel 2006). Neolithic skeletal remains prove that it was clearly present in the earliest human civilizations (Waksman 1964). Remains of Egyptian mummies dating to 3000 BCE and descriptions in both Hippocrates' (460-370 BCE) writings and in the Bible suggests that tuberculosis has been a chronic problem throughout human history (Dormandy 1999). Skeletal markings of tuberculosis have also been found in pre-Columbian Native American remains, suggesting it has a worldwide prevalence, although it is likely that tuberculosis was less of a problem in the Americas than in the Old World (Buikstra 1981). Increasing population density allowed tuberculosis to proliferate globally over the past 2,000 years, nearing an estimated 100% infection rate in some early European cities (Johnson 1993).

Throughout human history physicians have had trouble classifying tuberculosis; its variety of symptoms and manifestations lent itself to misdiagnosis as bronchitis, typhoid, or other diseases (Dubos & Dubos 1953). Disagreement also arose as to whether the disease was infectious or genetic, with many assuming the latter (Madkour & Warrell 2004). Others insisted that tuberculosis may be due to behavioral habit such as improper diet, exercise, or types of clothing worn (Gandy 2003). Commonly referred to as 'consumption', tuberculosis took a particular toll on Europe starting in the 17th century and lasting over two hundred years. This epidemic has been referred to as the Great White Plague, a contrast to the Black Plague, the medieval Eurasian epidemic of bubonic plague (Dormandy 1999). Some theories on tuberculosis as a contagion appeared throughout history, but did not take hold until the late nineteenth century, when the new science of bacteriology advanced the understanding of disease spread (Waksman 1964). In 1869 Jean Antoine Villeman, a French physician, demonstrated the transmissibility of tuberculosis from human cadavers to laboratory rats, proving the infectiousness of the disease but not yet identifying the causative agent (Barnes 1995). Less than two decades later, in 1882, a Prussian bacteriologist named Robert Koch discovered the tuberculosis bacterium, although the precise mode of common transmission continued to be debated (Rosenkrantz 1985).

Subsequent acceptance of germ theory allowed a widespread understanding of the disease and aided in discovering its airborne mode of transmission. Linked to this was tuberculosis' association with poverty and poor housing, particularly in cities (Sontag 1978). Public sanatoria were constructed in Europe and North America in the

early twentieth century as an attempt to treat the widespread tuberculosis problem. Originally for wealthier individuals, these health institutions later morphed into havens for all urban cases, although treatment methods were limited to heliotherapy (sunbathing) and nature-related activities (Gandy 2003). It soon became clear that tuberculosis disproportionately affected those in the lower social classes, who were relegated to the most crowded and least hygienic parts of cities. This uneven racial and class association of the disease led to the misconception that tuberculosis was related to an inherent social and physical 'constitution' which allowed the richer Caucasians of Europe and North America to resist infection (Gilman 1985). Because the only treatments at the time were good food, rest, and fresh air (all inaccessible to the marginalized populations in Western society), tuberculosis was approached as a social problem. Thus, research for treatment was overshadowed by a moral crusade to reform the behavior of the working class (Robbins 1997).

Albert Calmette and Camille Guerin created the bacille Calmette-Guerin (BCG) vaccine in 1922 from *Mycobacterium bovis.* This allowed widespread inoculation in Europe, but the use of the vaccine was limited in the United States (Gandy 2003). In 1944, Selman Waksman and colleagues isolated *Streptomyces griseus* to create streptomycin, the first true antibiotic and the first effective agent in treating *M. tuberculosis* infection (Daniel 2000). Streptomycin was the first among many antibiotics that would be used to treat tuberculosis, but widespread antibiotic use in the mid-twentieth century also gave rise to drug-resistant strains that have become a current public health threat.

Evidence shows that before the advent of either antibiotics or vaccines for the disease, tuberculosis was already declining. In 1840, the standardized notification rate was almost 400 per 100,000 population, which steadily declined throughout the rest of the nineteenth century. By 1900 the rate was just above 100 per 100,000, and by the time antibiotics were introduced in the 1940s, the rate was barely 60 per 100,000. By 1960, it seemed as though tuberculosis was nearly eradicated in all industrialized societies (McKeown 1976).

This seeming triumph over tuberculosis was cast into doubt in the 1980s, when the United States there witnessed a sudden increase to 20 new cases per 100,000 people in urban areas between 1985 and 1992 (Brudney & Dobkin 1991). The re-emergence has been attributed to several factors, including the relaxation of control mechanisms, increases in poverty and homelessness, and most importantly – the rise of HIV and the spread of drug-resistant tuberculosis strains. This resurgence in the United States soon echoed around the world, resulting in a global public health crisis. By 2000, the Stop TB Partnership was established through international cooperation in order to eliminate tuberculosis globally. As detailed in the previous section, the World Health Organization launched the Stop TB Strategy in order to establish guidelines for tuberculosis prevention and treatment throughout the world. The ultimate goal of these agendas was to prevent new incidences of tuberculosis by the year 2015, although the strategy and timeline are continually modified (Stop TB 2011).

VIII. Geography

Tuberculosis has been found throughout the globe, wherever humans have settled. As mentioned in the section on the history of the disease, it has been found throughout prehistoric Europe, Asia, and the Americas. Because tuberculosis is spread through respiratory droplets, it is often associated with close contact and crowding. Therefore, despite its worldwide prevalence, it is most common in areas of dense populations, such as in urban centers. The current distribution of tuberculosis shows increased concentration in Africa, Southeast Asia, western South America, and South Pacific Islands (WHO 2011). Eastern Europe, the former Soviet Union, and some areas in Central America also report a large number of cases. This distribution coincides with several influential factors, including the prevalence of HIV as previously explained and a lack of healthcare; common situations in many of the aforementioned areas.

Poverty and healthcare are the most significant factors that influence community-level transmission. Density of bacteria in air droplets, as previously mentioned, is particularly important because of the mode of transmission. Close contact is necessary to transmit the tubercle and therefore urbanization leads to greater prevalence of the disease. Poverty also results in increased transmission for a myriad of reasons, not least because the inability to pay for individual housing and proper ventilation increases exposure to other individuals' respiratory droplets. Infrequent or non-existent access to healthcare, both preventive and diagnostic, is also associated with poverty. Poverty-stricken areas can be localized, as in a subset of a population, or

widespread due to government negligence. This latter factor is the biggest issue influencing community-level transmission of tuberculosis in the former Soviet Union.

When tuberculosis began to disappear in the mid-twentieth century, it did so uniformly throughout the world. There were, however, some areas that still had more cases than others. Reporting may have influenced this uneven distribution; nonetheless, tuberculosis was more common in the former Soviet Union than in other areas of Eurasia. In Australia and the Americas tuberculosis was a much smaller problem. Re-emergence first occurred in the 1980s, and spread rapidly due to modern transportation such as air travel. The long incubation and infectious periods aided its transmission through these modes during its re-emergence. From 1985 to 1992 there was a 20% increase in global incidence (CDC 2007). Multi-drug resistant tuberculosis (MDR-TB) appeared at this time, and extensively drug-resistant TB (XDR-TB) soon followed. By the early 2000s, 79% of drug-resistant tuberculosis strains were classified as XDR-TB (CDC 2007). The appearance of these strains intensified the worldwide re-emergence of the disease, which has spread globally but continues to be the biggest problem where poverty and HIV are also prevalent.

IX. Tuberculosis in the Baltic States

Tuberculosis has a history of affecting the Baltic region, similar to other areas in Europe. When absorbed into the Soviet Union, Estonia, Latvia, and Lithuania were introduced to the USSR's system of tuberculosis control. This system involved a network

of sanatoria, dispensaries, and hospitals dedicated specifically to treating tuberculosis, which had been in use in the Soviet Union since 1918 (Perelman 2000). This system was based on five rudiments: yearly mass population screenings via chest radiography with follow-up, long-term hospitalization and isolation of active cases, use of surgery as primary treatment in addition to multi-drug regimens, BCG vaccination among children, and biannual treatment with isoniazid to prevent relapse in pulmonary cases (Kimerling 2000). Although effective at identifying active cases of tuberculosis, the Russian resistance to sharing scientific discoveries with the West prevented them from identifying passive cases via sputum smear microscopy (Hønneland & Rowe 2005).

In its basic tenets, the Russian system of tuberculosis treatment in the Baltic was very similar to the later-adopted DOTS strategy. This internationally implemented system was incorporated into the Baltic States' tuberculosis control programs, and by 2001 DOTS projects covered 100% of the Estonian and Latvian populations, and 51% of Lithuanians (WHO 2004). One major difference between the WHO's DOTS program and the Soviet Union's system of treatment was use of hospitalization. In the Soviet system, in-patient care received more funding than out-patient care; thus, the numbers of hospitalizations were high across the Soviet Union (Perelman 2000). The method of Russian diagnosis relied on chest radiography, so it was often diagnosed after the bacilli had multiplied and manifested a Gohn focus. This diagnostic method detects tuberculosis much later than the skin test emphasized in DOTS, and also strains resources more when patients are required to be hospitalized for treatment (Hønneland & Rowe 2005). In contrast, DOTS emphasizes out-patient care and relies on primary care

physicians more than hospitals. Otherwise, the strategies of tuberculosis control in Russia's healthcare and WHO's DOTS programs are similar.

Tuberculosis has steadily been increasing throughout the Baltic republics since the early 1990s. HIV has also been increasing in this region, particularly from a large number of intravenous drug users (Alban & Kutzin 2006). The rise in HIV is significant, as the virus has been globally responsible for the re-emergence of tuberculosis. Between 1996 and 1999, the WHO began implementing DOTS regimens in the region to prevent further incidence of tuberculosis; this action resulted in a slight decline in incidence, but it did not affect the increase in MDR-TB among new tuberculosis cases. The Baltic region is considered by the WHO to have a high MDR-TB burden; in 2008, 11% of new TB cases in Lithuania were MDR, 13% of Latvia's new cases were MDR, and 22% of new cases in Estonia were MDR (WHO 2009c). To compensate for the continued problem tuberculosis poses, special units have been implemented in hospitals and prisons to detect and treat infection in high-risk crowded areas before it spreads (Alban & Kutzin 2006).

Tuberculosis has become a big issue in the post-Soviet Baltic republics' healthcare systems, and each country provides direct governmental funding for control efforts (Alban & Kutzin 2006; WHO 2009c). Multi-drug resistant strains are addressed in each country's current tuberculosis strategy, and the attempts at MDR-TB control are particularly relevant since the introduction of DOTS-Plus by the WHO in 1998 (Hønneland & Rowe 2005). While advanced strategies are in development, tuberculosis

continues to be a problem in the Baltic region; however, each country affected adopted the DOTS system in the mid-1990s, and achieved full DOTS coverage by 2009 (WHO 2009a). The effects of this action will be seen in Chapter 4.

CHAPTER 4 – DATA, ANALYSIS, AND RESULTS

Emerging and re-emerging infectious diseases become global problems through a variety of factors, including increased human susceptibility, economic development, demographics and behavior, technology and industry, poverty and social inequality, war and famine, a breakdown in public health measures, and lack of political will (Smolinski et al. 2003; Weiss & McMichael 2004; Suhrcke et al. 2011). Changes in these factors are often associated with developing countries and regions with high political tension (Jones 1997; Rajabali et al. 2009). Seceding from the Soviet Union in 1991, the Baltic republics experienced over a decade of political, economic, and demographic changes before emerging as strong nations and being accepted into the European Union in 2004. Although some argue that Latvia, Lithuania, and Estonia are economically still developing, as of 2010 they were recognized as stable in politics and infrastructure (IMF 2010).

The Baltic's greatest period of instability stretched between 1990 and the early 2000s, contemporaneous with the global re-emergence of tuberculosis (Smith et al. 2002; Blanc & Uplekar 2003). Given the factors of re-emergence mentioned above, I will explore these in terms of tuberculosis for the Baltic republics. I have five main hypotheses concerning their rates of tuberculosis:

1) Tuberculosis incidence rates will be greatest in all three Baltic republics during the first few years after their split from the Soviet Union in 1991.

2) Tuberculosis rates will decrease as the Baltic economies strengthen.
3) There will be the fewest differences in development and disease trends between Latvia and Estonia due to their joint history and population configuration, while Lithuania will differ most.
4) Changes in treatment proxies, such as the number of hospitals, physicians, and pharmacists, will be very important to changes in tuberculosis incidence and mortality. As treatment is more available, incidence and mortality rates will decline.
5) HIV co-infection will be the most closely correlated factor with tuberculosis trends.

Each of these hypotheses will be explored throughout this chapter in relation to the factors that will support or disprove their relevance. The specific results will be described in section IV.

I. Demographics

Illustrating changes in the Baltic republics over a twenty year period first requires understanding the basic demographics of each area. Comparing demographics for each country will reveal any discrepancies in their incidence or mortality rates that may be due to differential population distribution rather than social or economic factors. For the purposes of this study, only those demographic parameters that affect disease status will be considered. Demographic measures that may influence tuberculosis risk

factors were identified from information in Lonnroth et al. (2009), Murray (2009), Aspler et al. (2010), and Dye & Williams (2010). These measures include population size, population growth, age distribution, crude death rate, life expectancy at birth, and migration. Additional incidence and mortality rates will be discussed in section III.

Some basic demographic measures will not be considered because their relationship to tuberculosis risk factors is less significant. Birth rates are a basic population measure and may increase or decrease the susceptible population. However, birth rates alone do not reflect the size of a susceptible population, so they do not need to be considered independently from overall population size and composition. While many sexually transmitted diseases benefit from comparing sex distributions, physiological tuberculosis susceptibility does not correlate with sex (Diwan & Thorson 1999), so it will also not be considered. Gendered activities, however, may influence exposure to the pathogen. Activities such as care giving, travelling, or employment indoors increase the chance of contracting tuberculosis in endemic areas (Thorson & Diwan 2003). Some of these activities may pertain more to one sex than the other, but cannot be delineated with the available data; thus, these will not be considered beyond the activity itself. These activities will be explained in more detail in section II.

a. Population Size

Using data gathered from the World Bank, the population total is represented in five year intervals from 1985 to 2009, as 2010 estimates are not yet available (Table 3.1). For most of the data in this chapter, 1989 is the start date. This is one year before

the Baltic republics declared independence from the USSR, and so it is a good starting time for tracking their political and economic independence. General population structure requires inclusion of a date prior to the beginnings of independence in order to control for trends in place before the breakup of the Soviet Union. Table 4.1 shows the differences between the three countries; despite their similar landmass, Lithuania has nearly a million more people than Latvia, which has a million more than Estonia. This trend remains throughout time.

Table 4.1: Land mass and total population in millions

Year	Estonia (17,413 sq mi)	Latvia (24,938 sq mi)	Lithuania (25,174 sq mi)
1985	1.53	2.62	3.55
1990	1.57	2.67	3.70
1995	1.44	2.52	3.63
2000	1.37	2.37	3.50
2005	1.35	2.30	3.41
2009	1.34	2.26	3.34
Total change:	-12.4%	-13.7%	-5.9%

The estimation of total change in population size was calculated by dividing the total number of people lost from 1985 to 2009 by the population total in 1985, converted to a percent. The population totals did not change much between 1985 and 1990; however this is the only period where population increased slightly. After 1990, all three republics declined in numbers, with Estonia and Latvia losing over 10% of their population, and Lithuania almost 6%. This decline is not surprising, as it coincides with their independence. The decline could be due either to withdrawal of Russian citizens

and troops, emigration after the borders were opened, or increased mortality. These possibilities will be considered below.

b. Age Distribution

Another measure of the differences between these countries is the age distribution (Figure 4.1, also see Appendix Table B.1). The three Baltic States show not only similar age distributions, but similar trends over time. In 1985, around 22% of the population was aged 0 to 14 years. The population aged 15 to 64 was roughly 67%, and over age 65 composed about 11%. In 1989, the elderly population increased and the youngest age range decreased, until both made up about 15% of the population. Concurrently, individuals aged 15 to 64 increased slightly; however these are proportions rather than numbers, so the changes in the proportion of the total this age group represents may not reflect actual changes in their numbers. This is true for all three Baltic States. This result reveals that the basic age composition is the same in all three countries, and will not be a source of contention when discussing death rates.

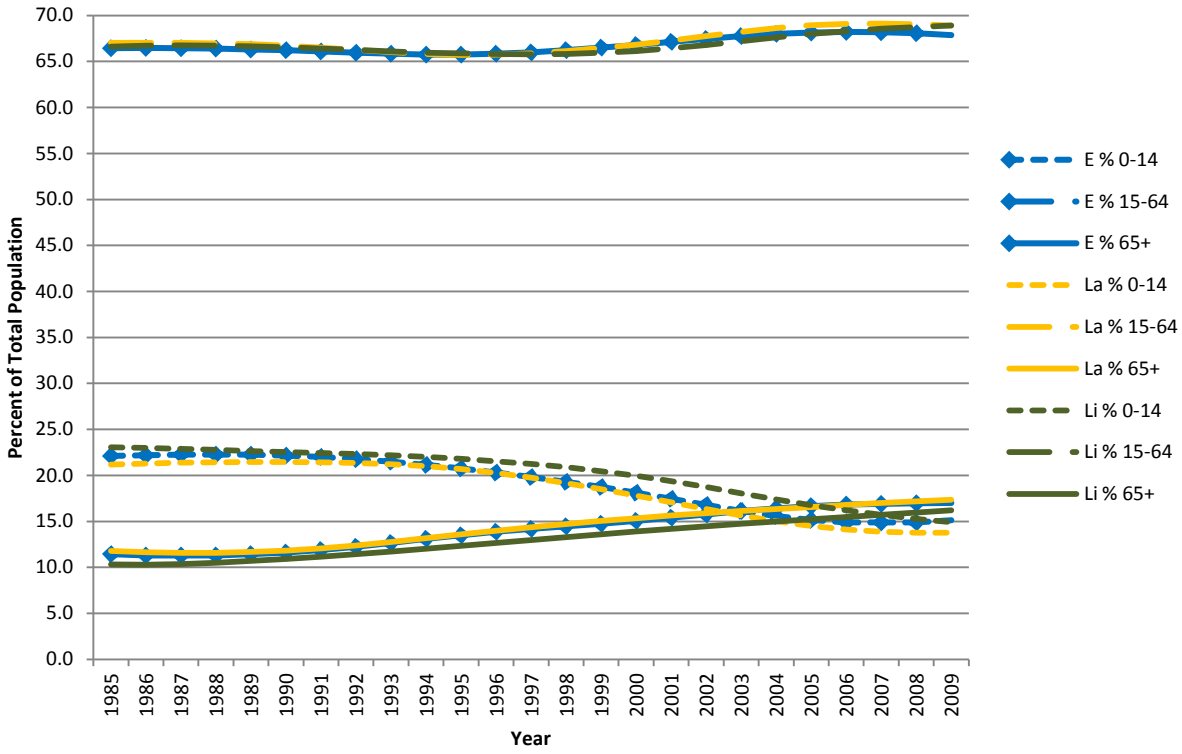

Figure 4.1: Percent Age Distribution, 1985 - 2009

The World Bank age distributions are broadly defined, but over twenty-five years the decrease in the youngest age class could be due to lower birth rates, or higher infant and childhood mortality. Another possibility for the decline in the youngest class is a decline in reproductively aged individuals; but this cannot be proven because the data only supply ages 15-64 in a single category. However my primary interest is in overall adult mortality, so the increase of individuals over 65 without an increase in those aged 15 to 64 may be due to lower death rates and longer life expectancy. Life expectancy data will not be considered in this study because the primary focus is overall mortality and tuberculosis at *any* age. Sex and age-specific death rates will remain absent for the same reason. My assumption is that the greater 65+ population in the late 1990s and

2000s is due to an increased number of individuals younger than 64 surviving in the mid-1990s.

c. Mortality

To confirm the presumption that those younger than 64 are living longer in the 1990s than their predecessors did, age-specific death rates would be the ideal measure. However, these data are not available; instead I will look at crude death rates (CDR). Although this does not inform on specific ages, a decrease in overall death may indicate a trend towards stabilization in mortality for the Baltic States. The World Bank does not yet provide death rates after 2008, so the crude death rates shown below (Figure 4.2, see also Appendix Table B.2) extend only nineteen years.

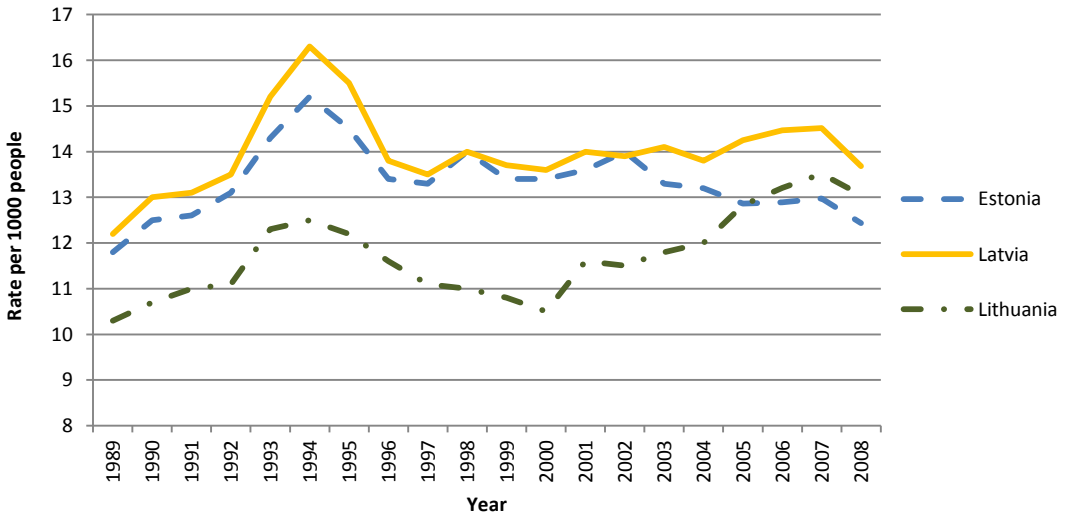

Figure 4.2: Crude Death Rates, 1989 - 2008

Figure 4.2 shows an increase in mortality in the early 1990s in all three countries, followed by a sharp decline after 1994 and then relative stability. While Latvia maintains stability over time, Estonia's CDR begins to decline again after 2002. Lithuania's CDR is

the outlier, with a marked increase after the year 2000, despite its previous position with the fewest deaths per 1000 individuals compared to Latvia and Estonia. Figure 4.1 indicates that variation in population decrease between the three republics is not due to differences in age distribution; because Estonia, Latvia, and Lithuania share similar age distributions, the greater population loss seen in Estonia and Latvia cannot be explained by a larger elderly population. Therefore the differences in crude death rates explain the difference of magnitude of population decrease between the countries. This conclusion is supported by the data in Table 4.1, which shows that the greatest decrease in population occurred in Latvia, which has the highest CDR, averaging 14.0, and an overall loss of 13.7% of its population during this twenty year span. Most notably deaths in Latvia reach over 16 per 1000 people in 1994, and the population declines most markedly between the years 1995 and 2000. In Latvia, then, mortality has a very strong role in the decline of overall population numbers. Estonia has an average CDR only slightly lower than Latvia's, at 13.3 with an overall loss of 12.4% of its population, where it shares Latvia's dramatic spike in mortality in the mid-1990s, but this affects population change to a lesser degree. In Estonia, the greatest period of population loss is between 1990 and 1995; while mortality is rising during this period, it likely plays a smaller role in overall population decline. Lithuania has the lowest crude death rate, averaging 11.7 with a loss of 5.9% of its population over two decades.

These observations indicate that death rates are important to overall population loss in the Baltic republics. Knowing that crude death rates affected the overall number of inhabitants in the region, I can later revisit this with tuberculosis-specific death rates

to clarify whether they followed the trend in CDR. If they do follow this trend, it is possible that tuberculosis can be held accountable for overall death rate trends. In turn, having shown that higher crude death rates led to population loss in the region, tuberculosis would prove to have had a devastating effect on the overall population. However, changes in CDR does not fully account for total population loss. Additional population loss may be due to outmigration from the Baltic.

d. Migration

Net migration data are also available from The World Bank. Net migration is calculated as the total number of emigrants subtracted from the total number of immigrants. The net increases or decreases represented in Table 3.2 are estimates drawn from sources including surveys, censuses, administrative records, and border statistics (data.worldbank.org). The estimates are given in five year intervals. Rather than representing these data in rates, Table 4.2 shows the net gains or losses of individuals for each country. There are mostly losses in all three countries, with the exception of Estonia's turn toward immigration in the mid-2000s. Because all three countries show outmigration in the 1990s and 2000s, the net population loss is likely not from individuals moving within the Baltic region, but outside the Baltic entirely.

Table 4.2: Net Migration, 1990 - 2005

Year	Estonia	Lithuania	Latvia
1990	15032	52445	44186
1995	-107795	-98795	-133799
2000	-36571	-105528	-39965
2005	910	-35840	-19584

Conducting a comparison using Pearson's correlation coefficient between net population change (Table 4.1) and net migration (Table 4.2) showed whether the two variables were correlated. A weak positive correlation between migration and population change was seen in Estonia ($r = 0.21$) and Latvia ($r = 0.24$), with only a slightly stronger correlation in Lithuania (where $r = 0.42$, also see Appendix Table C.1). However, when tested, the numbers were not significant ($p \leq 0.1$). Therefore, although migration appears to have an effect on overall population loss in the Baltic, the effect is not statistically significant and does not surpass crude death rates in relevance.

II. Risk Factor Prevalence

Risk factors for tuberculosis relate primarily to its mode of transmission and treatability; however other general issues of immune function and susceptibility are also important. Because tuberculosis is an airborne pathogen, close proximity to infected individuals and sharing common areas increase the likelihood of contact with the bacteria. Activities and living conditions that relate to transmission include mobility, crowding, and urbanization (Aspler et al. 2010; Gandy & Zumla 2003). Susceptibility can relate to many factors, including malnutrition, income, alcohol use, smoking, air quality, HIV infection, and healthcare prevalence (Gandy and Zumla 2003; Lonnroth et al. 2009; Murray 2009). Treatability is measured through public and private health expenditure (from World Bank 2010), hospital availability, and physician availability (WHO 2009; Dye

et al. 2008; Russell et al. 2010). Data pertaining to treatability are most readily available, therefore these factors will be considered first.

a. Treatability: Healthcare expenditures

Overall funds for healthcare increase the likelihood of individuals in the Baltic receiving medical attention. This medical attention increases the amount of preventive care, diagnosis, and treatment of not only tuberculosis, but conditions that increase susceptibility to infection as well. The World Bank provides health expenditure per capita in current US dollars, which reflects overall amount of healthcare sought. Data for Baltic health expenditure are available only for the mid 2000s. This does not provide a basis for comparison to the rise of TB; however, all three countries nearly triple per capita health expenditures between 2003 and 2007 (see Appendix Table B.3). It cannot be assumed that this has been a steady trend extending to the years before 2003, but it shows at least a later increase in healthcare.

As a different measure of healthcare, the WHO estimates the amount of public sector (government) health payments as the percent of total health expenditure. Changes in the public contribution to health may correlate with accessibility of medical services. The WHO estimates begin for the Baltic in 1995, where all three countries show the highest public contribution to health, 90% for Estonia, 66% for Latvia, and 74% for Lithuania. Government subsidies for healthcare steadily decrease in the Baltic, reaching the lowest rates in the early 2000s before increasing again to 79%, 60%, and 73% in Estonia, Latvia, and Lithuania respectively (see Appendix Table B.4). Latvia

maintains the lowest government contributions from 1995-2008, while Lithuania has the fewest fluctuations. Public contributions towards healthcare decrease, and so the increase in overall expenditure is likely due to an increase in private health payments. Therefore, neither of these measures adequately assesses changes in medical availability in the Baltic. Instead, I will consider more tangible proxies for treatment.

b. Treatability: Hospitals, physicians, and pharmacists

Tangible measures of medical treatment include the presence of hospitals, number of hospital beds, number of physicians, and number of pharmacists. These may provide a measure of supply-and-demand, assuming that if more individuals are admitted and treated in hospitals, there will be a larger number of hospitals and beds. The same is true for physicians and pharmacists; their presence implies that they are performing their intended occupation. The WHO provides data to answer these queries.

The number of hospitals per 100,000 individuals decreases throughout the Baltic from 1989 to 2008, as do the number of hospital beds which decrease by many hundreds (see Appendix Tables B.5-6). Primary health care units, however, increase in number over time for all three countries. The number of physicians varies somewhat. The numbers of doctors in Estonia and Latvia decline throughout the 1990s; in Latvia this trend reverses in 2001 while Estonia sees a rebound of practicing physicians after 2002. Lithuania differs from its neighbors in this respect; the number of physicians available increases in the country throughout the 1990s and then begins to steadily decrease after 1998. Some recovery is seen after 2004, but the increase is minimal. Data

are limited for the number of pharmacists; the WHO provides estimates for as early as 1989, but Lithuania's first estimate appears in 1994, and Latvia not until 2003 (see Appendix Table B.9). Despite the limited availability of data, there is only a slight increase in pharmacists across the Baltic in the late 1990s into the 2000s. The degree to which the data on pharmacists may be relevant will be explored when discussing Hypothesis 4.

Hospitals and pharmacists can be classified as treatment proxies, while primary care centers and physicians may serve for both treatment and preventive care. Pharmacists and physicians per 100,000 population change only slightly while primary care units clearly replace hospitals. This indicates an increase in general healthcare rather than emergency care. It is not a leap to assume the increase in general healthcare is the causative agent behind the lag in emergency care by providing early diagnosis and treatment. This does not conflict with the decrease in health expenditures because regular doctor visits and treatments are likely much less expensive than hospital visits for emergency care. I conclude, then, that healthcare prevalence increases throughout the Baltic in the late 1990s and 2000s.

c. Susceptibility: HIV infection

Human Immunodeficiency Virus (HIV) has long been implicated in a host of co-infections due to its suppression of the infected person's immune system (Pontali 2000; Riesenberg et al. 2008; Nakaoka et al. 2009; Medrano et al. 2010). The relationship between HIV and tuberculosis co-infection has been well documented, and most

researchers agree that HIV prevalence is the single most important reason for the global re-emergence of tuberculosis (Mayoral-Cortes et al. 2001; Silversides 2006; Moran & Jordaan 2007; Verma & Mahajan 2008). Given the global burden of HIV and its causative relationship in the rise of tuberculosis in the late 20th century, I expect that trends in tuberculosis incidence in all three Baltic republics will echo their incidence rates of HIV. Tuberculosis incidence will be discussed in section III, so here HIV incidence is considered alone.

The European branch of the WHO collected HIV incidence rates throughout the world from the Louis Pasteur Scientific Institute of Public Health (WHO/Europe 2011). In 1989, HIV incidence was low in all three Baltic countries, less than 2000 individuals per 100,000 population in Estonia and less than 400 per 100,000 for both Latvia and Lithuania. HIV rates rose to significant levels first in Latvia in 1997, Estonia in 1999, and Lithuania in 2001. Latvia had 1.3 new HIV cases per 100,000 people in 1996, peaking at 34.27 per 100,000 in 2001. Estonia had a 0.87 new HIV cases per 100,000 in 1999 which rose sharply to 108.06 per 100,000 by 2001. Lithuania had a slightly delayed rise in HIV incidence compared to Estonia and Latvia, changing from 2.07 new cases per 100,000 in 2001 to 11.44 per 100,000 by the following year. After reaching their individual peaks, incidence rates initially declined in all three countries. While Lithuania continued the downward trend to 2.83 per 100,000 people, Estonia had a small increase in incidence rates in 2006, and then continued its decline. Latvia declined to 13.0 new cases per 100,000 people in 2005 before steadily rising up to 15.8 per 100,000 in 2008. It is not surprising, given their overall similarities and geographic proximity that the trends in

Estonia and Latvia correlate so closely. Both reached their highest HIV incidence rates in 2001 and then experience an echo of resurgence beginning in 2006.

Presence of HIV alone does not indicate immune system suppression. Onset of AIDS is associated with a compromised immune system, and may occur many years after HIV infection (Muñoz et al. 1989). Immune system suppression is the causative factor in the TB-HIV relationship; therefore it is perhaps better to compare incidence of AIDS to TB, rather than HIV. In addition, HIV appears very suddenly in the Baltic States in the late 1990s; such high incidence may reflect new diagnostics rather than an increase in new cases. If this is true, then AIDS diagnosis also may not appear until the late 1990s. Analyzing the World Bank data on AIDS incidence, there is not a significant trend as seen in HIV incidence. The first cases appear in Latvia and Lithuania in 1990, reflecting the presence of diagnostics for the syndrome. A very gradual rise in newly diagnosed AIDS cases occurs in all three republics throughout the late 1990s, most significantly in Latvia. The patterns do not correlate with HIV incidence, and the rate remains under 5.0 new cases per 100,000 people for all years considered (see Appendix Table B.10). These results show that AIDS was recognized by physicians and public health authorities early in the 1990s. Therefore the increase in HIV rates in the Baltic is not due to new diagnostics or a delay in the region's acceptance of the AIDS epidemic, but instead reflects a true increase in cases.

d. Susceptibility: Smoking & air quality

As stated in Chapter 2, tuberculosis often manifests as a pulmonary disease. Its effects are exacerbated by additional damage to the lungs from smoking and poor air quality (Gandy & Zumla 2003; Murray 2009). Tobacco smoking has been linked to immune system suppression as well as increased susceptibility to contracting and dying from tuberculosis infection (Arcavi & Benowitz 2004). Poor air quality and ventilation can result in similar effects, increasing exposure and complications from infection, particularly related to second-hand smoke (Arcavi & Benowitz 2004; Gandy & Zumla 2003). Although researchers and public health advocates agree that smoking and air quality are important factors in susceptibility to pulmonary tuberculosis, data from the European WHO office has only a handful of years for Estonia and Lithuania, while there are no data at all for Latvia (WHO/Europe 2010). Independent studies have addressed this important issue in the Baltics and found that in 1997 over 50% of males in all three countries were regular smokers, with fewer women smokers at roughly 24% in Estonia, 11% in Latvia, and 8% in Lithuania (Pudule et al. 1999). Unfortunately, there are no comparable figures available for other years. Thus, despite the importance for including smoking in a study on tuberculosis, it cannot currently be included.

e. Susceptibility: Malnutrition, poverty, alcohol use

Low income and poverty often show a positive correlation with malnutrition; this is because low income decreases food supplies and access to healthcare (Peña & Bacallao 2002). Malnutrition weakens the immune system and leaves an individual

susceptible to contracting and dying from infectious diseases (Macallan 2009). Malnutrition also correlates with alcohol abuse, where decreased self-awareness from alcohol use results in a lack of self-care (MacGregor 1986). In addition, alcohol abuse serves a more direct role in susceptibility, suppressing immune response and causing an individual to participate in risky behavior that may enhance exposure (Roselle 1992).

Higher poverty, malnutrition, and alcohol use all correlate strongly with an increase in tuberculosis cases (Dye et al. 2009; Lonnroth et al. 2009). Unfortunately, consistent data are not available to measure these factors. While the World Bank measures income levels and gaps, only a handful of data are available for Latvia, Lithuania, and Estonia in the past two decades. What little is available shows a high poverty level in 1988 before splitting from the Soviet Union, followed by a decrease in poverty in the early 1990s where it stays steady throughout the next decade (see Appendix Table B.11). Malnutrition data are only available for anthropometric measures of children under five years old (World Bank 2009). The World Health Organization (WHO) does not make income or malnutrition data available to the public, and neither the WHO nor the World Bank provides consistent alcohol abuse data for all three countries.

The WHO Regional Office for Europe provides a brief summary of alcohol consumption in several segments of the European population from 1990 to 2006 (WHO/Europe 2011). The region containing the Baltic states varies dramatically in average alcohol consumption throughout the 1990s, followed by a slow and steady

increase in consumption in the early 2000s (see Appendix Figure B.1). The lack of a consistent pattern in alcohol consumption, and the inclusion of the Baltic republics with six other countries suggest that alcohol cannot be a reliable measure for the purposes of this study in addition to the lack of malnutrition and poverty data.

f. Transmission: Mobility

The World Bank provides multiple measures of mobility, including number of motor, passenger, or total vehicles per 1000 people, rail lines in kilometers, and percent of roads that are paved. These indicators are chosen to reflect the average amount of mobility of the country's citizens. Unfortunately, most of these data from The World Bank are only available from 2002 to the present, which is not a sufficient time frame for the scope of this study. The only measure available is the total kilometers of rail lines available for train service, which surprisingly shows a decrease in all three countries between 1989 and 2007 (see Table 4.3; only every other year shown).

Table 4.3: In-service rail lines per km, 1989 – 2007

Year	Estonia	Latvia	Lithuania
1989	1026	2397	2005
1991	1026	2397	2007
1993	1024	2413	2002
1995	1021	2413	2002
1997	1000	2417	1998
1999	968	2417	1905
2001	967	2305	1282
2003	959	2270	1774
2005	959	2375	1775
2007	962	2269	1766

Rail lines, however, are not a good indicator of mobility because there are many other transportation options. The decrease in rail lines is likely due to either national cost cutting measures or an increase in vehicle use; however the data are not available for all three countries to ensure that this is the case. The Statistical Office of Estonia offers the number of registered passenger vehicles per year, which shows a significant increase from 177,000 cars in 1985 to 546,000 cars in 2009 and supports the idea of increased personal transportation (see Appendix Table B.12). However similar data are not available for Latvia and Lithuania. Therefore average mobility for all three countries cannot be adequately measured for this study.

g. Transmission: Urbanization

Crowding and urbanization can be measured in several ways; the simplest measures are density of population per square kilometer or average number of persons per room in a housing unit. Given the mode of transmission for tuberculosis, average population density in each country is not sufficient; instead more exact spatial detail would be necessary at the community and household level. Unfortunately community-level population density data are not available, and the number of persons per housing unit has very limited data published by the World Health Organization's European Regional Office. Because these measures are not available, instead I will determine the amount of crowding based on the percentage of the total population living in urban areas. This information is available from The World Bank, and was calculated from

World Bank population numbers and urban ratios from the United Nations World Urbanization Prospects using the definition of urban areas from national statistical offices.

There were almost no changes in urbanization in terms of percent of the population living in urban areas for any of the countries. Estonia declined slightly from 71% in 1989 to 69% in 2009, while Latvia changed from 69% to 68% in the same time period, and Lithuania stayed steady at 67% over the twenty year span (see Appendix Table B.13). While these percentages are only in ratio, the same data source publishes total urban population numbers, which show a decline in urbanites in all three countries throughout the 1990s and 2000s (see Appendix Table B.14). Because there is a decrease in urbanization over time, a cautious conclusion would be these numbers suffice to show that there was *not* an increase in crowding. Because greater crowding increases the likelihood of tuberculosis spread (Gandy & Zumla 2003), but they do not change much in the Baltic over the study time period, urbanization and crowding are dismissed as significant factors for the purposes of this paper.

III. Incidence and Mortality Rates

Moving on to incidence and mortality, I will first discuss general death rates for the Baltic before exploring tuberculosis incidence in particular. I find that not only are tuberculosis incidence and mortality important, but so is the ratio to overall infectious disease mortality. This will give a better idea of the scope to which tuberculosis is a

burden at different times. Tuberculosis death rates will be put in context of overall death rates in order to interpret TB's relative impact on each country. As previously stated, 1989 is the start year for this study because it marks the most tumultuous point in recent Baltic history, and is one year prior to the republic's independence from the USSR. To dispel any concerns that an earlier date should be set for comparison to Soviet mortality prior to resistance, as previously mentioned: in the USSR, information on cause of death was not published, and it was only in 1989 and after that mortality data by cause of death became available to the public (Krumins & Zvidrins 1992). Therefore while conclusions made from these incidence and mortality rates could be stronger if compared to a previous time period, the data are not reliable prior to 1989 because they were not publicly available, and therefore unable to be independently verified.

a. Mortality: Standardized death rates

Standardized death rates (SDR) were obtained from the European Health for All Database (HFA-DB), supported by the World Health Organization Regional Office for Europe. According to the HFA-DB, the SDR is standardized using the direct method to a standard European population. The standardized death rates are shown in Figure 4.3. Present SDR estimates are only published through 2008, so this will serve as "present day".

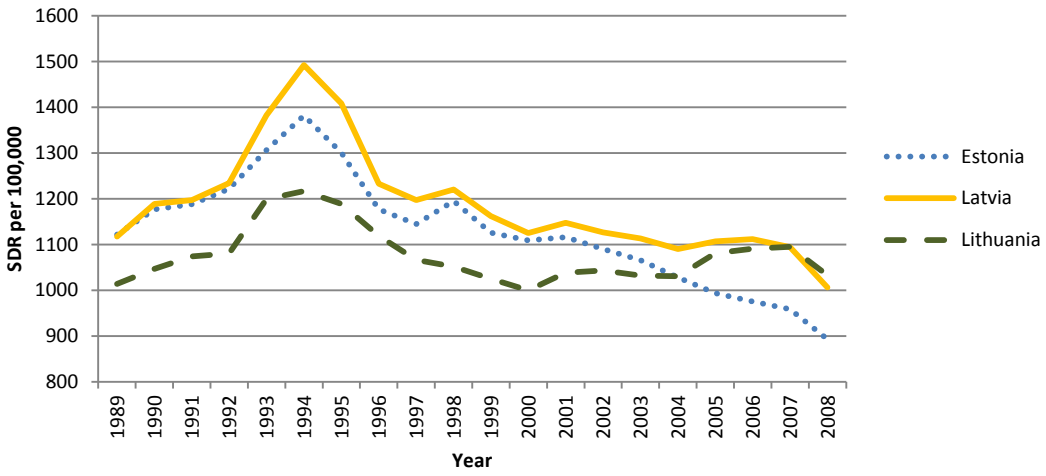

Figure 4.3: Standardized Death Rates, 1989 - 2008

The Baltic republics' SDR peaks in 1994, and declines throughout the rest of the 1990s and 2000s. All three countries initially follow the same trends, but Latvia's SDR far exceeds Estonia's in 1994, reaching almost 1500 per 100,000 individuals. Lithuania is lowest of all three countries until 2004, when it and Latvia increase. Interestingly, Estonia's SDR decreases below both countries for the first time in this study's time frame. While all three decline after 2007, a trend in reducing mortality cannot be assumed until data for 2009 and 2010 are available. The increase in Baltic death rates after 1992 coincides with the brunt of their political and economic struggles in official independence. If death rates alone are indicators of national stability, it appears that the Baltic achieved this position in the late 1990s, and maintained this position through 2004 to their acceptance into the European Union.

b. Mortality: Tuberculosis

Having considered overall death rates, I will now look at standardized tuberculosis death rates. While the proportionate mortality ratio for TB would show the

degree to which TB influences overall mortality, and the cause-specific death rate would identify the risk of TB to the whole population, these cannot yet be calculated. Crude death rates are available from The World Bank, but both calculations also require the total number of deaths from tuberculosis. Unfortunately these counts have not yet been located, and currently only the standardized death rate from tuberculosis is available from the HFA-DB. Figure 4.4 shows the TB SDR in all three countries from 1989 to 2008 (also see Appendix Table B.15).

These rates show more variation than the total SDR, reflecting the importance of considering each country's disease determinants and policy efforts that may influence tuberculosis. Despite occasional dips and rises in each country, all three show a rise in deaths from tuberculosis in the early 1990s, and a decline after 1998. Estonia is lowest overall with less than 4 deaths per 100,000 population in 2008, while Lithuania climbs to 10 per 100,000 in 2004. Latvia's TB SDR rises most dramatically from less than 7 per 100,000 in 1991 to over 14 per 100,000 in 1995, but also declines to less than 5 per 100,000 in 2008. These figures coincide with global trends. In 1993, the World Health Organization declared TB a global public health emergency, and in 1998 the Stop TB initiative was formed to implement a directly-observed treatment strategy worldwide (Blanc and Ulepkar 2003:96). This is reflected in the Baltic by the rise in TB deaths in the early 1990s, and decline in deaths in the late 1990s and throughout the 2000s. The Stop TB efforts may be at least a partial cause of this decline.

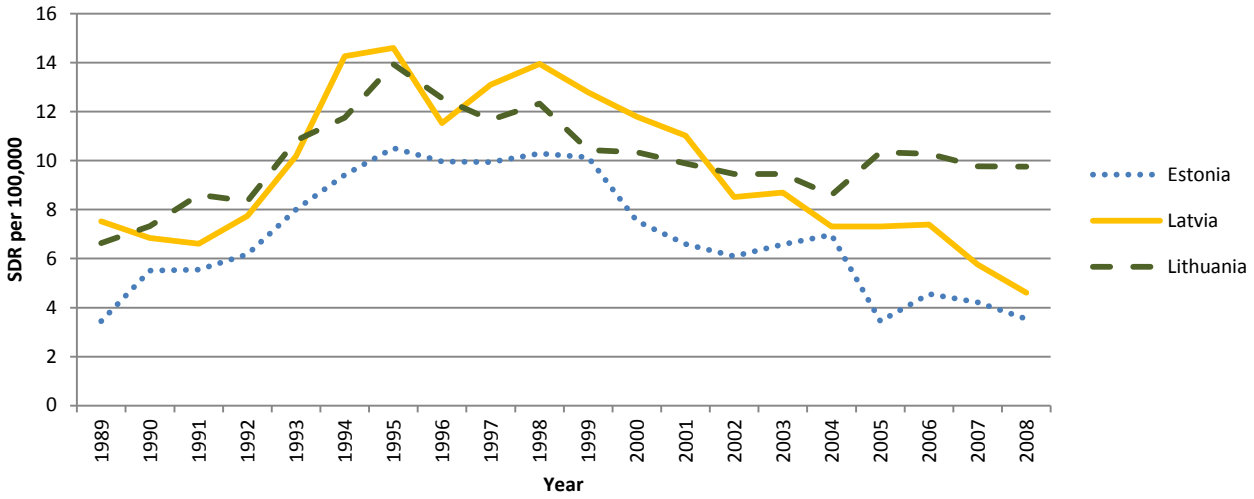

Figure 4.4: Standardized Death Rates from Tuberculosis, 1989 - 2008

Tuberculosis mortality is essential to assess the relevance of treatment strategies. However, death rates do not necessarily reflect a change in incidence, as incidence reflects the number of new cases diagnosed per year. To determine whether incidence of tuberculosis is on the rise as well, these data were obtained from the HFA-DB. Because of the previously mentioned global link between HIV and TB, data for HIV incidence was taken from the same database to visualize whether HIV and TB are similarly linked in the Baltic. If there is a causative relationship, a rise in HIV incidence would cause an echo rise in TB incidence; Figure 4.5 shows that this is not the case in the Baltic. HIV does not appear in the Baltic States until the late 1990s, when TB incidence is already declining. Despite the sudden rise in HIV, particularly in Estonia, there is no subsequent rise in tuberculosis. There may be a slight echo effect in Lithuania, where a sharp increase of HIV in 2002 is followed by a sharp increase of TB in

2003; however TB increases again in the late 2000s without a rise in HIV.

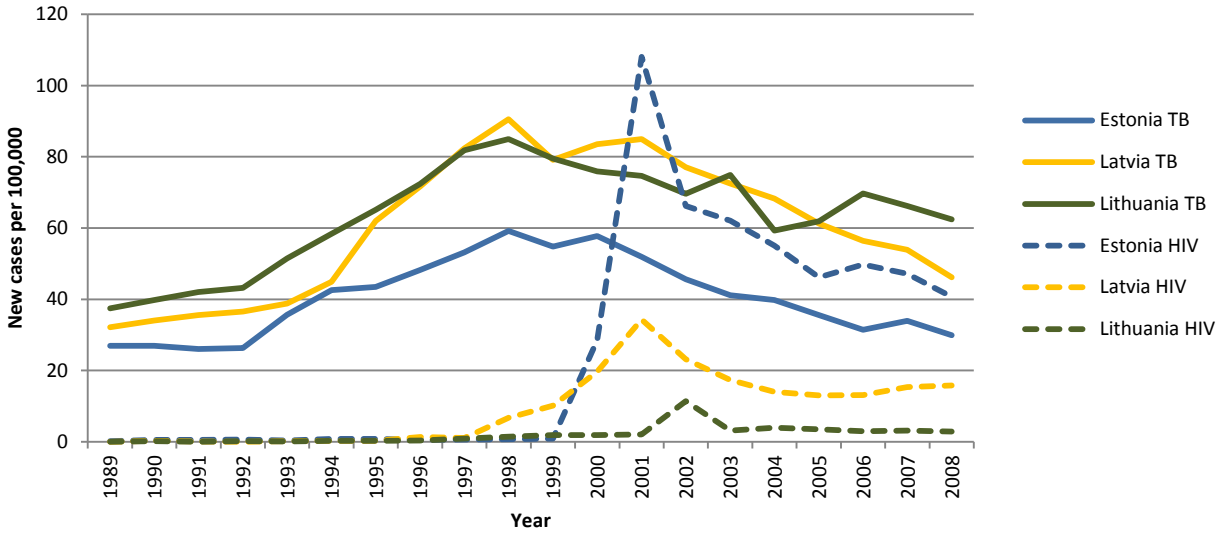

Figure 4.5: Incidence of Tuberculosis and HIV, 1989 - 2008

c. Incidence: Tuberculosis and HIV

Comparing the incidence rates of tuberculosis to the mortality rates, the mortality is rather low. In 1998, at the peak incidence rates in all three countries (Estonia at 59.16 per 100,000 population, Latvia at 90.54, Lithuania at 84.97), the mortality is less than 20% of cases in all three countries. This is lower than the approximate 50% probability of death from untreated tuberculosis; however, this does not mean that treatment is widespread. Infected individuals may go many years without treatment before dying, so it is better to compare the peak incidence rates in 1998 with the peak in mortality rates. Strangely, peak mortality occurs in 1995, before widespread incidence. Comparing 1995 incidence and mortality rates, over 20% of cases result in death, but the highest percentage is in Estonia, which is still under 25%. Having

compared this difference, it is now safe to conclude that at any given time at least some treatment was available in the Baltic republics.

IV. Discussion

Collecting activities and behavior that affect tuberculosis rates is not without its limitations. Ideally, data on transmission, susceptibility, and treatability would paint a fuller picture than the one presented above. However, there is a severe lack of quantitative substance for mobility, crowding, poverty, air quality, and treatment. Therefore tuberculosis incidence and mortality must be analyzed with only the material available. Where necessary I assessed the correlation between the above data using Pearson's correlation coefficient, where *r* signifies the linear relationship between two variables. The sample correlation coefficient *r* is given as a number between 1 and -1; these correlations were then tested via Student's t-test to determine their significance. I now return to the hypotheses presented at the beginning of this chapter.

a. Hypothesis 1

The first hypothesis proposed that tuberculosis incidence rates will be greatest in all three Baltic republics during the first few years after their split from the Soviet Union in 1990. This idea was based on the presumption that greater political and economic tumult associated with independence and rebuilding a country weakens healthcare and sanitation, increasing communicable disease trends (Freudenberg et al. 2006; Suhrcke et al. 2011). Given that the Baltic countries were at their weakest in this respect between

1990 and the early 2000s (as shown in Chapter 2), I assumed that this would be reflected by a rise in both tuberculosis incidence and TB-related deaths during this time. As shown in section III of this chapter, this hypothesis is only partially supported by the available data.

Peak incidence of tuberculosis occurred in 1998 in all three Baltic countries, whereupon incidence declined through the 2000s, except in Lithuania where a rebound of incidence rates occurred in the mid-2000s. The peak in deaths from tuberculosis occurred in the mid-1990s for all three countries (see Figure 4.4). Latvia reached its peak in SDR from tuberculosis in 1994 with 14.27 deaths per 100,000 population. The other two countries peaked in 1995, where Estonia had 10.51 TB-related deaths per 100,000 and Lithuania had 13.94 per 100,000. Deaths from tuberculosis remained high in Estonia and Latvia until 1999-2000, then began to decline. Lithuania differed in a slowing SDR in the early 2000s, but deaths from TB did not decline to the drastic degree seen in the other two countries. In addition, the peak time where the percentage of deaths from tuberculosis composed the greatest amount of total deaths from infectious diseases varied somewhat. The highest point for Estonia and Lithuania was in 1996 with TB composing 82.26% and 81.65% of infectious deaths, respectively. Tuberculosis deaths in Latvia composed the greatest percentage in 2000 with 76.86%.

Incidence rates were not highest in the early 1990s, as expected. However, deaths from tuberculosis were high in 1994 and 1995, which may support the premise of social and industrial upheaval affecting mortality from infectious diseases, rather than

transmission. Indeed, the mid-1990s saw the greatest period of political and economic upheaval in the Baltic republics (Kirk & Silfverberg 2006).

b. Hypothesis 2

The second hypothesis suggested that tuberculosis rates will fall as the Baltic economies strengthened. A marker of their strength was determined through the achievement of international milestones explained in Chapter 2, where Estonia's realization of independent strength was 2002, Latvia's was 2004, and Lithuania's was 2003 (see Table 2.1). Using these dates as a representation of each republic's increasing development, tuberculosis rates should already be declining by this point. Indeed, the data show this to be the case. Deaths from tuberculosis began to decline in the mid-1990s (Figure 4.4) and new cases of tuberculosis began to decline in the late-1990s to early-2000s (Figure 4.5). The exception is Lithuania, where incidence rates spiked in 2003 and again in 2006, and mortality rose in 2005. While their milestone years did not have either the lowest rates of deaths or number of new cases in any of the Baltic countries (the lowest recorded were in the early 1990s), it does represent the expected downward trend. Therefore, this hypothesis is supported by the data for Estonia and Latvia, but not Lithuania.

c. Hypothesis 3

The third hypothesis stated that there will be the fewest differences in development and disease trends between Latvia and Estonia due to their joint history and population configuration, while Lithuania will differ most. The similarities in

population changes and crude death rates foreshadow that other similarities will follow. Transmission behavior and treatability appear to be similar in trends for all three republics. HIV incidence is unusually high in Estonia compared to the other two, while Latvia's HIV rate increases after 2005 although the others decline. Overall death rates are similar in all three countries. Initial trends in tuberculosis mortality are similar in Lithuania and Latvia, while Estonia differs most. After 2002 tuberculosis SDR decreases in Latvia and Estonia while Lithuania increases, therefore differing most in overall trend. Tuberculosis incidence is lowest overall in Estonia, as it was with mortality. However, the trends are similar between Latvia and Estonia, both decreasing in 1999, then increasing again soon after. Lithuania varies greatly in incidence and forms no clear pattern.

There are few differences in trends for movement and infrastructure between the three countries. There are many differences in disease trends; Estonia and Latvia differ in HIV and TB rates but their trend lines follow the same pattern. Lithuania is most divergent in this respect. Therefore this hypothesis is partially correct, but only in terms of HIV and tuberculosis. This perhaps shows that despite shared histories and social composition, all three Baltic States diverge from each other in most traits after their independence from the Soviet Union. As shown in Chapter 3, the Baltic region's industrial and economic purposes in the greater Union were often lumped together by the Soviet government. Upon obtaining liberty from the USSR, each country followed its own trajectory and reclaimed its pre-Soviet roots, independent from its neighbors. It is through their individual government and social movements post-1990 that each Baltic

country diverged onto their own course, which is reflected in their different disease and healthcare trends.

d. Hypothesis 4

The fourth hypothesis suggested that changes in treatment factors will be very important to changes in tuberculosis rates. Treatment is the key to preventing death in those already infected as well as preventing new cases from occurring (Dye & Williams 2010). Using Pearson's correlation coefficient and a test for significance, both mortality and incidence rates showed that this hypothesis is unsupported for most of the parameters discussed. When analyzing SDR-TB with treatability factors, a significant (over 99%) correlation was shown with the number of pharmacists for all three countries, despite the limited data. The number of pharmacists in Lithuania is available after 1993, and in Latvia it was only available after 2003. However, only two years (1993 and 1994) are missing data for Estonia, thus the significance of the correlation ($p \leq 0.01$) between SDR-TB and the number of pharmacists per 100,000 people may be an accurate reflection showing that an increase in pharmacists corresponds with a decrease in deaths from tuberculosis.

There was no correlation between SDR-TB and the number of hospitals, hospital beds, or the number of primary healthcare units in Estonia and Lithuania. When SDR-TB data were compared to the number of physicians per 100,000 population, some significance was seen. In Latvia it was significant at the 0.025 level with a t-score of –2.449, meaning that as the number of physicians increase, deaths from tuberculosis

decreased. However in Lithuania t = 3.10 and was significant at the 0.005 level, meaning that as the number of physicians increased, so did deaths from tuberculosis. This may be due to its delay in implementing the WHO's DOTS program of treatment (WHO 2004). Because of this, increasing numbers of physicians alone would not decrease tuberculosis deaths due to less effective treatment practices.

All correlations between treatability factors and mortality rates from tuberculosis failed to reach statistical significance. The only exception was in Latvia, where the correlation between deaths rate and the number of hospitals was significant at the 0.025 level, and with the number of primary care health units at the 0.01 level. Thus the hypothesis that treatability factors influence tuberculosis trends is not supported for TB standardized death rates in Estonia and Lithuania, but is partially supported in Latvia.

Comparing treatment data with incidence rates results in a stronger correlation than was seen with mortality rates. Density of pharmacists in the population shows an insignificant correlation with incidence rates in Estonia and Lithuania, but a highly significant relationship in Latvia (where $t = -5.46$, $p \leq 0.005$). However, as mentioned above, the data were limited in scope and this correlation is only accurate between 2003 and 2008. Therefore the number of pharmacists will be disregarded as a possible causative agent for tuberculosis transmission in the 1990s and early 2000s. There was also no significant correlation between tuberculosis incidence and the number of

primary health care units per 100,000 people, although the correlation between these variables for Lithuania approached significance at the 0.1 level.

Other measures of treatment fare better when compared with incidence rates. Number of hospitals per 100,000 people is significant only in Lithuania ($t = -4.04$, $p \leq 0.005$), where transmission increases with a decrease in hospital availability. The number of hospital beds per 100,000 is significant in Latvia and Lithuania at the 0.005 level, but only approaches significance in Estonia ($t = -1.68$, $p \leq 0.1$). This shows that as the number of hospital beds (a proxy for capacity of treatment) decrease, as they do steadily after 1991, tuberculosis incidence increases significantly in two of the three Baltic republics. Yet after tuberculosis incidence slows, the number of hospital beds continues its decline.

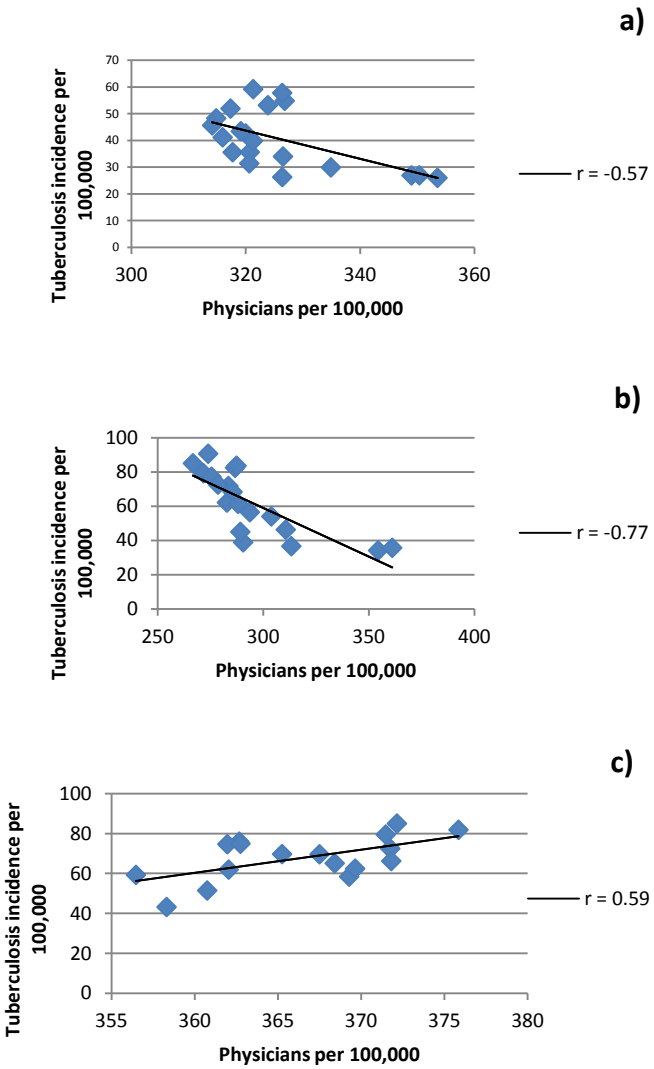

Figure 4.6: Correlation between Physicians and Tuberculosis Incidence
a) Estonia, $p \leq 0.005$, b) Latvia, $p \leq 0.005$, c) Lithuania $p \leq 0.025$

The most striking correlation with incidence rates is the number of physicians per 100,000 people (see Figure 4.6). When the correlations were tested, Estonia was significant at the 0.005 level (where t = -2.94), which means that as the number of physicians decrease the number of new cases of tuberculosis increases. In Latvia significance was shown far above the 0.005 level (where t= -5.12), which shows an even

stronger correlation between physician availability and transmission. Strangely, Lithuania also showed a significant correlation at the 0.025 level, but as a positive correlation between the two sets of data (where t = 2.45). This means that as the number of physicians increase, the incidence of tuberculosis increases as well. This is particularly true after 2004, when Lithuania's national integration of the DOTS program was intensified (WHO 2009a). For incidence rates, it is possible that this correlation reflects an increase in better trained, WHO-informed physicians who effectively increased diagnostics. This reveals one drawback in using the number of physicians as a proxy for treatment; it may truly be reflecting difference in diagnoses.

e. Hypothesis 5

The final hypothesis surmised that HIV co-infection will be most closely correlated with tuberculosis. As explained in Chapter 3, the global re-emergence of tuberculosis has been attributed to the rise of HIV incidence (Small et al. 1992; Castro 1995; Chaisson & Martinson 2008; Getahun et al. 2009). Therefore it was expected that there would be a positive correlation between HIV incidence and tuberculosis rates. This was tested using a correlation coefficient and t-test with both incidence and mortality rates, and the results were surprising. When compared with standardized death rates from tuberculosis, HIV incidence had no significant correlation in Latvia or Lithuania. There was a moderate correlation in Estonia ($t = -1.96$, $p \leq 0.025$), however this is surprising because this shows a negative correlation where deaths from tuberculosis decrease as HIV incidence increases. This is opposite from the expected, globally

supported trend. The correlation between SDR-TB and HIV incidence in Estonia is too weak to be significant, and therefore it is not a strong indicator for an opposing argument.

Concerning incidence of tuberculosis, there was only a minor correlation with HIV rates in the Baltic. Estonia with its high HIV incidence showed no correlation with tuberculosis incidence. Lithuania approached significance with moderately positive correlation between tuberculosis incidence and HIV ($t = 1.38$, $p \leq 0.1$). Latvia's data indicated a significant correlation ($t = 2.794$, $p \leq 0.01$) in these variables. This shows that tuberculosis incidence may have increased slightly due to HIV in Latvia, but Lithuania and particularly Estonia differ greatly from the global trend. Therefore tuberculosis rates in the Baltic were exacerbated by HIV incidence to a small degree, but the epidemic in this region overall was the result of factors other than HIV.

f. Synthesis of results

The results obtained in this study were surprising, particularly in terms of the proposed hypotheses. The overall tenet of this thesis is supported: economic and political upheaval resulted in higher infectious disease rates in the Baltic, as expected. Where it differs is the specific types of rates. Initially it was assumed that transmission would increase because susceptibility and treatment factors (key to heightening or dampening transmission) would be disrupted during the Baltic's economic emergence. However it was tuberculosis mortality that increased instead, as shown in examining Hypothesis 1. As the Baltic republics strengthened, both mortality and incidence rates

dropped, supporting Hypothesis 2 for Estonia and Latvia. In Lithuania SDR-TB declined throughout the late-1990s and early 2000s but rose again after 2004. Two questions emerge from this: 1) why these rates diverged in the mid-1990s, but coalesced in their decline in the early 2000s and 2) why Lithuania's SDR differs in its rebound of tuberculosis deaths in the mid-2000s.

Hypotheses 3, 4, and 5 should help to answer these questions. The third hypothesis (which suggested that Lithuania's data trends would diverge most from Latvia's and Estonia's) is not supported. Lithuania diverged in its tuberculosis mortality and incidence rates, but all three varied in HIV rates and in all the other factors discussed. Thus Lithuania's differing history and demographic composition will be disregarded as an explanatory mechanism for the rebound of tuberculosis in the mid-2000s. Hypothesis 5 was only supported in Latvia, thus changes in HIV rates cannot definitively answer these questions for the entire Baltic region either.

Hypothesis 4 discussed treatment factors, significant for both mortality and transmission. The only parameter that yielded a significant correlation for all three countries was the number of physicians. There was a significant negative correlation with the tuberculosis-related SDR in Estonia and Latvia, where the increasing number of physicians corresponded with the decrease in tuberculosis mortality. In Lithuania, there was a significantly positive correlation between the increase of physicians and the increase in mortality. Incidence rates also yielded a significant negative correlation with the number of physicians in Estonia and Latvia. As the number of physicians decrease,

incidence of tuberculosis increases in both countries. Between 2000 and 2002 the number of physicians increases in Estonia and tuberculosis incidence decreases; in Latvia this occurs after 2001. In Lithuania there is a strong correlation between the rise in physicians and the increase in incidence, particularly after 2004. Therefore change in physician availability is the most significant factor affecting the transmission of tuberculosis in the Baltic republics. Possible reasons for this will be discussed in the next chapter.

CHAPTER 5 – CONCLUSION

Undertaking this project has yielded several important considerations for the future of tuberculosis in humans; but before I explore these predictions, I will first revisit the inferences from the previous chapter. The most noticeable results from this enterprise are the importance of physician availability and the lack of impact HIV had on tuberculosis rates in the Baltic region. The number of physicians available was the only data-available element shown to significantly affect tuberculosis rates in Estonia, Latvia, *and* Lithuania.

In Estonia and Latvia, the number of physicians decreased throughout the 1990s as tuberculosis incidence soared. In both countries, but Latvia in particular, the number of physicians increased during the late 1990s and the 2000s as tuberculosis incidence slowed. Lithuania had the opposite effect, showing a significantly positive correlation where the number of physicians and new tuberculosis cases rose and fell together. Linear correlation does not necessarily mean that physicians influence tuberculosis rates in any of these countries; however they have been shown to be strongly linked entities (Daniel 2006; Dye et al. 2008).

There are several possible reasons that Lithuanian physicians could differ from those in Estonia and Latvia: one is that they lack the resources to effectively diagnose or treat the disease, another is that the methodology differs between doctors within the region. Looking at the available data, the former position is not likely to be the case. If

physicians lacked the ability to diagnose tuberculosis, then new cases would probably decrease or remain stable rather than increase. As for the inability to treat the infection, availability of antibiotics and pharmacists are crucial for treatment, yet there is no correlation between the number of pharmacists and new cases. There is a significant ($p \leq 0.01$) correlation between pharmacists and deaths from tuberculosis; however, this is true in Estonia and Latvia as well.

Therefore if deaths are prevented in Lithuania, but not new cases, it may be from ineffective practices by the doctors or pharmacists. Lithuania adopted the WHO-sanctioned DOTS method of tuberculosis treatment in the 1990s, but the country was slow to implement it. By 2001 the country had only 51% of clinics and hospitals using the DOTS method. In contrast, Estonia and Latvia had 100% coverage of this method (WHO 2004). As explained in Chapter 3, DOTS emphasizes out-patient care and relies on primary care physicians to effectively treat current cases and limit the number of infectious individuals. Therefore the primary difference in tuberculosis rates between Lithuania and the other two Baltic republics is not only the doctors, but how the doctors are trained and implement their practice.

The relationship between HIV and tuberculosis is another significant result from this study - significant because of the lack of a linear correlation between the two. The global re-emergence of tuberculosis is unequivocally linked to the spread of HIV and the subsequent onset of AIDS, even in close neighbors to the Baltic (Drobniewski et al. 2004; Hamers & Downs 2003), yet this is not the case in 1990s-era Baltic republics. AIDS does

not appear in the Baltic as a significant cause of mortality, although HIV was significantly correlated with tuberculosis incidence in Latvia. HIV also did not play a significant role in tuberculosis-related deaths in Latvia or Lithuania, but did somewhat affect Estonia's SDR. HIV is highly co-morbid with tuberculosis, yet it doesn't seem to aid the transmission of tuberculosis. With the transmission of HIV recently reduced in the Baltic, the new threat for tuberculosis-related incidence and mortality in the region is drug-resistant strains of tuberculosis.

The Future of Tuberculosis

Numerous studies have substantiated the threat of MDR and XDR-TB strains, particularly at the turn of the century (Kruuner 2001; Tracevska et al. 2002; Tracevska et al. 2003). MDR-TB has been on the rise since the late-1990s, and controlling this recent trend has proven difficult (Leimane 2007). Among the exceptions to this trend in the former Soviet Union are the Baltic States, where political and public health commitments are stabilizing the drug-resistant trend (Fears et al. 2010). Latvia, for example, successfully implemented WHO's DOTS program in 1997 and by 2003 had MDR-TB cure rates between 66 – 73%, with an 85% cure rate for newly diagnosed cases (Leimane & Leimans 2006). While this outlook seems positive for MDR-TB, increasing XDR-TB strains in the European Union sustain the threat for a drug-resistant epidemic throughout the continent (Wright et al. 2009). XDR-TB has been on the rise globally, with some of the highest prevalence rates of resistance reported in former Soviet countries, both for HIV and non-HIV cases (Schmidt 2008). This recent rise in extensively

drug-resistant strains stems from the lack of intensive multi-year therapy for patients and direct-observation of treatment, particularly in areas where DOTS is not fully implemented (Moonan et al. 2011). WHO's DOTS program has proven effective for treating MDR-TB (DeRiemer et al. 2005), but this is not always the case for XDR-TB (Alves de Araujo-Filho et al. 2008).

While some argue that the intensification of DOTS programs and the creation of new drugs is the answer to preventing a drug-resistant pandemic (Blondal 2007; Raviglione & Smith 2007; Basu et al. 2009), others endorse behavioral changes and multi-tiered research to combat the issue (Farmer 2001; Jassal & Bishai 2009; Lonnroth et al. 2009). The research presented in this thesis suggests that intensified focus on behavioral risk factors may be more beneficial to the control of drug-resistant tuberculosis. In my findings, the diagnostic power and care-giving of local doctors influenced overall tuberculosis incidence in the Baltic region. However this was only supported through the lack of other options; the data for social and behavioral risk factors was not substantial enough to be tested. Modern tuberculosis researchers extol the importance of social determinants for studying disease trends (Dye et al. 2008; Lonnroth et al. 2009; Dye & Williams 2010), yet the data are not readily available.

The case may be made that data for the purposes of this project were not available because the Baltic States had only recently gained independence from a nation that carefully guarded its information (Vlassov 2000). Implementing proper collection and recording is likely not a priority for a country with little self-sustaining infrastructure

or production value. Yet the emerging status of a new economy alone is a risk factor for high overall mortality and disease transmission (Field 2000; Falagas et al. 2009; Suhrcke et al. 2011). Thus, proper data collection during an economy's transition is an important preventive measure for infectious disease control. An ideal dataset to determine susceptibility would include the frequency of tobacco smoking, the frequency of alcohol consumption, income levels and gaps, types of and access to healthcare, and the prevalence of all co-morbid diseases (including HIV and diabetes) at both the community and national level. Additional data to determine transmission should include occupation, physical environment for each occupation, household size, cluster size of buildings within communities, the degree and type of movement within the community, as well as movement between communities and across borders. With statistics on the region's behavioral aspects such as smoking, alcohol use, occupation, social behavior, and living situations, a new disease threat may be more quickly tackled than it was in the Baltic region. Because the behavioral and lifestyle data were not available for rapid preventive health actions in the Baltic, Lithuania sustained greater mortality from tuberculosis, Estonia observed one of the greatest HIV loads in Europe, and Latvia endured a large burden of multi-drug resistant tuberculosis strains. Of particular concern is the tendency of problems within developing countries to extend to developed countries (Romaniuk & Crawford 2011). Thus if tuberculosis is allowed to re-emerge in a Second or Third World country, modern transportation and international relations allow its spread to First World countries as well.

Behavioral trends are also important considerations for drug resistance, as both antibiotics and human conduct towards medication influences the evolution of new tuberculosis strains. New drug-resistant strains of tuberculosis have been shown to be less transmissible, but more virulent than drug-susceptible strains (Dye & Espinal 2001). However, this is not necessarily true for all drug-resistant strains of tuberculosis. Research has found that the evolution of an infectious bacterium depends on local treatment success, relative transmissibility, the rate of emergence from latency, and host life expectancy (Basu & Galvani 2009). Any of these factors can affect the strain's level of virulence. Therefore research on population-level behavior would enlighten possible selective pressures on tuberculosis, in addition to antibiotic misuse. Antibiotics are undoubtedly the cause of drug-resistant strains, but their transmissibility and virulence should be further explored in the greater social context. In addition, ethnographic methods and behavioral research would reveal community-specific barriers to adopting the DOTS program of treatment. Rather than increasing funding for international health development programs to implement the globally-focused DOTS, a small-scale approach may be more effective for treating both drug-resistance and drug-susceptible tuberculosis cases. Using DOTS as the backbone for many of these programs, a community-specific tailored strategy could fill the gaps left from achieving the WHO's tuberculosis goals.

Using the Baltic republics as a case-study for investigating tuberculosis trends in newly emerging countries, I showed that healthcare and treatment factors cannot be divorced from the greater context of the country's development. Despite this, using

research-sanctioned methods for a parsimonious approach, a basic understanding of the importance of specific individuals (i.e. physicians) versus institutions (i.e. hospitals) was revealed in this one specific context. In addition, the impacts of the World Health Organization's programs were shown effective for disease control, albeit complicated by other issues such as drug-resistant bacteria. Given the region-specific focus of this thesis, broader research with additional published data would improve upon the analysis of tuberculosis' impacts in not only the Baltic republics, but in other recently emerging countries as well.

APPENDIX A

Table A.1: Gross national income, US$ per capita

Years	Estonia	Latvia	Lithuania
1989	3270	2860	...
1990	3190	2790	...
1991	3060	2540	...
1992	2590	1840	2320
1993	2590	1810	2020
1994	2690	1950	1900
1995	3020	2050	2100
1996	3320	2260	2290
1997	3590	2510	2590
1998	3820	2650	2850
1999	3880	2840	2980
2000	4220	3220	3200
2001	4430	3550	3420
2002	4780	3840	...
2003	5820	4440	4600
2004	7620	5460	5870
2005	9840	6810	...
2006	11500	8120	...
2007	13210	10090	9980
2008	14410	11940	11890
2009	14060	12390	11410

Source: WHO/Europe: European Health for All Database, data.euro.who.int

Table A.2: Gross domestic product, US$ per capita

Years	Estonia	Latvia	Lithuania
1989	3268.15	2865.24	...
1990	3192.96	2788.41	2841.18
1991	3064.8	2538.1	2777.27
1992	2600.53	1841.97	2314.14
1993	2583.44	1727.76	2015.91
1994	2710.14	1986.21	1902.31
1995	3029.26	2081.8	2176.46
1996	3339.47	2242.19	2337.48
1997	3608.36	2503.36	2829.25
1998	4038.5	2745.63	3165.7
1999	4147.48	3049.59	3107.16
2000	4144.38	3302.31	3267.36
2001	4574.51	3523.97	3492.73
2002	5391.03	3984.08	4082.9
2003	7273.89	4810.67	5387.21
2004	8918.7	5950.2	6564.11
2005	10328.6	6973.2	7603.98
2006	12359	8713.07	8864.99
2007	15938.3	12638.2	11584.2
2008	17541.3	14937.1	14034.3
2009	14238.1	11615.9	11141

Source: WHO/Europe: European Health for All Database, data.euro.who.int

Table A.3: UNDP Human Development Index (HDI)

Years	Estonia	Latvia	Lithuania
1989	...	...	...
1990	...	0.679	0.709
1991	...	...	...
1992	...	...	...
1993	...	...	...
1994	...	...	...
1995	0.7	0.652	0.677
1996	...	...	...
1997	...	...	...
1998	...	...	...
1999	...	...	...
2000	0.762	0.709	0.73
2001	0.772	0.722	0.741
2002	0.781	0.733	0.751
2003	0.787	0.742	0.761
2004	0.795	0.752	0.767
2005	0.805	0.763	0.775
2006	0.811	0.771	0.78
2007	0.816	0.777	0.785
2008	0.816	0.777	0.789
2009	0.809	0.769	0.782

Source: WHO/Europe: European Health for All Database, data.euro.who.int

APPENDIX B

Table B.1: Population total and percent age distribution

	Estonia				Latvia				Lithuania			
Year	Total pop	% 0-14	%15-64	% 65+	Total pop	% 0-14	%15-64	% 65+	Total pop	% 0-14	%15-64	% 65+
1985	1529000	22.1	66.4	11.4	2621000	21.2	67	11.8	3545000	23.1	66.6	10.3
1986	1540000	22.2	66.5	11.3	2636000	21.3	67	11.7	3579000	23	66.7	10.3
1987	1552000	22.3	66.4	11.3	2652000	21.4	67	11.6	3616000	22.9	66.7	10.4
1988	1562000	22.3	66.4	11.3	2668000	21.4	67	11.6	3654000	22.8	66.7	10.5
1989	1568000	22.2	66.3	11.4	2684000	21.4	66.9	11.7	3691000	22.7	66.6	10.7
1990	1569000	22.2	66.2	11.6	2670700	21.4	66.7	11.8	3698000	22.5	66.5	10.9
1991	1561000	22	66.1	11.9	2662000	21.4	66.5	12.1	3704000	22.4	66.4	11.2
1992	1533000	21.8	66	12.2	2632000	21.3	66.3	12.4	3700000	22.3	66.3	11.4
1993	1494000	21.5	65.8	12.7	2586000	21.2	66	12.8	3683000	22.2	66.1	11.7
1994	1463000	21.1	65.8	13.1	2548000	21	65.8	13.2	3658000	22	66	12
1995	1437000	20.7	65.8	13.5	2515000	20.7	65.7	13.6	3632000	21.8	65.9	12.3
1996	1416000	20.3	65.8	13.9	2491000	20.3	65.7	14	3605000	21.5	65.8	12.7
1997	1400000	19.8	66	14.2	2450000	19.8	65.9	14.4	3580000	21.2	65.8	13
1998	1386200	19.3	66.2	14.5	2410000	19.2	66.1	14.7	3555000	20.9	65.8	13.3
1999	1375649	18.7	66.5	14.7	2390000	18.5	66.5	15	3531000	20.5	65.9	13.6
2000	1369513	18.1	66.8	15.1	2372000	17.8	66.8	15.4	3499528	20	66.1	13.9
2001	1364098	17.5	67.1	15.4	2359000	17.1	67.3	15.6	3481295	19.4	66.4	14.2
2002	1358641	16.8	67.4	15.8	2338000	16.4	67.8	15.9	3469094	18.7	66.8	14.5
2003	1353520	16.1	67.8	16.1	2325342	15.6	68.2	16.1	3454240	18.1	67.2	14.7
2004	1348999	15.6	68	16.4	2312791	15	68.6	16.4	3435585	17.4	67.6	15
2005	1346100	15.2	68.2	16.7	2300500	14.5	68.9	16.6	3414300	16.8	68	15.2
2006	1343547	15	68.2	16.8	2287948	14.1	69.1	16.8	3394082	16.2	68.3	15.5
2007	1341672	14.9	68.2	16.9	2276100	13.9	69.1	17	3375618	15.7	68.6	15.7
2008	1340675	15	68.1	17	2266094	13.8	69	17.2	3358115	15.3	68.8	16
2009	1340345	15.1	67.9	17	2255128	13.8	68.9	17.3	3339550	14.9	68.9	16.2

Source: The World Bank, data.worldbank.org

Table B.2: Crude Death Rate, per 100,000 Population

Year	Estonia	Latvia	Lithuania
1989	11.8	12.2	10.3
1990	12.5	13	10.7
1991	12.6	13.1	11
1992	13.1	13.5	11.1
1993	14.3	15.2	12.3
1994	15.2	16.3	12.5
1995	14.5	15.5	12.2
1996	13.4	13.8	11.6
1997	13.3	13.5	11.1
1998	14	14	11
1999	13.4	13.7	10.8
2000	13.4	13.6	10.5
2001	13.6	14	11.6
2002	14	13.9	11.5
2003	13.3	14.1	11.8
2004	13.2	13.8	12
2005	12.9	14.2	12.8
2006	12.9	14.5	13.2
2007	13	14.5	13.5
2008	12.4	13.7	13.1

Source: The World Bank, data.worldbank.org

Table B.3: Health expenditure per capita, in US dollars

	Estonia	Latvia	Lithuania
2003	362.4463	297.3546	351.3955
2004	457.266	366.6795	374.1341
2005	516.5061	444.9932	447.3802
2006	622.9955	610.8766	550.9775
2007	836.8069	783.7324	716.8588

Estimates from The World Bank (2009)

Table B.4: Public health expenditure as percent of total health expenditure

Years	Estonia	Latvia	Lithuania
1995	89.8	66.3	74.2
1996	88.4	57.8	70.4
1997	89.2	55.8	72.5
1998	86.3	59.2	76
1999	81	58.4	74.9
2000	77.5	54.4	69.7
2001	78.6	51.2	72.6
2002	77.1	52.1	74.9
2003	77.1	52.8	76
2004	76	54.2	67.6
2005	76.9	57.1	67.3
2006	73.7	62.4	69.5
2007	76.5	57.9	73
2008	78.7	59.6	73

Source: WHO/Europe: European Health for All Database, data.euro.who.int (2010)

Table B.5: Hospitals per 100,000 Population

Years	Estonia	Latvia	Lithuania
1989	7.72	6.97	5.21
1990	7.97	7.06	5.33
1991	7.69	7.06	5.45
1992	7.7	6.73	5.32
1993	7.7	6.48	5.21
1994	7.32	6.74	5.22
1995	5.78	6.68	5.24
1996	5.58	6.43	5.08
1997	5.64	6.41	3.86
1998	5.63	6.22	3.47
1999	5.67	6.32	3.38
2000	4.97	5.98	3.46
2001	4.91	5.94	3.45
2002	3.75	5.52	3.43
2003	3.69	5.63	3.47
2004	3.78	5.15	3.32
2005	4.01	4.74	3.31
2006	4.09	4.63	3.39
2007	4.25	4.13	3.23
2008	4.48	3.88	3.36

Source: WHO/Europe: European Health for All Database, data.euro.who.int (2010)

Table B.6: Hospital beds per 100,000 Population

Years	Estonia	Latvia	Lithuania
1989	1193.08	1348.02	1265.93
1990	1155.32	1343.71	1248.7
1991	1128.92	1342.95	1246.53
1992	968.17	1268.62	1204.53
1993	962.23	1223.15	1183.51
1994	856.13	1205.52	1117.35
1995	834.87	1119.01	1094.02
1996	790.06	1043.5	1059.83
1997	771.26	979.92	959.91
1998	758.14	961.2	906.79
1999	752.95	903.33	895.29
2000	717.63	873.5	883.32
2001	671.5	820.29	830.81
2002	607.08	775.8	804.02
2003	592.29	781.35	776.53
2004	581.79	773.56	743.71
2005	547.81	768.39	708.78
2006	564.77	760.81	688.82
2007	556.99	757.13	688.26
2008	571.35	746.09	683.66

Source: WHO/Europe: European Health for All Database, data.euro.who.int (2010)

Table B.7: Primary health care units per 100,000 Population

Years	Estonia	Latvia	Lithuania
1989	22.96	47.62	11.1
1990	23.64	48.89	11.28
1991	...	46.37	12.77
1992	...	35.61	12.92
1993	...	35.74	11.35
1994	47.32	39.75	11.02
1995	52	37.87	11.1
1996	55.24	40.09	11.58
1997	41.16	42.09	11.66
1998	42.56	43.73	11.1
1999	43.91	46.6	21.08
2000	45.42	67.64	23.37
2001	47.8	86.67	25.68
2002	52.11	92.02	26
2003	58.81	97.71	26.66
2004	60.03	101.09	27.04
2005	62.92	105.98	29.23
2006	62.22	112.59	29.37
2007	...	116.78	28.82

Source: WHO/Europe: European Health for All Database, data.euro.who.int (2010)

Table B.8: Physicians per 100,000 Population

Years	Estonia	Latvia	Lithuania
1989	349.01	...	...
1990	350.38	354.43	...
1991	353.55	361.09	...
1992	326.4	313.31	358.31
1993	320.72	290.49	360.75
1994	320	289.16	369.28
1995	319.15	282.81	368.41
1996	314.85	283.49	371.75
1997	323.89	286.66	375.85
1998	321.32	273.94	372.15
1999	326.83	271.7	371.48
2000	326.39	287.36	362.68
2001	317.35	266.71	361.96
2002	314.14	275.5	367.5
2003	315.98	278.58	362.75
2004	321.28	285.5	356.47
2005	317.73	288.11	362.04
2006	320.64	293.67	365.25
2007	326.53	303.85	371.81
2008	334.91	310.67	369.64

Source: WHO/Europe: European Health for All Database, data.euro.who.int (2010)

Table B.9: Pharmacists per 100,000 Population

Years	Estonia	Latvia	Lithuania
1989	57.65	...	...
1990	59.01	...	...
1991	52.52	...	...
1992	45.46	...	...
1993	...	...	...
1994	...	...	51.9
1995	50.4	...	59.08
1996	50.86	...	57.86
1997	54.95	...	58.12
1998	56.05	...	58.41
1999	58.52	...	59.19
2000	59.51	...	59.35
2001	58.57	...	61.82
2002	55.5	...	60.62
2003	57.33	54.74	65.72
2004	62.55	53.61	63.45
2005	63.07	55.6	66.66
2006	64.68	58.7	60.49
2007	64.99	55.36	73.79
2008	64.3	59.13	77.31

Source: WHO/Europe: European Health for All Database, data.euro.who.int (2010)

Table B.10: HIV and AIDS incidence per 100,000 population

	HIV incidence per 100,000			AIDS incidence per 100,000		
Year	Estonia	Latvia	Lithuania	Estonia	Latvia	Lithuania
1989	0.1913	0.0377	0.0271	0	0	0
1990	0.5098	0.2253	0.2163	0	0.0751	0.027
1991	0.5124	0.1132	0.027	0	0.0377	0.027
1992	0.587	0.0383	0.1351	0.1305	0.0383	0.027
1993	0.3346	0.1951	0.1086	0.0669	0.117	0
1994	0.8205	0.2777	0.2461	0.0684	0.0793	0.0547
1995	0.7657	0.2817	0.3031	0.2088	0.1207	0.0276
1996	0.5651	1.3	0.3332	0.4945	0.2035	0.1388
1997	0.6431	1.03	0.8671	0.2144	0.2055	0.0839
1998	0.7214	6.72	1.47	0.2886	0.4979	0.2536
1999	0.8723	10.12	1.87	0.1454	0.753	0.1702
2000	28.48	19.64	1.86	0.2192	0.9692	0.2
2001	108.06	34.27	2.07	0.1466	1.7	0.2872
2002	66.17	23.18	11.44	0.4416	2.44	0.2594
2003	62.06	17.33	3.18	0.7388	3.44	0.2606
2004	55.07	13.97	3.93	2.15	3.89	0.6112
2005	46.13	13	3.51	2.15	5.13	0.2929
2006	49.72	13.07	2.95	2.38	3.89	0.7955
2007	47.18	15.38	3.14	4.25	3.38	0.8295
2008	40.65	15.8	2.83	4.55	4.37	1.64

Source: HIV Incidence: Louis Pasteur Scientific Institute of Public Health
AIDS Incidence: WHO European Centre for AIDS (Estonia & Latvia), National AIDS Centre (Lithuania)

Table B.11: Income share* held by lowest 20%

Year	Estonia	Latvia	Lithuania
1988	9.99	10.44	10.56
1993	6.41	9.5	7.98
1998	6.82	7.33	8.22
2002	6.62	6.95	7.72
2004	6.82	6.83	6.79

**Percentage of income or consumption is the shares that accrues to subgroups of population indicated by deciles or quintiles. Percentage shares by quintile may not sum to 100 because of rounding.*
Source: The World Bank, data. Worldbank.org

Table B.12: Registered passenger cars in Estonia, in thousands

Year	Cars
1985	177
1990	240.9
1991	261.1
1992	283.5
1993	317.4
1994	337.8
1995	383.4
1996	406.6
1997	427.7
1998	451
1999	458.7
2000	463.9
2001	407.3
2002	400.7
2003	434
2004	471.2
2005	493.8
2006	554
2007	523.8
2008	551.8
2009	545.7

Source: Estonian Motor Vehicle Registration Centre, www.stat.ee

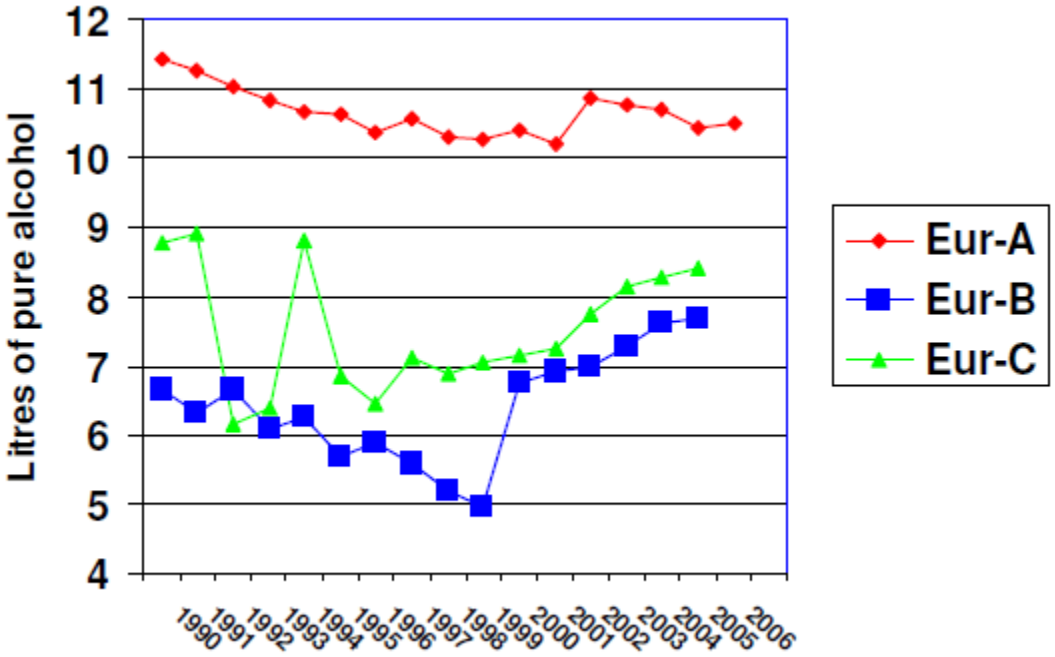

Figure B.1: Average adult alcohol consumption by European sub-region* (1990-2006). Eur-C includes 9 countries with low child but high adult mortality, including Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, the Republic of Moldova, the Russian Federation and Ukraine. *Source: WHO/Europe*

Table B.13: Urban population, percent of total population

Year	Estonia	Latvia	Lithuania
1989	71.04	69.16	67.08
1990	71.1	69.3	67.6
1991	70.88	69.2	67.54
1992	70.66	69.1	67.48
1993	70.44	69	67.42
1994	70.22	68.9	67.36
1995	70	68.8	67.3
1996	69.88	68.66	67.24
1997	69.76	68.52	67.18
1998	69.64	68.38	67.12
1999	69.52	68.24	67.06
2000	69.4	68.1	67
2001	69.4	68.08	66.92
2002	69.4	68.06	66.84
2003	69.4	68.04	66.76
2004	69.4	68.02	66.68
2005	69.4	68	66.6
2006	69.42	68.04	66.72
2007	69.44	68.08	66.84
2008	69.46	68.12	66.96
2009	69.48	68.16	67.08

Source: The World Bank, data.worldbank.org

Table B.14: Urban population, total

Year	Estonia	Latvia	Lithuania
1989	1113907	1856254	2475923
1990	1115559	1850795	2499848
1991	1106437	1842104	2501682
1992	1083218	1818712	2496760
1993	1052374	1784340	2483079
1994	1027319	1755572	2464029
1995	1005900	1730320	2444336
1996	989500.8	1710321	2424002
1997	976640	1678740	2405044
1998	965349.7	1647958	2386116
1999	956351.4	1630936	2367889
2000	950441.8	1615332	2344683
2001	946683.7	1606007	2329683
2002	942896.9	1591243	2318742
2003	939343	1582163	2306051
2004	936205	1573161	2290848
2005	934193.4	1564340	2273924
2006	932690.3	1556720	2264532
2007	931657	1549569	2256263
2008	931232.9	1543663	2248594
2009	930808.8	1537780	2240943

Source: The World Bank, data.worldbank.org

Table B.15: Standardized death rates (SDR)
per 100,000 Population

Year	Estonia	Latvia	Lithuania
1989	1121.73	1117.81	1014.08
1990	1176.85	1189.05	1046.81
1991	1188.52	1197.14	1074.45
1992	1221.95	1234.55	1080.45
1993	1306.53	1382.88	1199.4
1994	1382.02	1492.37	1217.22
1995	1301.18	1408.86	1188.69
1996	1177.01	1233.4	1119.15
1997	1145.27	1197.34	1066.78
1998	1195.26	1220.49	1051.95
1999	1126.14	1162.46	1025.55
2000	1109.21	1125.29	999.96
2001	1116.07	1147.48	1038.63
2002	1090.58	1126.71	1043.78
2003	1066.23	1113.62	1032.26
2004	1028	1090.63	1031.03
2005	993.64	1107.19	1081.6
2006	975.43	1112.26	1090.86
2007	958.94	1094.84	1095.45
2008	893.13	1006.22	1033.24

Source: WHO/Europe: European Health for All Database, data.euro.who.int

Table B.16: Standardized death rates (SDR) from Infectious Diseases per 100,000 Population

Year	Estonia	Latvia	Lithuania
1989	8.16	12.66	9.28
1990	8.45	11.3	9.64
1991	9.37	11.53	10.67
1992	9.1	13.92	10.89
1993	11.29	15.83	14.02
1994	11.64	21.05	15.49
1995	14.29	21.22	17.61
1996	12.12	16.42	15.37
1997	12.43	18.64	14.93
1998	13.11	19.91	15.11
1999	12.81	16.66	13.66
2000	10.52	15.34	13.83
2001	9.91	15.69	13.01
2002	8.43	12.91	13.26
2003	10.54	13.32	13.25
2004	10.66	11.78	12.45
2005	7.27	12.09	14.18
2006	10.13	12.27	14.06
2007	9.45	11.51	13.74
2008	8.12	11.47	12.77

Source: WHO/Europe: European Health for All Database, data.euro.who.int

Table B.17: Standardized death rate (SDR) from Tuberculosis per 100,000 Population

Year	Estonia	Latvia	Lithuania
1989	3.45	7.52	6.64
1990	5.51	6.84	7.32
1991	5.55	6.61	8.61
1992	6.17	7.74	8.34
1993	8.01	10.19	10.83
1994	9.42	14.27	11.76
1995	10.51	14.6	13.94
1996	9.97	11.54	12.55
1997	9.94	13.1	11.67
1998	10.29	13.95	12.33
1999	10.14	12.79	10.43
2000	7.54	11.79	10.34
2001	6.59	11.03	9.89
2002	6.1	8.51	9.45
2003	6.58	8.7	9.46
2004	6.97	7.31	8.59
2005	3.44	7.31	10.34
2006	4.56	7.39	10.28
2007	4.21	5.76	9.77
2008	3.53	4.61	9.76

Source: WHO/Europe: European Health for All Database, data.euro.who.int

Table B.18: Percent of tuberculosis composing total infectious SDR

Year	Estonia	Latvia	Lithuania
1989	42.28	59.4	71.55
1990	65.21	60.53	75.93
1991	59.23	57.33	80.69
1992	67.8	55.6	76.58
1993	70.95	64.37	77.25
1994	80.93	67.79	75.92
1995	73.55	68.8	79.16
1996	82.26	70.28	81.65
1997	79.97	70.28	78.16
1998	78.49	70.07	81.6
1999	79.16	76.77	76.35
2000	71.67	76.86	74.77
2001	66.5	70.3	76.02
2002	72.36	65.92	71.27
2003	62.43	65.32	71.4
2004	65.38	62.05	69
2005	47.32	60.46	72.92
2006	45.01	60.23	73.12
2007	44.55	50.04	71.11
2008	43.47	40.19	76.43

Source: WHO/Europe: European Health for All Database, data.euro.who.int

Table B.19: Tuberculosis incidence per 100,000 Population

Year	Estonia	Latvia	Lithuania
1989	26.91	32.13	37.48
1990	26.96	34.02	39.78
1991	26	35.58	42.01
1992	26.29	36.53	43.19
1993	35.61	38.78	51.46
1994	42.6	44.87	58.38
1995	43.43	62.01	65.08
1996	48.25	71.67	72.41
1997	53.16	82.33	81.84
1998	59.16	90.54	84.97
1999	54.81	79.11	79.45
2000	57.76	83.52	75.92
2001	51.9	84.93	74.63
2002	45.63	77.1	69.59
2003	41.15	72.51	74.87
2004	39.8	68.27	59.26
2005	35.58	61.25	61.92
2006	31.41	56.38	69.68
2007	33.99	53.91	66.21
2008	29.91	46.16	62.39

Source: WHO/Europe: European Health for All Database, data.euro.who.int

APPENDIX C

Table C.1: Correlation between Population Change & Net Migration

	Estonia		Latvia		Lithuania	
Year	Population	Migration	Population	Migration	Population	Migration
1990	1.57	15032	2.67	44186	3.7	52445
1995	1.44	-107795	2.52	-133799	3.63	-98795
2000	1.37	-36571	2.37	-39965	3.5	-105528
2005	1.35	910	2.3	-19584	3.41	-35840
	r =	0.212	r =	0.239	r =	0.425

Table C.2: Correlation between HIV incidence per 100,000 Population & TB incidence per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	HIV	TB	HIV	TB	HIV	TB
1989	0.1913	26.91	0.0377	32.13	0.0271	37.48
1990	0.5098	26.96	0.2253	34.02	0.2163	39.78
1991	0.5124	26	0.1132	35.58	0.027	42.01
1992	0.587	26.29	0.0383	36.53	0.1351	43.19
1993	0.3346	35.61	0.1951	38.78	0.1086	51.46
1994	0.8205	42.6	0.2777	44.87	0.2461	58.38
1995	0.7657	43.43	0.2817	62.01	0.3031	65.08
1996	0.5651	48.25	1.3	71.67	0.3332	72.41
1997	0.6431	53.16	1.03	82.33	0.8671	81.84
1998	0.7214	59.16	6.72	90.54	1.47	84.97
1999	0.8723	54.81	10.12	79.11	1.87	79.45
2000	28.48	57.76	19.64	83.52	1.86	75.92
2001	108.06	51.9	34.27	84.93	2.07	74.63
2002	66.17	45.63	23.18	77.1	11.44	69.59
2003	62.06	41.15	17.33	72.51	3.18	74.87
2004	55.07	39.8	13.97	68.27	3.93	59.26
2005	46.13	35.58	13	61.25	3.51	61.92
2006	49.72	31.41	13.07	56.38	2.95	69.68
2007	47.18	33.99	15.38	53.91	3.14	66.21
2008	40.65	29.91	15.8	46.16	2.83	62.39
	r =	0.098	r =	0.555	r =	0.312

Table C.3: Correlation between tuberculosis incidence rates & number of hospitals per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Hospitals	TB	Hospitals	TB	Hospitals	TB
1989	7.72	26.91	6.97	32.13	5.21	37.48
1990	7.97	26.96	7.06	34.02	5.33	39.78
1991	7.69	26	7.06	35.58	5.45	42.01
1992	7.7	26.29	6.73	36.53	5.32	43.19
1993	7.7	35.61	6.48	38.78	5.21	51.46
1994	7.32	42.6	6.74	44.87	5.22	58.38
1995	5.78	43.43	6.68	62.01	5.24	65.08
1996	5.58	48.25	6.43	71.67	5.08	72.41
1997	5.64	53.16	6.41	82.33	3.86	81.84
1998	5.63	59.16	6.22	90.54	3.47	84.97
1999	5.67	54.81	6.32	79.11	3.38	79.45
2000	4.97	57.76	5.98	83.52	3.46	75.92
2001	4.91	51.9	5.94	84.93	3.45	74.63
2002	3.75	45.63	5.52	77.1	3.43	69.59
2003	3.69	41.15	5.63	72.51	3.47	74.87
2004	3.78	39.8	5.15	68.27	3.32	59.26
2005	4.01	35.58	4.74	61.25	3.31	61.92
2006	4.09	31.41	4.63	56.38	3.39	69.68
2007	4.25	33.99	4.13	53.91	3.23	66.21
2008	4.48	29.91	3.88	46.16	3.36	62.39
	r =	-0.344	r =	-0.188	r =	-0.699

Table C.4: Correlation between tuberculosis incidence rates & number of hospital beds per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Beds	TB	Beds	TB	Beds	TB
1989	1193.08	26.91	1348.02	32.13	1265.93	37.48
1990	1155.32	26.96	1343.71	34.02	1248.7	39.78
1991	1128.92	26	1342.95	35.58	1246.53	42.01
1992	968.17	26.29	1268.62	36.53	1204.53	43.19
1993	962.23	35.61	1223.15	38.78	1183.51	51.46
1994	856.13	42.6	1205.52	44.87	1117.35	58.38
1995	834.87	43.43	1119.01	62.01	1094.02	65.08
1996	790.06	48.25	1043.5	71.67	1059.83	72.41
1997	771.26	53.16	979.92	82.33	959.91	81.84
1998	758.14	59.16	961.2	90.54	906.79	84.97
1999	752.95	54.81	903.33	79.11	895.29	79.45
2000	717.63	57.76	873.5	83.52	883.32	75.92
2001	671.5	51.9	820.29	84.93	830.81	74.63
2002	607.08	45.63	775.8	77.1	804.02	69.59
2003	592.29	41.15	781.35	72.51	776.53	74.87
2004	581.79	39.8	773.56	68.27	743.71	59.26
2005	547.81	35.58	768.39	61.25	708.78	61.92
2006	564.77	31.41	760.81	56.38	688.82	69.68
2007	556.99	33.99	757.13	53.91	688.26	66.21
2008	571.35	29.91	746.09	46.16	683.66	62.39
	r =	-0.372	r =	-0.647	r =	-0.638

Table C.5: Correlation between tuberculosis incidence rates & number of pharmacists per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Pharmacists	TB	Pharmacists	TB	Pharmacists	TB
1989	57.65	26.91	...	32.13	...	37.48
1990	59.01	26.96	...	34.02	...	39.78
1991	52.52	26	...	35.58	...	42.01
1992	45.46	26.29	...	36.53	...	43.19
1993	…	35.61	...	38.78	...	51.46
1994	…	42.6	...	44.87	51.9	58.38
1995	50.4	43.43	...	62.01	59.08	65.08
1996	50.86	48.25	...	71.67	57.86	72.41
1997	54.95	53.16	...	82.33	58.12	81.84
1998	56.05	59.16	...	90.54	58.41	84.97
1999	58.52	54.81	...	79.11	59.19	79.45
2000	59.51	57.76	...	83.52	59.35	75.92
2001	58.57	51.9	...	84.93	61.82	74.63
2002	55.5	45.63	...	77.1	60.62	69.59
2003	57.33	41.15	54.74	72.51	65.72	74.87
2004	62.55	39.8	53.61	68.27	63.45	59.26
2005	63.07	35.58	55.6	61.25	66.66	61.92
2006	64.68	31.41	58.7	56.38	60.49	69.68
2007	64.99	33.99	55.36	53.91	73.79	66.21
2008	64.3	29.91	59.13	46.16	77.31	62.39
	r =	-0.072	r =	-0.789	r =	-0.292

Table C.6: Correlation between tuberculosis incidence rates & number of physicians per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Physicians	TB	Physicians	TB	Physicians	TB
1989	349.01	26.91	...	32.13	...	37.48
1990	350.38	26.96	354.43	34.02	...	39.78
1991	353.55	26	361.09	35.58	...	42.01
1992	326.4	26.29	313.31	36.53	358.31	43.19
1993	320.72	35.61	290.49	38.78	360.75	51.46
1994	320	42.6	289.16	44.87	369.28	58.38
1995	319.15	43.43	282.81	62.01	368.41	65.08
1996	314.85	48.25	283.49	71.67	371.75	72.41
1997	323.89	53.16	286.66	82.33	375.85	81.84
1998	321.32	59.16	273.94	90.54	372.15	84.97
1999	326.83	54.81	271.7	79.11	371.48	79.45
2000	326.39	57.76	287.36	83.52	362.68	75.92
2001	317.35	51.9	266.71	84.93	361.96	74.63
2002	314.14	45.63	275.5	77.1	367.5	69.59
2003	315.98	41.15	278.58	72.51	362.75	74.87
2004	321.28	39.8	285.5	68.27	356.47	59.26
2005	317.73	35.58	288.11	61.25	362.04	61.92
2006	320.64	31.41	293.67	56.38	365.25	69.68
2007	326.53	33.99	303.85	53.91	371.81	66.21
2008	334.91	29.91	310.67	46.16	369.64	62.39
	r =	-0.568	r =	-0.772	r =	0.586

Table C.7: Correlation between tuberculosis incidence rates & number of primary health care units per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Units	TB	Units	TB	Units	TB
1989	22.96	26.91	47.62	32.13	11.1	37.48
1990	23.64	26.96	48.89	34.02	11.28	39.78
1991	...	26	46.37	35.58	12.77	42.01
1992	...	26.29	35.61	36.53	12.92	43.19
1993	...	35.61	35.74	38.78	11.35	51.46
1994	47.32	42.6	39.75	44.87	11.02	58.38
1995	52	43.43	37.87	62.01	11.1	65.08
1996	55.24	48.25	40.09	71.67	11.58	72.41
1997	41.16	53.16	42.09	82.33	11.66	81.84
1998	42.56	59.16	43.73	90.54	11.1	84.97
1999	43.91	54.81	46.6	79.11	21.08	79.45
2000	45.42	57.76	67.64	83.52	23.37	75.92
2001	47.8	51.9	86.67	84.93	25.68	74.63
2002	52.11	45.63	92.02	77.1	26	69.59
2003	58.81	41.15	97.71	72.51	26.66	74.87
2004	60.03	39.8	101.09	68.27	27.04	59.26
2005	62.92	35.58	105.98	61.25	29.23	61.92
2006	62.22	31.41	112.59	56.38	29.37	69.68
2007	...	33.99	116.78	53.91	28.82	66.21
	r =	0.148	r =	0.238	r =	0.351

Table C.8: Correlation between tuberculosis incidence rates & public sector health care expenditure as percent of total health expenditures, 1995-2008

	Estonia		Latvia		Lithuania	
Year	% of total	TB	% of total	TB	% of total	TB
1995	89.8	43.43	66.3	62.01	74.2	65.08
1996	88.4	48.25	57.8	71.67	70.4	72.41
1997	89.2	53.16	55.8	82.33	72.5	81.84
1998	86.3	59.16	59.2	90.54	76	84.97
1999	81	54.81	58.4	79.11	74.9	79.45
2000	77.5	57.76	54.4	83.52	69.7	75.92
2001	78.6	51.9	51.2	84.93	72.6	74.63
2002	77.1	45.63	52.1	77.1	74.9	69.59
2003	77.1	41.15	52.8	72.51	76	74.87
2004	76	39.8	54.2	68.27	67.6	59.26
2005	76.9	35.58	57.1	61.25	67.3	61.92
2006	73.7	31.41	62.4	56.38	69.5	69.68
2007	76.5	33.99	57.9	53.91	73	66.21
2008	78.7	29.91	59.6	46.16	73	62.39
	r =	0.499	r =	-0.484	r =	0.526

Table C.9: Correlation between tuberculosis standardized death rates & HIV incidence per 100,000 population

	Estonia		Latvia		Lithuania	
Year	HIV	SDR-TB	HIV	SDR-TB	HIV	SDR-TB
1989	0.1913	3.45	0.0377	7.52	0.0271	6.64
1990	0.5098	5.51	0.2253	6.84	0.2163	7.32
1991	0.5124	5.55	0.1132	6.61	0.027	8.61
1992	0.587	6.17	0.0383	7.74	0.1351	8.34
1993	0.3346	8.01	0.1951	10.19	0.1086	10.83
1994	0.8205	9.42	0.2777	14.27	0.2461	11.76
1995	0.7657	10.51	0.2817	14.6	0.3031	13.94
1996	0.5651	9.97	1.3	11.54	0.3332	12.55
1997	0.6431	9.94	1.03	13.1	0.8671	11.67
1998	0.7214	10.29	6.72	13.95	1.47	12.33
1999	0.8723	10.14	10.12	12.79	1.87	10.43
2000	28.48	7.54	19.64	11.79	1.86	10.34
2001	108.06	6.59	34.27	11.03	2.07	9.89
2002	66.17	6.1	23.18	8.51	11.44	9.45
2003	62.06	6.58	17.33	8.7	3.18	9.46
2004	55.07	6.97	13.97	7.31	3.93	8.59
2005	46.13	3.44	13	7.31	3.51	10.34
2006	49.72	4.56	13.07	7.39	2.95	10.28
2007	47.18	4.21	15.38	5.76	3.14	9.77
2008	40.65	3.53	15.8	4.61	2.83	9.76
	r =	-0.42	r =	-0.18	r =	-0.112

Table C.10: Correlation between tuberculosis standardized death rates & number of hospitals per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Hospitals	SDR-TB	Hospitals	SDR-TB	Hospitals	SDR-TB
1989	7.72	3.45	6.97	7.52	5.21	6.64
1990	7.97	5.51	7.06	6.84	5.33	7.32
1991	7.69	5.55	7.06	6.61	5.45	8.61
1992	7.7	6.17	6.73	7.74	5.32	8.34
1993	7.7	8.01	6.48	10.19	5.21	10.83
1994	7.32	9.42	6.74	14.27	5.22	11.76
1995	5.78	10.51	6.68	14.6	5.24	13.94
1996	5.58	9.97	6.43	11.54	5.08	12.55
1997	5.64	9.94	6.41	13.1	3.86	11.67
1998	5.63	10.29	6.22	13.95	3.47	12.33
1999	5.67	10.14	6.32	12.79	3.38	10.43
2000	4.97	7.54	5.98	11.79	3.46	10.34
2001	4.91	6.59	5.94	11.03	3.45	9.89
2002	3.75	6.1	5.52	8.51	3.43	9.45
2003	3.69	6.58	5.63	8.7	3.47	9.46
2004	3.78	6.97	5.15	7.31	3.32	8.59
2005	4.01	3.44	4.74	7.31	3.31	10.34
2006	4.09	4.56	4.63	7.39	3.39	10.28
2007	4.25	4.21	4.13	5.76	3.23	9.77
2008	4.48	3.53	3.88	4.61	3.36	9.76
	r =	0.151	r =	0.496	r =	-0.056

Table C.11: Correlation between tuberculosis standardized death rate & number of hospital beds per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Beds	SDR-TB	Beds	SDR-TB	Beds	SDR-TB
1989	1193.08	3.45	1348.02	7.52	1265.93	6.64
1990	1155.32	5.51	1343.71	6.84	1248.7	7.32
1991	1128.92	5.55	1342.95	6.61	1246.53	8.61
1992	968.17	6.17	1268.62	7.74	1204.53	8.34
1993	962.23	8.01	1223.15	10.19	1183.51	10.83
1994	856.13	9.42	1205.52	14.27	1117.35	11.76
1995	834.87	10.51	1119.01	14.6	1094.02	13.94
1996	790.06	9.97	1043.5	11.54	1059.83	12.55
1997	771.26	9.94	979.92	13.1	959.91	11.67
1998	758.14	10.29	961.2	13.95	906.79	12.33
1999	752.95	10.14	903.33	12.79	895.29	10.43
2000	717.63	7.54	873.5	11.79	883.32	10.34
2001	671.5	6.59	820.29	11.03	830.81	9.89
2002	607.08	6.1	775.8	8.51	804.02	9.45
2003	592.29	6.58	781.35	8.7	776.53	9.46
2004	581.79	6.97	773.56	7.31	743.71	8.59
2005	547.81	3.44	768.39	7.31	708.78	10.34
2006	564.77	4.56	760.81	7.39	688.82	10.28
2007	556.99	4.21	757.13	5.76	688.26	9.77
2008	571.35	3.53	746.09	4.61	683.66	9.76
	r =	0.068	r =	0.128	r =	-0.146

Table C.12: Correlation between tuberculosis standardized death rate & number of pharmacists per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Pharmacists	SDR-TB	Pharmacists	SDR-TB	Pharmacists	SDR-TB
1989	57.65	3.45	...	7.52	...	6.64
1990	59.01	5.51	...	6.84	...	7.32
1991	52.52	5.55	...	6.61	...	8.61
1992	45.46	6.17	...	7.74	...	8.34
1993	...	8.01	...	10.19	...	10.83
1994	...	9.42	...	14.27	51.9	11.76
1995	50.4	10.51	...	14.6	59.08	13.94
1996	50.86	9.97	...	11.54	57.86	12.55
1997	54.95	9.94	...	13.1	58.12	11.67
1998	56.05	10.29	...	13.95	58.41	12.33
1999	58.52	10.14	...	12.79	59.19	10.43
2000	59.51	7.54	...	11.79	59.35	10.34
2001	58.57	6.59	...	11.03	61.82	9.89
2002	55.5	6.1	...	8.51	60.62	9.45
2003	57.33	6.58	54.74	8.7	65.72	9.46
2004	62.55	6.97	53.61	7.31	63.45	8.59
2005	63.07	3.44	55.6	7.31	66.66	10.34
2006	64.68	4.56	58.7	7.39	60.49	10.28
2007	64.99	4.21	55.36	5.76	73.79	9.77
2008	64.3	3.53	59.13	4.61	77.31	9.76
	r =	-0.515	r =	-0.529	r =	-0.52

Table C.13: Correlation between tuberculosis standardized death rate & number of physicians per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Physicians	SDR-TB	Physicians	SDR-TB	Physicians	SDR-TB
1989	349.01	3.45	...	7.52	...	6.64
1990	350.38	5.51	354.43	6.84	...	7.32
1991	353.55	5.55	361.09	6.61	...	8.61
1992	326.4	6.17	313.31	7.74	358.31	8.34
1993	320.72	8.01	290.49	10.19	360.75	10.83
1994	320	9.42	289.16	14.27	369.28	11.76
1995	319.15	10.51	282.81	14.6	368.41	13.94
1996	314.85	9.97	283.49	11.54	371.75	12.55
1997	323.89	9.94	286.66	13.1	375.85	11.67
1998	321.32	10.29	273.94	13.95	372.15	12.33
1999	326.83	10.14	271.7	12.79	371.48	10.43
2000	326.39	7.54	287.36	11.79	362.68	10.34
2001	317.35	6.59	266.71	11.03	361.96	9.89
2002	314.14	6.1	275.5	8.51	367.5	9.45
2003	315.98	6.58	278.58	8.7	362.75	9.46
2004	321.28	6.97	285.5	7.31	356.47	8.59
2005	317.73	3.44	288.11	7.31	362.04	10.34
2006	320.64	4.56	293.67	7.39	365.25	10.28
2007	326.53	4.21	303.85	5.76	371.81	9.77
2008	334.91	3.53	310.67	4.61	369.64	9.76
	r =	-0.407	r =	-0.557	r =	0.597

Table C.14: Correlation between tuberculosis standardized death rate & number of primary health care units per 100,000 Population

	Estonia		Latvia		Lithuania	
Year	Units	SDR-TB	Units	SDR-TB	Units	SDR-TB
1989	22.96	3.45	47.62	7.52	11.1	6.64
1990	23.64	5.51	48.89	6.84	11.28	7.32
1991	...	5.55	46.37	6.61	12.77	8.61
1992	...	6.17	35.61	7.74	12.92	8.34
1993	...	8.01	35.74	10.19	11.35	10.83
1994	47.32	9.42	39.75	14.27	11.02	11.76
1995	52	10.51	37.87	14.6	11.1	13.94
1996	55.24	9.97	40.09	11.54	11.58	12.55
1997	41.16	9.94	42.09	13.1	11.66	11.67
1998	42.56	10.29	43.73	13.95	11.1	12.33
1999	43.91	10.14	46.6	12.79	21.08	10.43
2000	45.42	7.54	67.64	11.79	23.37	10.34
2001	47.8	6.59	86.67	11.03	25.68	9.89
2002	52.11	6.1	92.02	8.51	26	9.45
2003	58.81	6.58	97.71	8.7	26.66	9.46
2004	60.03	6.97	101.09	7.31	27.04	8.59
2005	62.92	3.44	105.98	7.31	29.23	10.34
2006	62.22	4.56	112.59	7.39	29.37	10.28
2007	...	4.21	116.78	5.76	28.82	9.77
	r =	0.026	r =	-0.548	r =	-0.185

Table C.15: Correlation between tuberculosis standardized death rate & public sector health care expenditure as percent of total health expenditures, 1995-2008

	Estonia		Latvia		Lithuania	
Year	% of total	SDR-TB	% of total	SDR-TB	% of total	SDR-TB
1995	89.8	10.51	66.3	14.6	74.2	13.94
1996	88.4	9.97	57.8	11.54	70.4	12.55
1997	89.2	9.94	55.8	13.1	72.5	11.67
1998	86.3	10.29	59.2	13.95	76	12.33
1999	81	10.14	58.4	12.79	74.9	10.43
2000	77.5	7.54	54.4	11.79	69.7	10.34
2001	78.6	6.59	51.2	11.03	72.6	9.89
2002	77.1	6.1	52.1	8.51	74.9	9.45
2003	77.1	6.58	52.8	8.7	76	9.46
2004	76	6.97	54.2	7.31	67.6	8.59
2005	76.9	3.44	57.1	7.31	67.3	10.34
2006	73.7	4.56	62.4	7.39	69.5	10.28
2007	76.5	4.21	57.9	5.76	73	9.77
2008	78.7	3.53	59.6	4.61	73	9.76
	r =	0.814	r =	0.178	r =	0.226

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