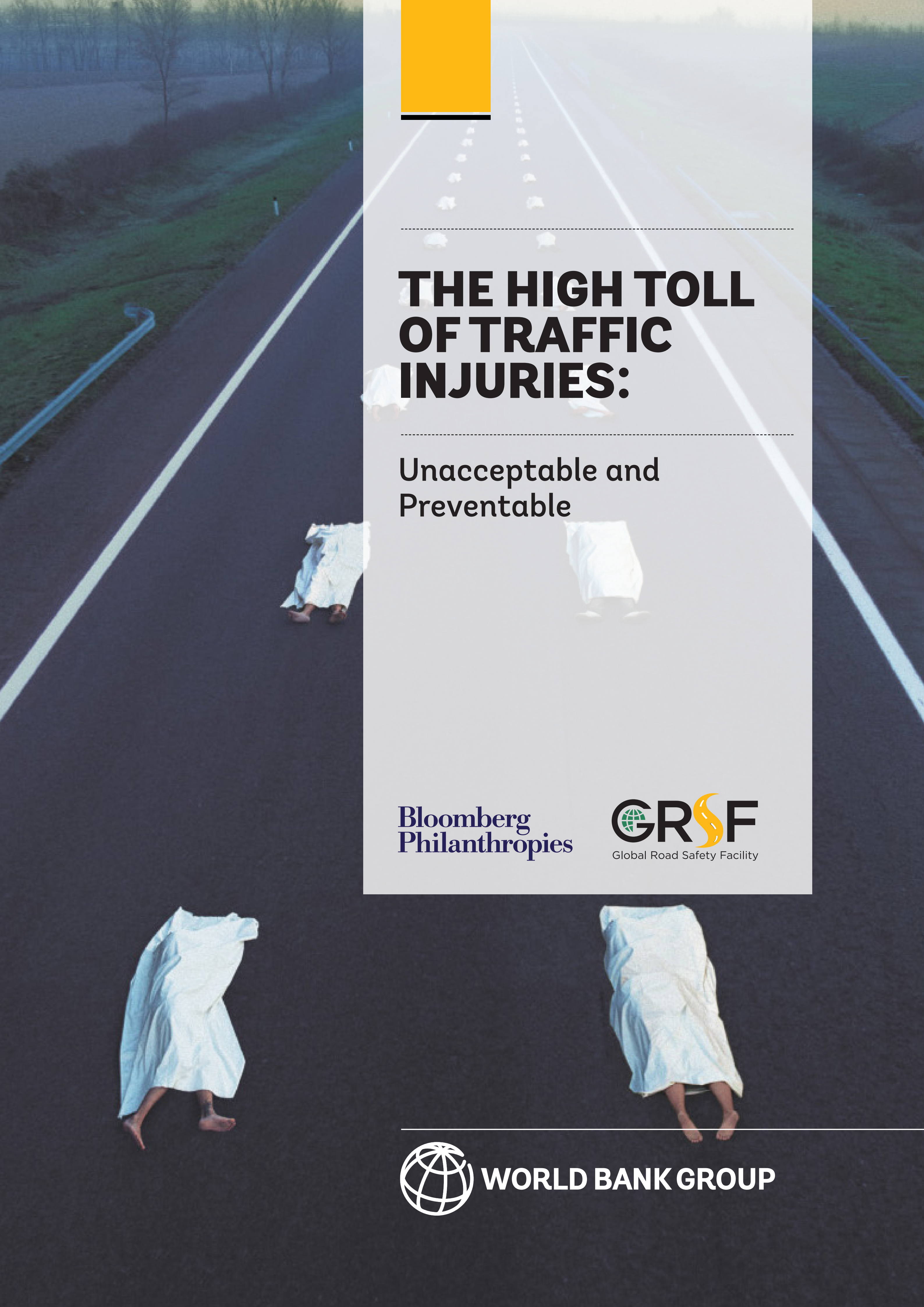

THE HIGH TOLL OF TRAFFIC INJURIES:

Unacceptable and Preventable

Bloomberg Philanthropies

GRSF
Global Road Safety Facility

WORLD BANK GROUP

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THE HIGH TOLL OF TRAFFIC INJURIES:

Unacceptable and Preventable

The Macro-Economic And Welfare Benefits of Reducing Road Traffic Injuries in Low- & Middle-Income Countries

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Transport & ICT

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FOREWORD

Road safety is a challenge of epidemic proportions. With 1.25 million people killed on the world's roads each year and another 20-50 million seriously injured, road traffic injuries have become a public health priority whose social and economic implications extend well beyond the transport sector.

Most of us know someone who has been affected by a road crash one way or another. We've also heard many individual stories describing how road injuries can cause a family not just heartbreak, but also serious financial hardship. But what about the impact on societies and economies at large? While policymakers across sectors increasingly recognize road traffic injuries as a socioeconomic burden, backing this assumption with solid evidence has proven difficult: the aggregate economic impact at the national level is not fully understood and remains largely underreported, mostly due to the lack of data.

This study, funded by Bloomberg Philanthropies, is an attempt to fill the void. Inspired by existing public health studies on the impact of other diseases, it is one of the first systematic efforts to estimate both the potential economic benefits and aggregate social welfare gains of reducing road traffic injuries in low- and middle income countries. The methodology developed in this report has been applied to an initial set of five countries: China, India, Philippines, Tanzania, and Thailand.

The results of the study and their development implications are hard to ignore.

Reducing road traffic injuries in half could translate into an additional 15% to 22% of GDP per capita income growth over 24 years. This means in practice that failing to meet the UN Sustainable Development Goal target to halving road deaths by 2020—this is, the cost of inaction—accrues to about 2-3 percent points in unrealized per capita GDP growth for low- and middle- income countries.

But the effect on the national income tells us only part of the story. Aside from their direct impact on the national product of a country, road traffic injuries also cause individual and social welfare losses that cannot be ignored. How can we evaluate these losses, and what is the price that society is willing to pay to avoid them? This is another important but often overlooked aspect of road traffic injuries that the report proposes to address. Once again, the results are quite significant: drawing on literature from insurance, disaster risk management, health, and others sectors, the study finds that, over a 24-year period, society would be willing to pay the equivalent of 6% to 32% of the national GDP to avoid the mortality and morbidity consequences of road traffic injures.

Now, what does this all mean for policymakers? For the transport sector, the results are humbling and underscore the responsibility the sector has towards the sustainable development agenda. Road traffic injury prevention is not a transport challenge, it is a development challenge with strong impact on health, wellbeing and economic growth.

For health planners and public health officials, these results make it clear that road traffic injury prevention should be regarded as a key pillar of the health agenda. First, most of the institutional costs of dealing with road fatalities and injuries are directly absorbed by countries' health systems. In addition, the way road injuries affect society and the economy is no different from other health conditions. Reducing road traffic injuries and deaths is at the core of supporting the progressive realization of universal health coverage, and the development of human capital, both strategic priorities for the World Bank Group. Developing countries have made important strides on reducing the proportion of communicable diseases, maternal deaths, nutritional diseases, and are making strides in dealing with non-communicable diseases. However, the benefits linked to reducing road injuries is yet to be realized.

Most importantly, this work reaffirms the importance of looking at road safety as a cross-cutting development issue. In other words, we won't move the needle on road traffic injury prevention unless we bring a wide range of stakeholders around the same table. If we get this right, curbing road traffic injuries would not just be a victory for the transport sector but a significant milestone for global development, with far-reaching benefits for public health, wellbeing, and economic growth.

Making this happen will not be easy. But we are convinced that this type of research will arm policymakers with the knowledge and data they need to design solutions that benefit the poor, create resilient economies, and save millions of lives.

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EXECUTIVE SUMMARY

Overview

An estimated 1.25 million people are killed on the world's roads every year, and between 20 and 50 million people are seriously injured. Every traffic crash is an individual loss. When death or serious injury results, this loss is compounded by the harm to people, households, and social networks. But what is the impact of road traffic injuries (RTIs) on the economic well-being of countries, particularly in low- and middle-income countries (LMICs) that are already struggling to address the needs of large populations in poverty?

Policymakers have been grappling with this question for decades. There is strong evidence that those who are killed or injured in road traffic crashes are disproportionately in their economically productive years. RTIs are the single largest cause of mortality and long-term disability among young people aged 15-29, and their impact is also considerable among the working-age population more broadly.

Clearly, RTIs pose a substantial burden on limited health system resources in LMICs, where the global burden of RTIs is now concentrated (following sharp declines in high-income countries over recent decades). LMICs suffer 90 percent of global road deaths, despite having only 50 percent of the vehicles.

Beyond that starting point, however, it is hard to draw firm conclusions. Existing estimates of the economic impact of RTIs in the developing world are imprecise and rely on extrapolation from high-income settings. Since economic impact is an important factor in setting budget priorities for health policy makers and transport or urban planning officials, this gap in the global knowledge base has undermined government efforts to address RTIs.

The present report represents an attempt to address this critical gap. Produced under the Bloomberg Initiative for Global Road Safety, it quantifies the macro-economic impact of RTIs in five LMICs: China, India, Philippines, Tanzania, and Thailand (the five countries are part of the Bloomberg Initiative for Global Road Safety Program 2015-2019). *It shows that, over time, sharply reducing the number of road traffic injuries and deaths would enable these countries to attain substantial increases in economic growth and national income, while leading simultaneously to clear welfare gains.*

Moreover, by estimating the macroeconomic and welfare effects of road traffic injuries, the report tries both to deepen the analysis and to address the needs of two important groups of government stakeholders. Officials responsible for national infrastructure are interested in evaluating road safety interventions as economic investments. For these stakeholders, a key question is the relationship between the reduction of road injuries and national income growth as measured by GDP metrics. Public health officials, meanwhile, are focused on promoting health, preventing road traffic injuries and deaths, as well as on reducing their health and social burden. These two analytical perspectives illuminate and complement each other, although they each apply a different methodology for the measurement of economic impact. The present report thus attempts to address these specific aspects of economic impact, while providing a comprehensive overview of the challenge in estimating the social impact of RTIs.

The report is only a starting point. Its analysis addresses potential growth impacts *via the health channel*, not via any other potential multiplier effect that better road infrastructure, and fewer crashes, may have. While the findings are not, in themselves, sufficient to mandate specific policies, the two complementary analyses contained in this report offer a conceptual basis for priority-setting exercises that would place greater focus on road traffic safety programs in national planning, and for support of these programs by the World Bank Group and other development partners. The report thus provides a foundation for the next step in improving road safety in LMICs: fully analysing the costs and benefits of specific road safety measures that save lives while contributing to human capital development, boosting economic growth, and increasing the total wealth of a country.

Findings

[1] Reducing road traffic injuries has a positive effect on national income growth

While there are obvious economic consequences of RTIs at the "micro" level—the individuals, families and communities directly affected—it is not obvious that such effects will carry over to the "macro" level of the economy at large. The hypothesis that RTIs have macroeconomic ripple effects gains plausibility from the fact that RTIs predominantly affect young people, and their impact toll is also considerable among the working-age population more broadly. Consequently, the disproportionate impact of RTI-related morbidity and mortality on the economically productive segment of the population is likely to depress GDP growth rates. As 90 percent of the world's RTIs occur in low- and middle-income countries (WHO, 2015), this is particularly ominous for the development prospects of these countries. However, the magnitude of the economic effect has not been clearly established in the literature through rigorous analysis. As a result, there is uncertainty as to whether this effect might be either non-existent or so small that its policy implications are negligible.

This study clearly demonstrates that there is a significant positive effect of reducing road traffic injuries on long-term income growth at the macro-level. This is estimated through the effects of road traffic death rates and disability metrics on income growth using the most comprehensive dataset available which includes a sample size of 135 countries with data collected over a period of 24 years between 1990 and 2014. The implication of this finding will open new pathways for future research and may also be useful to experts and decision makers as they compare the relative economic effects of averting disease and injuries. While there is general literature on the impact of health on economic growth (or on levels of GDP) the evidence on the macro-economic implications of RTIs is limited.

[2] Significant long-term income growth – 7 to 22 percent increase in GDP per capita over 24 years - can be achieved through substantial reduction in road traffic injuries in line with the current UN targets

Beyond establishing the above positive effect, the analysis clearly demonstrates a significant impact of reducing road traffic injuries and deaths on economic growth in the long term. For instance, the study shows that by reducing road traffic mortality and morbidity by 50 percent and sustaining it over a period of 24 years could generate an additional flow of income equivalent to 7.1 percent of 2014 GDP in Tanzania, 7.2 percent in the Philippines, 14 percent in India, 15 percent in China and 22.2 percent in Thailand. This puts into perspective the magnitude of economic benefits that the countries may realize with sustained action if they were to achieve the UN targets on road safety (e.g., the Sustainable Development Goal health target of reducing road traffic fatalities by half by 2020).

In other words, this analysis provides evidence that *there is an economic loss associated with every year of inaction where LMICs fail to move beyond* *their status quo performance on road safety and instead steer towards a trajectory of substantial reduction in road traffic injuries and deaths.* While RTIs constitute 2 to 5 percent of all causes of deaths, significant impact on the long-term income growth for the developing countries can be achieved through the reduction in current RTI rates.

[3] The impact on income growth only may under-value the broader welfare benefits to the society that comes through reducing road traffic injuries

The effect on the national income is only a part of the story. A strictly economic valuation of the impact of road traffic injuries on the national product of a country grossly underestimates the perceived loss of individual and social welfare. While reducing RTI has an impact on the income growth as measured through GDP, the study also estimates the enormous welfare benefits associated with what it would be worth to people to reduce the risk of road traffic mortality and morbidity, and hence to add healthy years of life free of injuries and lasting disabilities. This is in recognition that GDP is an imperfect measure of social welfare: it fails to incorporate the value of health. The true purpose of economic activity is the maximization of social welfare, not necessarily of the production of goods and services by itself. Since health is an important component of properly defined social welfare, measuring the economic cost of mortality only in terms of foregone GDP leaves out a potentially major part of its 'true economic' impact, defined as its impact on social welfare. The welfare benefits estimation is typically valued higher because we value better health for much more than the narrow productivity gains it may entail. The intangible value society assigns to health is not at all captured in the growth effect estimates (Cutler and Richardson, 1997).

The study uses various approaches using at their core the Value of Statistical Life (VSL) for each country, largely following the methods commonly used in the health literature. Data gaps plague such evaluations in the developing countries which are typically based on the estimation of VSL as measured through "Willingness-to-pay" surveys. Using five different methods cited in the literature to estimate the VSL, the current study estimates the welfare benefits that may be realized through different scenarios (25 percent, 50 percent, and 75 percent) of reducing road mortality and morbidity in each of the five countries over a period of 24 years. The measure of the welfare benefits is needed to assess whether the policy proposed represents "value for money", i.e., if its benefits are greater than its costs. Further, this study helps lay the groundwork for plausible cost-benefit assessments, which would be critical for prioritizing RTI policies and interventions.

[4] Welfare benefits equivalent to 6 percent to 32 percent of the national GDP can be realized from reducing 50 percent of road deaths and injuries over a period of 24 years

The study shows significant welfare gains associated with the decrease of RTIs in the five developing countries when evaluated over a period of 24 years. In one of the estimates, assuming that the monetary value of one Disability Adjusted Life Year (DALY)[1] averted is equivalent to one GDP per capita, the range of welfare benefits of reducing RTI mortality and morbidity by 50 percent over 24 years expressed as percentage of GDP are: 6.3 percent for China, 16.3 percent for India, 32 percent for Tanzania, 8.25 percent for Thailand, and 5.91 percent for Philippines. These figures are

[1] DALY is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. Numerically this is the sum of years of potential life lost due to premature mortality and the years of productive life lost due to death and disability.

the price that society is willing to pay to avoid the mortality and morbidity consequences of road traffic injures. While the estimated benefits are significant for the developing countries, it must be noted these are highly conservative estimates. Using higher values for the VSL comparable to rich countries (US$ 3 million), the welfare benefits from reducing 50 percent of road deaths over a period of 24 years in the five countries will yield economic benefits equivalent to 48 percent (in China) to 219 percent (in Tanzania) of the national GDP.

The use of VSL, is at the core of calculating welfare benefits in the study. It should be noted, however, that depending on the methodology used, there is wide variation in the estimation of VSL. This is likely the single biggest limitation that plagues any welfare benefit assessment of reducing RTIs in LMICs as there are no reliable measures of the VSL for most LMICs, including the five countries assessed here. Not only are the estimates of the VSL used here likely underestimates, but also the figures on RTI mortality could be underestimated or at least incomplete for the countries we focus on, adding to the concern that the estimated welfare benefits may be distorted downwards.

[5] Reducing RTI should be at the core of any strategy aimed at developing health capital, and hence to contribute to human capital accumulation and enhancing overall social welfare.

As the report shows, the economic and social costs of preventable road traffic injuries and premature death are unacceptably high. Key road safety interventions can be viewed as among the "best buys" in development since they both yield measurable results more rapidly than many other investments in human capital and involve relatively modest implementation costs. Investments in the prevention of road traffic injuries and premature deaths will pay off maximizing healthy life years, free of injuries and disabilities, contributing to build health capital (the value of a person's lifetime health), and hence to human capital (the sum of knowledge, skills, and know-how possessed by the population), which have a positive effect on a country's total wealth. Investments in human capital have shown to have had a huge impact on economic growth and the increase on prosperity in countries. Indeed, recent estimates indicate that over the last 25 years, the difference in economic growth between countries that invested the most in building human capital and those that invested the least is as much as 1.25 percent of GDP per year (Kim JY, 2017a b). Scaled up efforts to prevent road traffic injuries and fatalities, therefore, are fully aligned with and will actively support the achievement of two WBG global priorities: on one hand, it will contribute to the overall well-being, physically and mentally, for everybody in all countries as part of the progressive realization of universal health coverage; and on the other hand, to its recently-launched Human Capital Project , an accelerated effort to help countries invest more-and more effectively—in their people.

Next Steps for Policy Making

RTIs and their associated burden are largely preventable, if governments adopt, enforce and sustain proven measures. In Australia, the country's RTI mortality rate fell from 30 per 100,000 inhabitants in 1970 to 5 in 2010, as a result of policy interventions including the prohibition of drink-driving, the imposition of speed limits, and the introduction of road and car safety devices. Australia is not alone. Between 1990 and 2015, average RTI mortality declined from 22 to 8 per 100,000 inhabitants among all OECD countries.

Thus, although the large reductions in RTI mortality and injuries modelled for this study are ambitious, they are by no means out of reach. Such progress is well within the reach of an increasing number of countries, when evidence-based and determined action is taken.

To begin to comprehensively address the problem of road traffic injuries and fatalities, governments and international partners need to:

- Recognize that preventable injuries, premature mortality, and lasting disability, as well as the social and economic impacts stemming from road traffic crashes in low- and middle-income countries is unacceptable.

- Commit to implementing road safety measures that are: (a) sustainable, which requires proper sequencing and a long-term commitment; (b) integrated, which requires multisectoral and multidisciplinary engagement; and (c) inclusive, which considers country development objectives and recognizes that the poor and those thrust into poverty by road crashes have rights that deserve protection (WHO, 2017).

- Recognize the broader implication of reducing road traffic injuries as investment towards developing a framework for sustain able transport while at the same time achieving a net improvement in social welfare that will result from reduced direct costs borne by the health care and social insurance system as well as the indirect costs associated with absenteeism, productivity losses, and lose of human capital due to injuries, premature deaths, and lasting disability.

The findings of this report are only a first step, but they offer insights for policy deliberations. The report's welfare-based simulations could provide an input into future cost-benefit analyses, in that the "benefit" side of hypothetical RTI reductions are estimated—though without consideration of the costs involved for any given scenario. The development of robust and complete cost-benefit analyses will constitute a critical next step.

RTIs are leading but preventable causes of mortality and morbidity across the population.

The fact that there are cost-effective measures for prevention makes it an attractive policy target. Many RTI interventions such as safer infrastructure, better enforcement of speed limits, curbing drink driving and increasing helmet and seatbelt usage can be viewed as "low hanging fruit," and can serve as an immediate starting point, even in countries with low infrastructure/capacity levels, while other more resource and time-intensive interventions are scaled-up, more gradually anchored in robust "safe systems" to ensure long term sustainability of the effort as shown by the evidence from several developed countries.

In short, the road is open for leaders who commit to addressing RTIs, securing healthier lives for their people, boosting health capital and human capital accumulation, and hence the total wealth of countries.

"Traffic crashes kill more than 1.25 million people around the world each year and they also take a huge economic toll, with so much human potential being lost. Investments in road safety pay for themselves many times over, and hopefully this new report will spur governments to take actions that save lives"

Michael Bloomberg
philanthropist, three-term Mayor of New York City and entrepreneur

"The car crash alerted me to the possibility that the world can change in a flash for the worst"

Daniel Ellsberg
"Lunch with the FT"
Financial Times, December 8, 2017

"Our research shows that human capital is the most powerful engine for sustainable and inclusive economic growth…. human capital accounts for two thirds of a country's total wealth – far more than natural capital and produced capital"

Jim Yong Kim – President, World Bank Group
Universal Health Care (UHC) Forum Opening Session Remarks
December 14, 2017, Tokyo, Japan

PART ONE: INTRODUCTION

Road Traffic Injuries: The Shadow of Development

If road construction is the quintessential development project, then the increasing burden of road traffic injuries (RTIs) in developing countries shows how economic integration can transform not just everyday life, but also sickness and death.

Fifty years after the 19th World Health Assembly called for the World Health Organization to intervene in "the heavy losses resulting from the ever-increasing number of traffic crashes," RTIs are as common and as deadly as ever. Their burden has shifted, however, to low- and middle-income countries (LMICs). Each year, despite having only about half the world's motor vehicles, LMICs now suffer 90 percent of the worldwide toll of 1.25 million road traffic deaths and 20-50 million non-fatal road crash injuries. It will be a significant challenge to meet the U.N.'s Sustainable Development Goals Target 3.6 ("halve the global number of deaths and injuries from road traffic crashes by 2020").

The decline of RTIs in high-income countries was quite rapid. In 1966, the year of the World Health Assembly resolution on "prevention of traffic crashes" (WHA 19.36), the National Academy of Sciences attributed 1.7 million deaths in the United States over the previous six decades to RTIs. Motor vehicle fatalities, it reported, were increasing at a rate of three percent annually, making them the country's leading cause of death in people under 75 (NAS 1966: 8).

Ten years later, the global burden of RTIs had begun to tilt sharply toward the developing world. The increasing number of motor vehicles and greater traffic volumes in LMICs led to many more opportunities for crashes (Jacobs & Cutting 1986). Meanwhile, as governments and their development partners attempted to spur economic growth by constructing roads through rural areas, the toll of injury and death rose sharply, following the pattern in earlier settings of motorization (Sachs 1992). Researchers found that the death rate per vehicle was sharply higher in LMICs than in high-income settings, likely in part as a result of their inability to finance improvements in road design, maintenance and traffic enforcement (USAID 1980). By the mid-1970s countries like Peru, Panama, Jamaica and Guatemala were recording "spectacular" increases in traffic fatalities (Alvarez & Díaz-Coller 1977).

With RTIs spiking in the developing world, the trend line in high-income countries was moving in the opposite direction. Between 1990 and 2015, average RTI mortality in all OECD countries declined from 22 to 8 per 100,000. Australia, for example, lowered its RTI mortality rate from 30 per 100,000 inhabitants in 1970 to just five per 100,000 in 2010, as a result of largely common-sense policy interventions, including the prohibition of alcohol consumption while driving, the imposition of speed limits, and the introduction of road and car safety devices (Marquez 2017). By the early 1990s, an estimated 74 percent of global traffic fatalities were in LMICs (World Bank 1993).

While road safety has gained more prominence as a global public health concern, and ample evidence has emerged that government intervention in road design (e.g., median separation and crash barriers), vehicle safety (e.g., seatbelts and airbags), access to timely emergency medical care both at pre-hospital and facility levels, and behavior change through legislation and enforcement of existing regulations (e.g., lowering and enforcing speed limits and preventing drink driving) can reduce RTI deaths and injuries, the global burden of RTIs continues to rise. Many LMICs have made little progress towards clearly identifying the most-affected groups, the causes of crashes, or national strategies for reducing the incidence of injury and death (Marquez 2017). Ever-increasing motorization and urbanization in LMICs could further augment RTI rates in many countries in the years ahead (Marquez et al. 2009). Without appropriate preemptive action, an already bad problem is likely to get worse.

The global burden of RTIs has now reached alarming proportions, yet mitigation measures to lower it is known. So why isn't it happening? With many issues competing for government attention and investment, road safety too often slips down lists of priorities. Yet, there is evidence to suggest that RTI reduction is not simply an urgent public health priority, but also an economic one. Road safety is a prerequisite for stable and sustainable economic development. *Reframing the problem of RTIs in economic terms could be transformative, both among policymakers responsible for protecting the health and prosperity of their people, and among their development partners.*

[2] While in many societies men tend to be household breadwinners and typically are more attached to the labor market than women, over recent decades. Women have been participating increasingly in the labor force. In many developed countries, women's labor market participation rate is now at par with their male counterparts. Moreover, the proportion of women with high education levels is growing, and often females are, on average, more educated than males.

Economic Analysis of RTIs

There has long been assumed among policy analysts that road traffic injuries cause damage across the economy, well beyond the cumulative impact on households. There is little agreement, however, on how to demonstrate this phenomenon empirically.

The hypothesis that RTIs have macroeconomic ripple effects gains plausibility from the fact that they are more common among economically active people than within the population at large. Recent WHO estimates suggest that RTIs account for the greatest share of mortality and long-term disability among individuals aged 15-29 years, and a considerable toll among the working-age population as a whole, aged between 15 and 64 years (WHO 2015). Stark gender differentials may also be economically significant: three out of four road deaths are among men, the primary sources of cash income for households in many societies (GBD 2015 Mortality and Causes of Death Collaborators 2016; Marquez 2017).[2] Furthermore, rural areas often suffer a disproportionate burden from RTIs, a pattern that is again familiar from previous experience with motorization of transport, including in the United States (NAS 1966: 8). This could be understood to exacerbate human resources shortfalls in economically productive areas already partially depopulated by migration to cities.

This intuitive sense of a possible macroeconomic impact from RTIs has pervaded the literature of infrastructure planning in LMICs for at least fifty years, but evidence from a rigorous analysis is limited. One early survey claimed that although "the skilled and educated part of the population is a small proportion of the total" in developing countries, it was nonetheless "these people who have more chances of being involved in crashes, since they travel more than the average and they are the vehicle-owning section of the community. If they are killed or disabled, the loss to the community is a heavy one." (Hawkins 1960). This contention however was deductive and no effort was made to validate it empirically.

In general, claims about the economic impact of RTIs point to losses at the "micro" level, i.e., for the individuals and families killed and injured by road traffic crashes. There can be no question that road injuries are often catastrophic for crash victims and their households, particularly low-income households. An untimely crash event may also impede a family's progress in moving out of poverty, particularly when high out-of pocket payments are required to access medical care in countries without universal health coverage arrangements. But demonstrating how this carries over to the economy at large has presented a methodological dilemma since the earliest systematic national and multilateral efforts to reduce road traffic crashes in the 1960s. Analysts grappled with "enormous valuation problems in describing what it is worth to have the accident rate decline" (Wilson 1964).

Beginning in 1972, the Transport and Road Research Laboratory in the U.K. attempted to circumvent these difficulties by using an actuarial framework broadly compatible with recent "cost of illness" (COI) studies. This analysis valued the cost of traffic crashes (including both morbidity and mortality from RTIs and property damage) at about 1-2 percent of GNP annually across all developing countries. But due to limited data the project was forced to rely on a method that, by the researchers' own admission, excluded many cost categories typically used in high-income countries to evaluate traffic crashes, and it made no attempt to understand broader economic relationships (Jacobs & Sayer 1983; Downing et al. 1991).

A compelling case can be made that these more profound impacts of RTIs are likely to be highly significant. In addition to the toll road traffic crashes exact on human health, one may posit a variety of pathways, both short- and long-term, ranging from morbidity- and mortality-related lost productivity, to property effects and destruction, to increased out-of-pocket and public health care expenditures (McMahon and Dahdah, 2008). Today, however, key aspects of RTIs' economic effects remain incompletely understood.

Impact of Ill Health and Injuries on the Economy

There is increasing attention in the international development community to understand the economic impacts of RTIs to individuals, families, and societies, over and above the burden they cause to the public health (Mock, Nugent, Kobusingye, Smith, 2017). For example, a recent WHO analysis of eight countries in the East Asia and Pacific Region (Australia, Cambodia, Japan, the Lao People's Democratic Republic, Malaysia, New Zealand, the Philippines, the Republic of Korea, and Viet Nam) suggested that road trauma has a substantial negative macroeconomic impact in low-and middle-income countries, with losses to GDP ranging from 1.03 percent in the Republic of Korea to 2.9 percent in Vietnam (WHO, 2016).

What are the pathways through which this broader impact of RTIs on the economy could be felt? Clearly this question demands a consideration of macroeconomic harm from other kinds of diseases and injuries. The preamble to the 1946 WHO Constitution clearly positions health not only as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity", but also as one of the "fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition" (WHO 1946). The right to health has been codified as part of International Covenant on Economic, Social and Cultural Rights of 1966, and more recently, as one of the key goals of the 2030 Agenda for Sustainable Development (United Nations, 2015).

Among economists and public health specialists, it is now widely accepted as well that good health, free of injuries and disability, is an important component of human development, not only because it makes people's lives better, but also because having a healthy and long life enhances their ability to learn, acquire skills, and contribute to society (Sen 1999; WHO 2001). Good health among a population can also enhance economic performance by improving labor productivity and reducing economic losses that arise from illnesses and injuries (Sen, A. 2011; Smith, J. P. 1999; Case, A., Fertig, A., and Paxson, C. 2005; Bloom, D. E., Canning, D., and Sevilla J. P. 2004). The relationship between health and economic growth is clearly illustrated by evidence from global and country cases presented in Box 1. on page 19.

There are four channels through which good health, free of injuries and disabilities, could contribute to an economy and ultimately economic growth. These are: enhanced labor productivity; greater labor supply; education and training fostering higher skills; and more savings available for investment in physical and intellectual capital (Bloom, D. E., D. Canning, and D. T. Jamison. 2004). Also, as observed in different countries, as an economy grows, health improves.

Labor productivity. Healthier individuals could reasonably be expected to produce more per hour worked. On the one hand, productivity could be increased directly by enhanced physical and mental activity. On the other hand, more physically and mentally active individuals could make a better and more efficient use of technology, machinery, and equipment. A healthier labor force could also be expected to be more flexible and adaptable to changes (e.g., changes in job tasks and the organization of labor), reducing job turnover with its associated costs (Currie and Madrian 1999).

Labor supply. Somewhat counter-intuitively, economic theory predicts a more ambiguous impact of health on labor supply. The ambiguity results from two effects working to offset each other. If the effect of poor health is to reduce wages through lower productivity, the substitution effect would lead to more leisure and therefore lower labor supply as the return for work diminishes. On the other hand, the income effect would predict that as lifetime earnings are reduced through lower productivity, the individual would seek to compensate by increasing the labor supply. The income effect is likely to gain importance if the social benefit system fails to cushion the effect of reduced productivity on lifetime earnings. The net impact of the substitution and income effects ultimately becomes an empirical question (Currie and Madrian 1999).

Education. Human capital theory suggests that more educated individuals are more productive (and obtain higher earnings). If children with better health and nutrition attain higher education and suffer less from school absenteeism and dropping out of school early, then improved health in youth would contribute to future productivity. Moreover, if good health is also linked to longer life, healthier individuals would have more incentive to invest in education and training, as the rate of depreciation of the gains in skills would be lower (Strauss and Thomas 1998).

Savings and investment. The health of an individual or a population is likely to impact not only the level of income but also the distribution of income among consumption, savings, and investment. Individuals in good health are likely to have a wider time horizon, so their savings ratio may be higher than that of individuals in poor health. Therefore, a population experiencing a rapid increase in life expectancy may be expected, other things being equal, to have higher savings.

While the above mechanisms clearly suggest that health improvements are associated with higher

BOX 1:
Economic Justification for Investments in Health

Different studies have explored the impressive economic gains that countries are likely to derive from investment and effective action on health similarly to the results presented in this report for RTIs. These studies are based on economic impact simulations that use market valuations and the economic payoff is depend on what proportion of anticipated costs will be averted.

Economic Value of Dealing with Drug-Resistant Infections at the Global Level (Jonas et al, WBG 2017). The cost of AMR containment measures is estimated at $9 billion annually in low- and middle-income countries. The recommended investments in AMR containment are justified according to two key economic criteria. First, the test of net present value (NPV) is unambiguously satisfied. Even when discounted, the values of the net benefits of AMR containment that reduces costs by 50 percent range from very large in the low-AMR scenario with a high discount rate ($5.8 trillion, discounted at 5.5 percent), to extremely large in the high-AMR scenario with a moderate discount ($26.8 trillion, discounted at 3.5 percent), to enormous ($42.2 trillion) in the high-AMR scenario when the 1.4 percent annual discount rate is adopted. The second test of the investment case for AMR control considers the expected economic rate of return (ERR) on the $9 billion annual investment. Assuming that investments would be made for seven years before any benefits materialize, the ERR ranges from 31 percent annually (if only 10 percent of AMR costs can be mitigated) up to 88 percent annually (if 75 percent of AMR costs are avoided). The chance to obtain returns of this magnitude constitutes an exceptional investment opportunity for countries.

Stemming the Rise of Non-Communicable Diseases in China (Wang, Marquez, Langenbrunner, WBG, 2011).
Non-communicable diseases (NCDs) are the leading cause of ill health, premature mortality, and disability in China. By adopting effective policies and interventions across sectors would enhance the health and welfare of China's population. At the microeconomic level: A change in adult health status can result in a 16 percent gain in hours worked and a 20 percent increase in individual income. Tackling NCDs, on top of being a valuable health investment, may thus be seen as an investment into people's productivity and hence their earnings potential. At the macroeconomic level: Reducing mortality from CVD by 1 percent per year over a 30-year period (2010–2040) could generate an economic value equivalent to 68 percent of China's real GDP in 2010, more than US$10.7 trillion at purchasing power parity. The society-wide 'economic costs' of NCDs are even larger if the value which people attribute to health is captured. Reducing CVD mortality by 1 percent per year produces – if the intrinsic value that is attributed to life is measured – an annual benefit of about 15 percent of China's 2010 GDP (US$2.34 trillion at purchasing power parity), while a 3 percent reduction would amount to an annual benefit of 34 percent (US$5.40 trillion at purchasing power parity).

Addressing Premature Mortality and Ill Health Due to Non-Communicable Diseases and Injuries in the Russian Federation (Marquez, Suhrcke, Rocco, et al, WBG, 2006). Poor adult health due to NCDs negatively affects economic wellbeing in Russia.

Cost of absenteeism: On average, 10 days per employee per year are lost due to illness in Russia, while in the EU-15 the average is 7.9 days. Sickness absence incurs a direct cost from benefits paid to absent employees and an indirect cost of lost productivity. The overall cost varies between 0.55 percent and 1.37 percent of GDP (annual absenteeism rates can be converted into a monetary value either by using the average wage rate, resulting in the lower value, or the GDP per capita, resulting in the higher value).

Impact on the labor supply: Ill health also impacts labor supply because jobholders with chronic diseases or alcoholism are more likely than healthy individuals to either retire early or lose their jobs and draw on state pensions.

Impact on the family: The death of a household member affects other household members' welfare and behavior in various ways. Alcohol consumption was found to increase by about 10 grams per day as a consequence of the death of an unemployed household member and by about 35 grams if the deceased had been employed. Also, the probability of suffering depression increased by 53 percent when controlling for other relevant factors. Chronic illness has also negatively affected household incomes.

With mortality (morbidity was not included) due to NCDs and Injuries, the economic impact was estimated as:

- The static economic benefits (i.e., valuing a year of life by one GDP per capita) of gradually bringing the adult NCD and injury mortality rates down to the EU-15 rates by 2025 were estimated to be equivalent to 3.6 percent and 4.8 percent of the 2002 Russian GDP.

- When a broader concept than GDP per capita is considered (measured by adding the value of changes in annual mortality rates using a "value of a statistical life" to changes in annual GDP per capita), the "welfare" benefits from achieving EU-15 rates by 2025 are estimated to be as high as 28.9 percent of the 2002 Russian GDP.

rates of growth, empirical growth literature findings also show that mortality and related sources of fatalities (other than suicides) show a "procyclical fluctuation," that is, they tend to increase during periods of economic growth. The variations are largest for those causes and age groups which may be affected by changes in behavior, and there is some evidence that the unfavorable health effects of temporary increases in mortality are partially or fully offset if growth is long-lasting.

For example, a recent analysis of microeconomic data indicated that when the economy strengthens, smoking and obesity increase, whereas physical activity is reduced and diet becomes less healthy (Ruhm, 2000). In addition, research on the changing relationship between health, income, and the environment in the United States, shows that scientific advances have played an outsize role, that health improvements were largest among the poor, and that health improvements were not a precondition for modern economic growth (Costa, 2015).

These findings suggest that gains to health are largest when the economy has moved from "brawn" (mostly agricultural production) to "brains" (mostly industrial and information-economic production) because this is when the wage returns to education are high, leading the healthy to obtain more education. In other words, more education may improve use of health knowledge, producing a virtuous cycle (Costa, 2015).

Recent research using data from over 100 birth-cohorts in 32 countries, shows that booms from birth to age 25, particularly those during adolescence, lower adult mortality. The research also indicates that economic conditions may affect the level and trajectory of both good and bad inputs into health in different ways depending on the setting. While pollution and alcohol consumption increase in booms, booms in adolescence raise adult incomes and improve social relations and mental health, suggesting these mechanisms dominate in the long run (Cutler, Huan, Lleras-Muney, 2016).

The Purpose of this Report

This report attempts to lay the groundwork for a more comprehensive economic evaluation of RTI reduction strategies by estimating both their macroeconomic impact (on rates of GDP per capita growth) and contribution to welfare (in terms of costs and benefits). The two types of economic analysis are complementary, though because the estimated magnitude of the effect differs, they are not directly comparable to each other. In the report, *analysis is presented for five LMICs: China, India, the Philippines, Tanzania, and Thailand*.

When this analysis was initially undertaken, it was not clear what results were to be expected. Although RTI-related deaths and disability-adjusted life years cause considerable, and avoidable, harm, they nevertheless represent a relatively small share of all-cause mortality and morbidity (around 5 percent on average in the countries considered here). Meanwhile, although the victims of RTIs are disproportionately young, meaning that road injuries necessarily cause the loss of many life years at the scale of society, it may nonetheless be impossible to demonstrate substantive growth effects.

One reason is that a macroeconomic assessment approaches the economic system holistically, aggregating the contribution of all participants to the system in order to estimate the national output and its rate of growth. So, for instance, the production lost because of a road crash can in principle be promptly compensated by the contribution of individuals who previously were either employed in less productive tasks, under-employed, or else fully unemployed and out of the labor force. In other words, the natural dynamics of an economic system might promptly replace any workforce lost to RTIs. As so often with economic questions, it depends on the particularities of the setting.

Another reason why the demographics of RTI burden may not self-evidently point to macro-economic impact is that the economic productivity of younger populations is uncertain. On the one hand, they have great potential to contribute to the national income. Similarly, morbidity among younger people might be more detrimental to the prospects of economic growth than morbidity among the more senior, because injured or disabled young people would require support from the health care system for a longer time. On the other hand, younger people are also those with less experience in the labor market, and can be easily replaced in the workplace by drawing from the reserve of youth unemployment that exists in many countries.

What the analysis set out to measure, then, were effects of RTIs on economic growth *for which the economy cannot compensate automatically*. For instance, individuals removed from the workforce by RTIs might possess job-specific human capital, and those who filled these vacancies in the workforce might not be as productive as the victims, at least in the short run.

Recent economics literature on the relationship between population health proxies like life expectancy and adult mortality, and economic growth is ambiguous and contradictory, compounding our uncertainty at the outset. One widely-cited paper by Acemoglu and Johnson (2007) found unexpectedly that, in 47 countries for which relevant data were available, higher life expectancy leads to *lower* per-capita GDP. On the other hand, an equally rigorous paper, Lorentzen, McMillan and Wacziarg (2008) came to the opposite conclusion: based on a larger sample of 88 countries, it found that lowering adult and infant mortality leads to *higher* per-capita income growth.* This research has given rise to further studies, some of which try to reconcile the opposing findings (Aghion, Howitt & Murtin 2011; Cervelatti & Sunde 2011a, b). Yet the bottom line remains that based on the current, nuanced evidence on the relationship between general health indicators and economic growth, one cannot readily expect that a comparatively small sub-set of health like RTI mortality and morbidity will have a major impact on economic growth.

In this report it is stressed, that even if the economic growth impact of reducing RTIs turned out to be negative or insignificant, this would not detract from the "value for money" argument for RTI-reduction efforts. The "value for money" can only be determined through a cost-effectiveness or cost-benefit assessment of specific interventions or policies to address RTIs (see e.g. Chisholm et al. 2012). It is the consideration of such economic evaluation approaches that should ultimately inform priority setting and resource allocation among the potential RTI policies, and between RTI policies and other health policies. The goals of this study were more modest: to see whether different types of economic analysis, undertaken in tandem, can help reframe the policy discussion on road traffic injuries.

Welfare Assessment

In contrast to the macroeconomic assessment, welfare benefit assessment has been widely used in the transport and road traffic-related literature. This approach is at least in principle capable of capturing a broader view of the economic *benefits* of reducing RTIs (or the present *costs* of RTIs). Several guidelines and authoritative methodological contributions recommend the use of this approach in the case of RTIs (see e.g. Dahdah and McMahon 2008; Vecino-Ortiz and Hyder 2014), especially when it comes to cross-country analyses (Bhalla et al. 2013). While welfare impact assessment can hardly be considered a "macroeconomic" assessment, it undoubtedly represents a key workhorse of economic evaluation in the RTI field (as in many other domains of public policy) and does capture some "macro" level information on the burden of RTIs.

The welfare assessment has two main parts: the sheer health effects (in terms of mortality and possibly morbidity) and the monetary valuation of these health effects. Thus, in contrast to the a priori uncertain sign of the economic growth impact, the welfare benefits of any reduction in RTIs will certainly be positive. It is important not to understate the differences between the welfare and the economic growth approach. While both are expressed in monetary terms, the growth impact focuses on economic benefits that enter the GDP calculation (and are affected by reductions in mortality and morbidity). By contrast, the welfare benefit seeks to capture what it would be worth to people to reduce the risk of mortality and morbidity. The latter likely far exceeds all that enters GDP, because we value better health for much more than the narrow productivity gains it may entail. The intangible value we assign to health is not at all captured in the growth effect estimates.

What This Report Does *Not* Do

One method that has sometimes been applied to RTIs in the public health literature is the "cost-of-illness" (COI) approach. The term COI encompasses a wide variety of studies aimed at assessing the direct and indirect costs incurred due to road traffic injuries (see e.g. Garcia-Altes and Pérez 2007). Examples of direct costs include medical treatment (e.g. ambulance and hospital costs) and funeral costs. Examples of indirect costs include the income foregone due to the

* For a fuller review of the literature on this topic see Appendix 5.

loss of wages when a person cannot return to work because of disability or death. The uses—and the limitations—of COI studies in general (Chisholm et al. 2010) and for RTIs specifically (Bhalla et al. 2013) have been well described. Although their findings are often expressed as a share of GDP, thereby giving the impression that they would capture a macroeconomic cost to national income, this is in fact not justified.[3] Therefore, the COI approach was not assessed in this report.

The report also does not address the "microeconomic" consequences of RTIs, i.e. their impact at the individual or household level on employment opportunities, earnings, or wages. Typically, studies of these phenomena employ regression-based approaches that allow researchers to control for potential confounders as well as – ideally – for endogeneity in the relationship between the health issue in question and the relevant economic outcome (e.g. employment probability, earnings, income). While this approach has successfully been applied in many areas of health (Currie and Madrian 1999), it remains rare in the RTI context, possibly because few standard household surveys capture road traffic injuries (see Alam and Mahal 2016 for a household-level impact study).

How achievable are the RTI Reduction Scenarios?

The intervention scenarios used in the simulations posit large reductions in road traffic deaths and injuries in the five countries and may seem optimistic. However, these scenarios are not unreasonable, considering historical experience and the availability of interventions proven effective in cutting road traffic injuries and deaths. Even though RTIs are not one of the leading causes of total mortality and morbidity, what makes them an attractive policy target is that they are largely preventable. Furthermore, key RTI interventions, including engineering and non-engineering measures, are relatively straightforward to implement using knowledge transfer from countries who have successfully done so. Known policies have great potential for reducing the probability of road crashes and their severity, as illustrated by the experience of many high-income countries. So, it is reasonable to imagine sizeable future cuts in RTI mortality and morbidity and to evaluate their economic benefits in terms of additional long-run growth rates.

[3] For example, payments for medical treatments (i.e., "direct costs") of injuries are not in themselves a loss of GDP, but are very much part of GDP.

PART TWO: FINDINGS

The Economic Impact of Reducing Road Traffic Deaths and Injuries

Data for this analysis were drawn from five low and middle-income countries (LMICs): China, India, the Philippines, Tanzania, and Thailand. While results from five countries cannot be generalized to all LMICs, the countries selected here are geographically, demographically, and economically diverse, and results obtained in these five cases may have suggestive value for many countries.

The analysis used economic simulations to measure: (1) the change in national income (measured as per capita GDP) that the five countries would see under different scenarios of reduction in RTI mortality and mortality + morbidity; and (2) the effects of substantial reductions in road traffic mortality on economic measures of welfare in the study countries. For these five LMICs, we have estimated the macroeconomic benefits of cutting road traffic mortality and morbidity by 25, 50, or 75 percent. We have also estimated the welfare gains countries could achieve by reducing road traffic deaths. We found that reducing RTIs can make a small but significant contribution to the growth rate and level of per capita income of the countries.

For instance, our results indicate that halving RTI mortality and morbidity over a period of 24 years could generate an additional flow of income equivalent to 7.1 percent of 2014 GDP in Tanzania, 7.2 percent in the Philippines, 14 percent in India, 15 percent in China and 22.2 percent in Thailand, the country among the five with the largest scope for reducing RTIs.

Background: Health Patterns in the Five Countries

What are the characteristics of the five countries in our survey? Their populations are both more likely to die early and more likely to die from RTIs than people in high-income countries. But the five study countries also vary considerably. Overall, RTI mortality and morbidity account for a relatively small proportion of total mortality and morbidity in the working-age population (and for even less in the total population) in these five countries. The proportion of deaths due to RTI out of all deaths in the 15-64 age group ranges between 2.6 percent in Tanzania and 7.8 in China; the proportion of DALYs due to RTI ranges between 2 percent in Tanzania and 6.1 percent in Thailand.

Life expectancy at birth and healthy life expectancy complete the overview of the countries' health conditions, giving us a "big picture" sense of population health status in these contexts. China and Thailand score relatively well compared to the OECD countries, while India, Philippines, and especially Tanzania lag markedly. China's and Thailand's achievements are particularly remarkable if we consider that their per capita GDP is about one-third of that in OECD countries.

It is useful to track the relative importance of RTIs as a cause of mortality in the different countries over time. These trends further underscore a diversity of country experiences. In Tanzania, road crashes' relative impact as a cause of mortality changed little between 1990 and 2015. In the Philippines, RTIs rose from the 17th to the 13th rank among the country's causes of death.

In contrast, in Thailand, road injuries stood as the country's fourth leading cause of mortality in 1990, but had dropped to eighth place 25 years later.

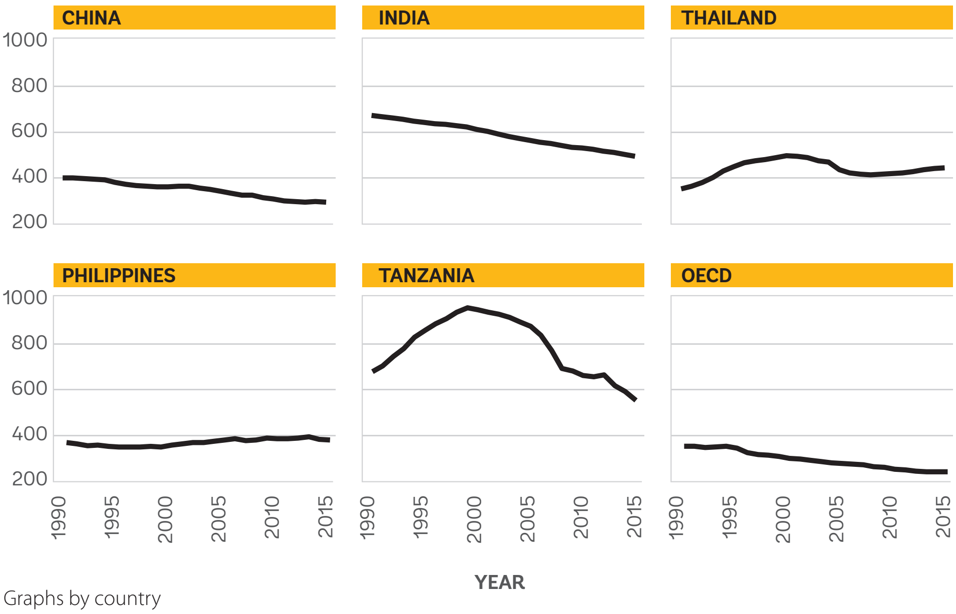
Total mortality and RTI mortality are larger in China, India, Thailand, Philippines, and Tanzania than in the developed OECD countries (Figure 1and Figure 2). However, there is also considerable heterogeneity within the group. In 2015 China had the lowest all-cause mortality rate among the five (306). This rate had steadily declined since 1990 from an already relatively low figure. Conversely, Tanzania, which suffered from the HIV/AIDS epidemic, had a mortality rate which was more than twice as high as that of OECD countries (534 versus 241).

Regarding RTI mortality, in OECD countries the trend has been steadily declining over the past quarter-century. In the five countries analyzed here, in contrast, RTI mortality remained roughly stable during that period. In 2015, the RTI mortality rate in our countries was a multiple of the OECD average rate except in Tanzania, whose RTI mortality rate was nonetheless considerably higher than that in OECD countries.

Figure 3 and Figure 4 provide another perspective on trends in road traffic deaths in two of our study settings, again underscoring the diversity of experiences among these countries. Road deaths in India increased steadily between 1990 and 2015, and the burden and impact of RTIs in India are likely to be much higher than reported in the official statistics. Independent studies have shown underreporting of deaths by 10 to 30 percent and serious injuries by 50 percent (different studies cited by Hijar, Chandra, Perez-Nunez, et al, 2012). In China, a rising curve has given way to a downward trend since about 2005, but still more than 260,000 RTI deaths were estimated to have occurred in 2013 (WHO, 2016).

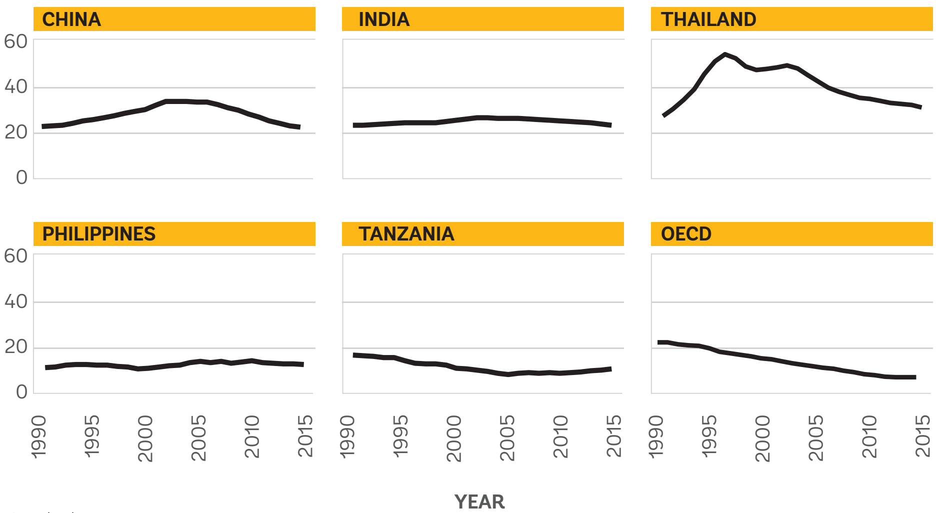
In assessing the situation in the five countries, however, it is important to keep in mind that for every RTI death, nearly 20 to 30 people are likely to be admitted to the hospital and some 50 to 100 more will probably receive emergency medical care (Peden et al, 2004). In addition to emergency medical care, those involved in RTIs may require longer-term health and rehabilitation care as well. Economic growth and increasing motorization, therefore, are likely to be associated with an increased burden of RTIs if appropriate policy measures and interventions are not adopted.

Figure 1. All-Cause Mortality Rate (Deaths per 100,000 Inhabitants Aged 15-64), by Country



Graphs by country

Figure 2. RTI Mortality Rate (Deaths per 100,000 Inhabitants aged 15-64), by Country



Graphs by country

Figure 3. Road Traffic Deaths, India, 1990-2015. Source: Global Burden of Disease 2015

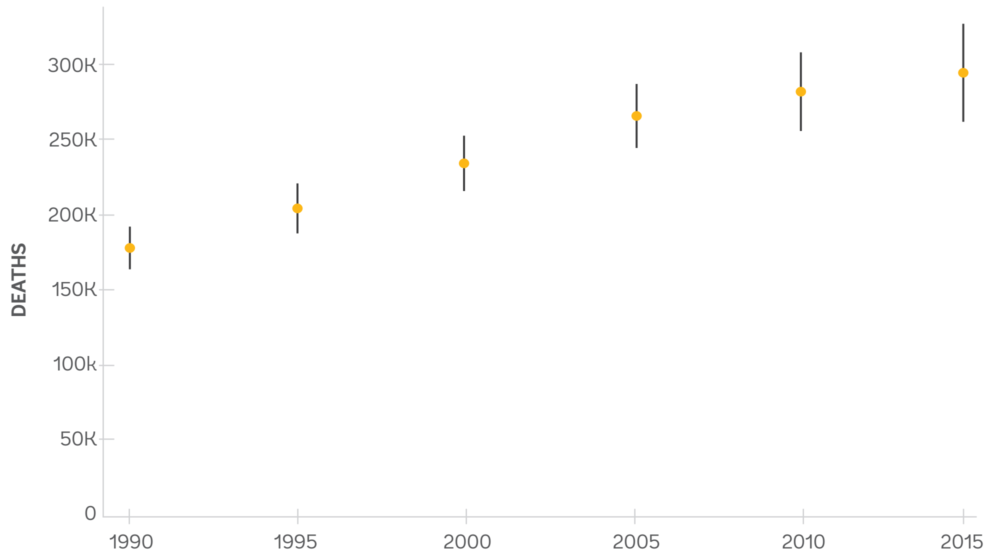
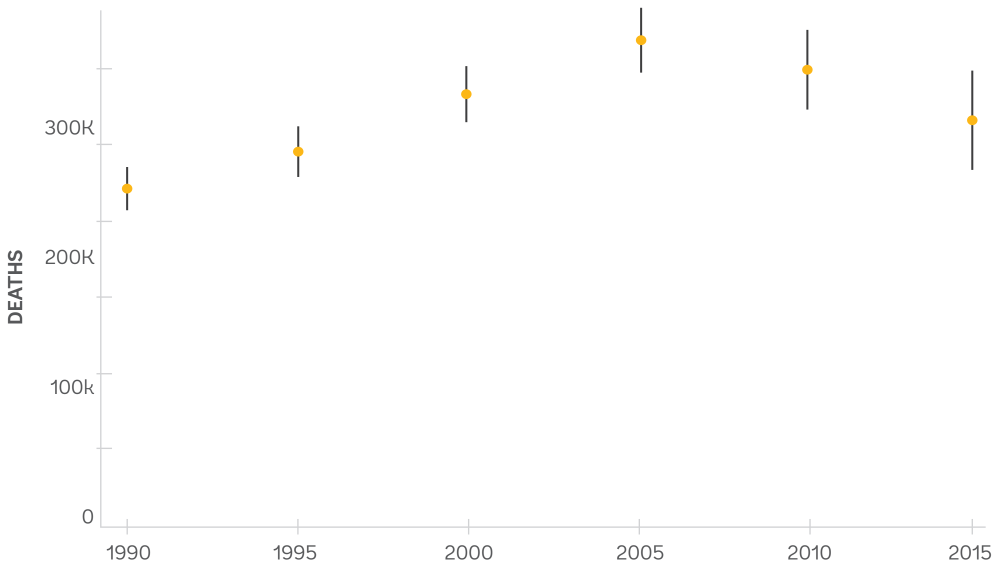


Figure 4. Road Traffic Deaths, China, 1990-2015. Source: Global Burden of Disease 2015



The Effect of RTIs on Economic Growth[4]

The first task is to understand how RTIs influence national income and economic growth. Building on this, it can then – under certain assumptions and using a simulation exercise – predict how countries' future incomes would change, were they able to reduce the RTI mortality rate and RTI injuries (as captured in DALYs) under different scenarios.

To answer this, the study used economic simulations to predict the gains in long-run economic growth that would be expected to result from reducing the RTI mortality rate and RTI injuries (as measured in DALYs) under different scenarios.

The simulations in this study started from 2014, the most recent year for which complete information on all the variables included in the models is available. To show the effects of interventions, we compare them to a "no-intervention" (or "status quo") scenario, created by predicting countries' real per capita GDP growth for the subsequent 24 years (i.e., between 2014 and 2038), if all covariates, including mortality and morbidity, remained at their 2014 level.

The status quo trajectory was compared with three hypothetical scenarios, in which countries reduce their average RTI mortality and injury rates by 25, 50, or 75 percent, respectively. These intervention scenarios are designated as 'moderate,' 'median,' and 'optimistic.'

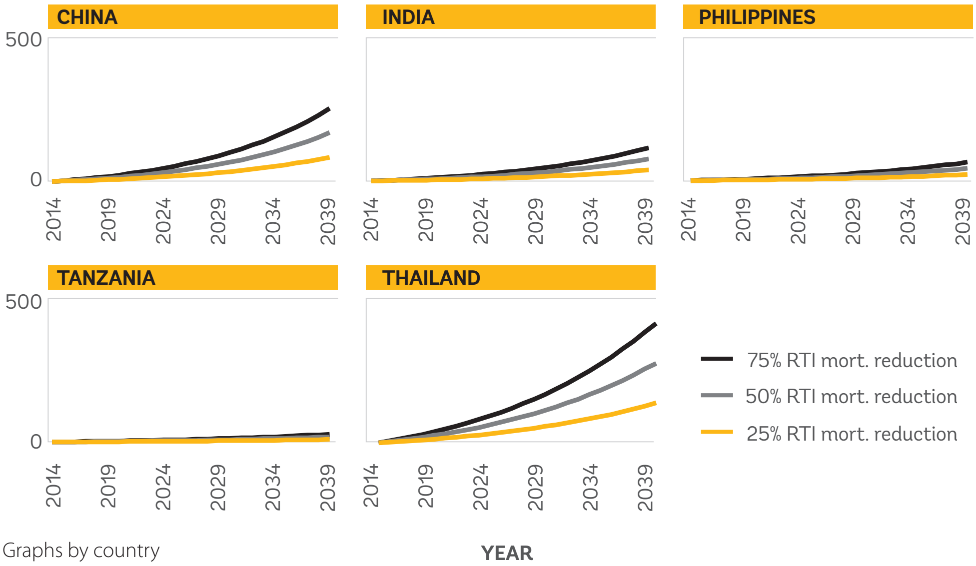
Reducing Road Traffic Mortality Would Boost National Income

Our models show that reducing deaths from RTIs would have a notable positive effect on economic growth in all five countries analyzed. The size of the effect differs across countries. But all would experience significant income gains. Larger RTI reductions lead to higher income benefits. Reducing road crash injuries along with deaths further strengthens countries' economic growth gains. Thus, over our 2014-2038 simulation period, halving RTI mortality and morbidity has the potential to produce an additional flow of national income as large as 7.1 percent of 2014 GDP in Tanzania, 7.2 in the Philippines, 14 in India, 15 in China and 22.2 percent in Thailand, the country with the largest scope for reducing RTIs.

Figure 5 shows the results of the simulation of reducing RTI mortality, holding everything else constant. For each year between 2014 and 2038, the additional income per capita that would result from moving to each intervention scenario (a reduction of 25, 50, or 75 percent in RTI mortality) from the status quo scenario is computed. Income gains would result from the additional yearly growth rate.

[4] For the full analysis see Appendix 1.

Figure 5. Estimated GDP per capita Gain Associated with a Reduction of RTI Mortality, by Year and Intervention Scenario (in US$ per capita). Note: Real GDP at constant national prices (in 2011 US$).



The example of China may serve to illustrate the magnitude of the numeric findings: China's predicted long-run growth from 2014 to 2038 in the status quo scenario is 258 percent, equivalent to 5.4 percent annually. A reduction in RTI mortality of 50 percent will imply a reduction of all-cause mortality by 3.9 percent. Using formulas explained in the full report, the study calculates that this lower RTI mortality will produce an additional predicted economic growth of 1.36 percentage points for China in the long run, that add to 258 percentage points of the status quo scenario, corresponding to an additional yearly growth rate of about 0.02 percent.

More Lives Saved Mean Bigger Benefits

More optimistic scenarios correspond to higher income gains and, since the effect of additional annual growth accumulates over time, income gains exponentially increase as they approach the end of the period. A different way of expressing the expected economic gains is in the form of the discounted sum of all income gains by intervention scenario, using a 2 percent annual discount rate, and relating these numbers to the countries' respective real per capita GDP figures for 2014 (see Box 2 for discount rate sensitivity analysis)

It turns out that reducing RTI mortality by 25 percent will produce a flow of additional future income over 24 years that ranges between 2.5 percent of 2014 per capita GDP in the Philippines and 7.3 percent in Thailand. The stronger reduction of RTI mortality implied by the median scenario will produce total income gains ranging between 4.7 percent in the Philippines and 14.6 percent in Thailand. Finally, in the optimistic scenario (a 75 percent reduction in RTI deaths), the highest income benefits accrue to Thailand, at 21.9 percent. In this scenario of outstanding achievement in RTI mortality reduction, all five countries would show substantial income gains: 7.0 percent in the Philippines, 8.6 percent for Tanzania, 14.1 percent in China, and 14.9 percent for India, rounding out the picture.

Reducing Road Injuries Along with Deaths: Even Bigger Gains in View

Benefits of reducing both RTI mortality and morbidity are significantly larger than those estimated when looking at RTI mortality alone. Specifically, the moderate scenario yields returns in terms of faster economic growth that range between 3.5 percent of 2014 real per capita GDP in Tanzania and 11.1 percent in Thailand. These numbers double and triple in the median and optimistic scenarios.

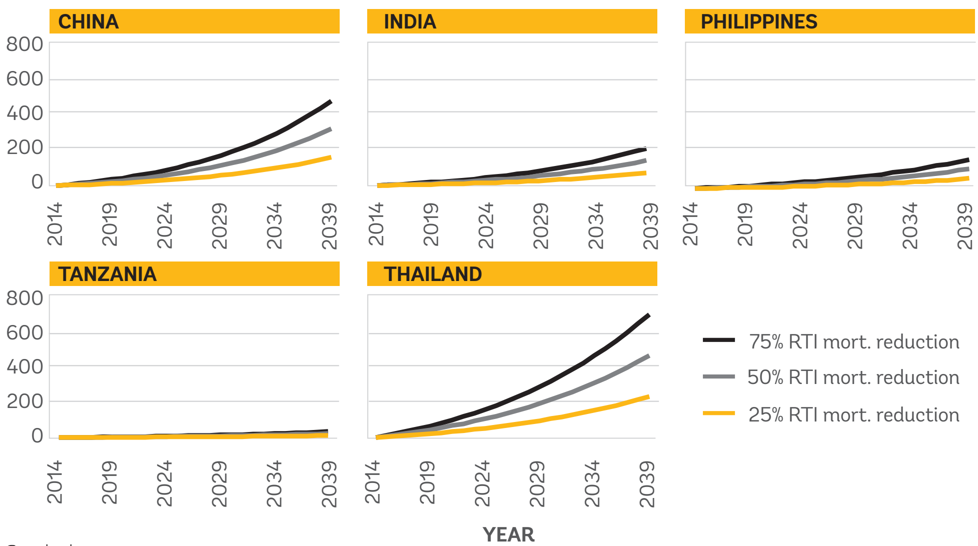
Halving RTI mortality and morbidity has the potential to produce an additional flow of income as large as 7.1 percent of 2014 GDP in Tanzania, 7.2 in the Philippines, 14 in India, 15 in China and 22.2 percent in Thailand, the country with the largest scope for reducing RTIs, over the period between 2014 and 2038 (shown in Figure 6).

Effects Will Differ Across Countries

Across all scenarios, benefits from reducing road traffic deaths are consistently the smallest in Philippines, because RTI mortality there is already low, and little margin exists for further reduction. The opposite is true for Thailand, which has the highest RTI mortality rate among the five countries.

In the case of reductions in both RTI deaths and injuries, cross-country differences depend on the different starting levels of RTI DALYs and on the variation in the importance of RTI compared to other causes of mortality and morbidity.

Figure 6. Estimated GDP per capita Gain Associated with a Reduction in RTI DALYs, by Year and Intervention Scenario (in US$ per capita). Note: Real GDP at constant national prices (2011 US$)



Graphs by country

BOX 2:

Sensitivity of income growth results to discount rate selection

The social discount rate is one of the key parameters used for predicting the long-term GDP per capita gain as a function of RTIs reduction as detailed in Appendix 1. The Impact of RTIs on Economic Growth. The social discount rate measures the rate at which a society would be willing to trade present for future consumption (Lopez, 2008). The higher the discount rate, the smaller is the present value of future amounts. In the context of using a social discount rate it must be understood that social welfare is not the same as standard of living but is more concerned with the quality of life that includes factors such as healthy life expectancy, the quality of the environment (air, soil, water), level of crime, extent of drug abuse, availability of essential social services, as well as religious and spiritual aspects of life. The rate of discounting has a large effect on which age group is perceived to be best off over time.

The literature reports on a wide range of discount rates used for economic evaluation of illness and injuries. Given that the healthy life expectancy of the population is increasing, countries such as the Netherlands and France use the lower 1.5% and 2% rates, respectively, so the future value of benefits is not being diminished too greatly to the present value. That is, the "consumption" of a health life year without injuries or disability due to averted RTI at present is as valuable the "consumption" of a healthy life year in the future. However, in cost-effectiveness analysis, often a higher discount rate has traditionally been recommended. For example, the WHO manual for estimating the economic costs of injuries due to interpersonal and self-directed violence uses a discount rate of 3 percent, and the National Institute for Health and Care Excellence [NICE] uses a discount rate of 3.5 percent. In current study a rate of 2 percent was used based on Moore & Viscusi 1990. Further, Table 1 presents the sensitivity analysis when higher discount rates of 3 percent and 5 percent are used for the scenario with 50 percent reduction in RTI mortality and DALYs averted. Therefore, in terms of DALYs averted, while a 2 percent discount rate predicts gains in GDP per capita in the range of 15 -22.2 percent, the same range is reduced to 9 to 13.5 percent when a discount rate of 5 percent is used.

Table 1. Discount rate sensitivity to predicted GDP per capita (GDPpc) gain with 50 percent reduction in RTI mortality and DALY averted

Discount Rate	Additional GDPpc gain from 2014 to 2038 for 50% reduction in RTI mortality)				
	China	India	Philippines	Tanzania	Thailand
2%	9.4%	10.0%	4.7%	5.7%	14.6%
3%	7.9%	8.4%	3.9%	4.8%	12.3%
5%	5.6%	6.0%	2.8%	3.5%	8.9%
Discount Rate	**Additional GDPpc gain from 2014 to 2038 for 50% reduction in RTI DALYs)**				
	China	**India**	**Philippines**	**Tanzania**	**Thailand**
2%	15.0%	14.0%	7.2%	7.1%	22.2%
3%	12.6%	11.8%	6.0%	6.0%	18.7%
5%	9.0%	8.5%	4.3%	4.3%	13.5%

Assumptions and Limitations

The macroeconomic analysis in this study has several limitations and rests on certain assumptions, which need to be borne in mind when interpreting the findings. Most importantly, our predictions for each single country are extrapolated from the average past performance of a sample of 135 countries. While the analytic procedure used prevents distortions due to differential effects of mortality and morbidity in high-income countries or in the global regions where this study's countries are situated, the possibility that the relation between mortality and morbidity on the one hand and economic development on the other follows country-specific patterns that our analysis does not capture, cannot be excluded.

Estimating the Impact of RTIs on Welfare Measures: An Input for Policy[5]

To decide whether an intervention is good "value for money", policy makers should assess whether the gains obtained will at least equal the costs of implementing the measure. Direct costs are often relatively straightforward to calculate, but estimating benefits can be complex. A welfare analysis is required to develop the "benefit" piece of the cost-benefit comparison. The second part of our study aims to quantify the welfare gains countries could obtain from successful RTI prevention.

Background: Placing a Value on "Statistical Life"

Economists have created an important analytic concept to help quantify the welfare benefit generated by a health policy. This is the "value of a statistical life" (VSL). This concept allows us to place a monetary value, for statistical purposes, on a life saved through a policy measure (an RTI prevention program, for example). In the more elaborated analysis (Appendix 2), the following aspects are discussed: (i) theory behind the VSL, (ii) the discomfort people may feel with the concept when its meaning is imperfectly understood; and (iii) the VSL's significance for evidence-based policy making.

Applying the VSL concept is critical for calculating the benefits that may be obtained from policies and interventions, so decision makers can accurately compare benefits and costs.

Working Around Data Gaps

Ideally, to estimate welfare benefits for any given country, we would use VSL figures specifically derived within that country. Unfortunately, for many LMICs, including those covered in this study, reliable VSL estimates are not available. Hence the need and the approach in the present study to employ a set of alternative approaches. Our strategy involves using four different statistical "rules of thumb" that incorporate different values for countries' respective VSLs. This procedure allows us to set upper and lower boundary values for the benefits that would be expected from RTI reductions in each country. Despite gaps in country-specific data, this approach can still provide us with a "ballpark sense" of the magnitude of economic benefits countries can expect from successful RTI control.

For the lower boundary values, a measure based on work by Milligan et al. (2014) was used, that suggests a VSL for LMICs for applications in transport safety. To set an upper boundary value for countries' potential gains, VSL values of US$3 and US$5 million have been used, roughly in line with the values researchers have applied in wealthy countries like the United States (Viscusi and Aldy 2003).

How Much Could Countries Gain?

Using each of the four statistical "rules of thumb," the study computed the value of the gains obtained in each country by reducing RTI mortality by 25, 50, or 75 percent. Those values are expressed as a share of GDP.

[5] For the full analysis see Appendix 2

A first fundamental observation is that results vary considerably, depending on the "rule of thumb" applied. This confirms that, in the current state of knowledge, it's better to report upper and lower bounds, rather than try to advance a single number for the welfare benefits countries might expect to see in each scenario.

Lower bound: Using the Milligan et al. (2014) approach, VSL estimates range from $1.81 million in Thailand to $5,283 in Tanzania. Such values are low compared to the ones estimated for developed countries. Therefore, the value of the gain obtained by reducing RTI mortality by 25, 50 or 75 percent as a share of GDP ranges from 0.19 percent for Tanzania in the case of a 25 percent mortality cut (least optimistic case) to 45.7 percent for Thailand assuming a 75 percent mortality cut (most optimistic case).

Upper bound: To define an upper boundary for the expected welfare benefits, VSL values of US$3 million and $5 million were used. These values are close to the low end of the VSL estimated by Viscusi and Aldy (2003) for the United States in 2000 dollars. With a VSL of $3 million, the gains in terms of GDP in international 2005 prices now range from 19.9 percent in Philippines in the least optimistic scenario (25 percent mortality reduction) to 329 percent in Tanzania for the most optimistic scenario (75 percent mortality drop). Adopting a VSL of $5 million, the GDP gains range from 33 percent in Philippines in the least optimistic case to 547 percent in Tanzania for the most optimistic case.

We can be reasonably confident that, for each RTI-reduction scenario, the actual welfare benefits countries would lie between the lower and upper boundary values defined by this procedure. While these results must clearly be refined, they can already provide rough inputs for initial policy discussions, and they can spur further work.

Limitations

As noted, the major limitation on this study's welfare analysis is the absence of reliable VSL measures for the relevant countries, as for most LMICs. It is also important to acknowledge several factors that have probably caused this study to underestimate the welfare benefits countries would obtain from reductions in RTI mortality. To begin with, VSL figures themselves are likely to be underestimates. In addition, the figures on RTI mortality could be underestimated or at least incomplete for the countries we focus on, adding to the concern that the resulting welfare benefits are distorted downwards. Furthermore, our estimates refer to RTI mortality only and exclude RTI morbidity, which is certainly a major component of the total RTI burden.

These figures may at first glance appear higher than those in some previous "economic cost" (or benefit) assessments, such as in the WHO Global Status Report (2015). The WHO research produced estimates of the cost of existing RTI mortality (and morbidity) – rather than the benefits of reducing it – in the range from 2-5 percent of GDP for a large set of countries. A more important difference regarding these results (and those from McMahon and Dahdah 2008) is in that those previous estimates focused on the annual costs only, while we accumulate the future expected benefits over 24 years, discounting them to 2014 and expressing the sum of its present value as a share of the 2014 GDP. We have chosen this approach because our objective is the assessment of the cumulative benefits of a set of RTI reduction scenarios that will take effect over multiple years. As such, a net present value approach would seem the more appropriate alternative.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PART THREE: NEXT STEPS

The analysis presented in this report has independent scientific value, but its true significance will emerge only in conjunction with rigorous policy and planning. Evidence on the economic growth impacts of RTIs can inform policy discussions and energize advocacy, but they are only a starting point.

The five countries chosen for analysis were a convenience sample: all five were participants in an existing program. The sample includes two very large economies, China and India; two medium sized middle-income countries, Thailand and the Philippines; and one low-income country, Tanzania. The convenience sample does, then, offer an entry point for the analysis of most other LMICs.

How can the analysis be extended to other countries? How can the model be run in any other country of interest? What would it then mean to take action? When weighing specific policy options for RTI control, policy makers and those advising them, will need additional evidence. Decisions about investing in specific policies and interventions must be informed by cost-effectiveness analysis.

This is one of the considerations prompting our inclusion of a welfare analysis in this report. At least in principle, our welfare-based analysis could provide an input into future cost-benefit assessments, in that it gives estimates of the "benefit" side of hypothetical RTI reductions. As with our growth estimates, our welfare analysis has not included considerations of the costs involved in achieving any given scenario. Thus, more work is required to deliver all the tools leaders will need for evidence-driven decisions on specific policies. We hope our contribution will encourage and inform that future work.[6]

Scaling up Implementation: What Is to be Done?

The United Nations Decade of Action for Road Safety 2011-2020 and the Sustainable Development Goals set an ambitious goal to stabilize and then reduce by half the predicted level of traffic fatalities in low and middle-income countries by 2020. This would imply around 5 million lives saved, 50 million serious injuries avoided, and providing an economic benefit of more than US$3 trillion. Impacts on this scale will enhance country and regional development opportunities.

In line with this goal, the Global Plan for the Decade of Action for Road Safety 2011-2020 identified five priorities: 1) road safety management capacity, 2) infrastructure safety, 3) vehicle safety, 4) road user behaviour, and 5) post-crash care. This integrated development perspective is also reflected in the World Bank's transport sector business strategy.

[6] The estimates presented should be qualified, limitations that are largely rooted in the challenge of identifying reliable VSL measures for LMICs. For the approach to be of greater direct use in guiding policy decisions in LMICs, more efforts will be needed to set up suitable willingness-to-pay elicitation methods.

The strategic initiatives necessary to operationalize the Global Plan and improve country road safety performance are based on six over-arching recommendations outlined in a landmark WHO/WBG report on road safety (Peden et al., 2004):

- Identify a lead agency in government to guide the national road safety effort.
- Assess the problem, policies and institutional settings relating to road traffic injury, and the capacity for road traffic injury prevention in each country.
- Prepare a national road safety strategy and plan of action.
- Allocate financial and human resources to address the problem.
- Implement specific actions to prevent road traffic crashes, minimize injuries and their consequences, and evaluate the impact of these actions.
- Support the development of national capacity and international cooperation.

Implementing these recommendations at country level requires building capacity, to create the resources and tools necessary to implement target initiatives on a scale capable of reducing road deaths and injuries significantly and sustainably. It also requires an integrated framework that treats the recommendations of the WHO/WBG report as a totality, and ensures that institutional strengthening initiatives are properly sequenced and adjusted to the absorptive and learning capacity of the country concerned (Bliss and Breen, 2009).

As shown by international experience, systematic responses based on the Safe System concept developed in Sweden and the Netherlands in the 1980s and 1990s (OECD, 2016), help countries anchor sustainable action at the national and local levels. The holistic Safe System concept adapted to road transport begins by accepting a simple ethical imperative and a "Vision Zero" or "Towards Zero" policy framework: no human being should be killed or seriously injured because of a road crash (OECDs 2016). This presupposes that a traffic safety system should be designed to this end.

In practice, as summarized in a WBG regional report (Marquez, et al 2009), managing for improved road safety results must address three inter-related elements of the road safety management system: institutional management functions, interventions, and results; with prime importance being placed on institutional management functions and more specifically the role of the lead agency. *Interventions alone will not suffice*.

Some key requirements for building institutional management functions include:

- Strengthening institutions and governance capacity for RTI prevention, including lead agency capacity, targeting evidence-based training of senior policymakers, executive managers in the various relevant sectors, and ministry focal points and practitioners, especially in transport, justice, traffic police, and health. Creating space for civil society and private sector participation has the potential to galvanize political support based on well-articulated social demands from communities that bear the burden of RTIs.

- Improving nationwide traffic injury surveillance systems to better map the causes, risks, extent, and consequences of injuries; to pinpoint risks for more effective action; and to evaluate the effectiveness of those actions.

National road safety reviews are a sound basis for formulating policies and plans. These reviews help identify main risk groups and exposures to determine priorities, set realistic targets, allocate budgets, specify implementation responsibility, and ensure rigorous evaluation.

Creating a Focus on Results and Cost-effectiveness of Interventions

Establishment of a results-oriented safe system is facilitated by integrating road safety in all phases of planning, design, and operation of road infrastructure. At the planning stage, before project approval, strategic comparative analysis of substantial changes and new construction need to be conducted to examine the network's safety performance. In addition, risk mapping of road sections need to be undertaken to help target investments to road sections with the highest crash concentrations and/or the highest crash reduction potential.

Greater attention to road safety naturally incurs costs. Interventions must be paid for, and this demands that they be balanced against a country's budgetary constraints. The call to allocate additional funds or to reallocate existing funds to expanded road safety programs will depend on a clear policy decision by governments to assign greater priority to these efforts.

One approach for priority setting is the comparison of the likely costs and impacts of single and combined interventions. Since the costs of, responses to, and effects of interventions differ substantially among countries, this should be seen only as an attempt to provide a "sense of priority" among various road safety interventions and not as a prescription on how to rationalize the allocation of public resources.

Examples of proven and promising road safety interventions implemented in LMICs are shown in Table 2, adapted from the recent Disease Control Priorities Report (3rd ed.)'s chapter on Injury Prevention (Mock, Nugent, Kobusingye, and Smith 2017). Other assessments on the cost-effectiveness of RTI prevention strategies in different regions has been carried out by WHO (e.g., Chisholm and Naci 2008), where results are expressed in terms of the cost of achieving one additional year of healthy life (or averting one disability-adjusted life year). An important factor that needs to be kept in mind is that estimates of what works best in a given country or region depend crucially on the underlying distribution of fatal crashes and non-fatal RTIs by road user group (pedestrians, bicyclists, motorcyclists, car occupants, and bus/lorry drivers and occupants), and on various risk factors that are the target for interventions (speeding, drunk driving, and not wearing seatbelts or helmets).

The generation of "tangible results" over the short-and medium-terms, measured in terms of reduction in avoidable road traffic injuries and deaths, will help to enhance the credibility of the program, and build political and population-wide support for a sustained effort. Indeed, some of the cost-effective policies and interventions listed in Table 2 would yield significant safety benefits. For example, reducing speed limits, particularly in urban areas, and strengthening these efforts with road design, enforcement, publicity, speed cameras and appropriate penalties, will prevent unnecessary RTIs given that an increase of 1 km/h in mean vehicle speed results in an increase of 3 percent in the incidence of crashes resulting in injury, and an increase of 4–5 percent in the incidence of fatal crashes. Further, an adult pedestrian's risk of dying is less than 20 percent if struck by a car at 50 km/h and almost 60 percent if hit at 80 km/h. Likewise, reducing drinking and driving is another "quick win". Blood alcohol limits aligned with international practice and systematic general deterrence-based police enforcement with severe penalties have shown to have a major impact in reducing RTIs, particularly among the youth. Increasing seatbelt and helmet use through enforcement and publicity campaigns, revising specifications (at least for new cars), promoting vehicle seatbelt reminder systems, and undertaking periodic surveys to monitor front and rear seatbelt usage rates also help to drive down RTIs. Wearing a motorcycle helmet correctly can reduce the risk of death by almost 40 percent and the risk of severe injury by over 70 percent. Wearing a seat-belt reduces the risk of a fatality among front-seat passengers by 40–50 percent and of rear-seat passengers by between 25–75 percent. Adopting and enforcing laws to prevent "distracting driving" due to use of mobile phones and texting while driving is acquiring greater importance with the rapid and far reaching penetration of such devices.

The role played by interconnected pre-hospital and facility-based emergency medical services to deal with crash victims is critical to save lives, limit the severity and suffering from injuries, and ensure optimal functioning of the survivors and reintegration into the community (Peden and others 2004).

The integration of road safety and transport policy also offers policy makers the opportunity to help reduce RTIs by improving public transportation options (for example, better walking and cycling conditions, and improved ride sharing and public transport services) can reduce car collision frequency.

The formulation and implementation of well-designed demonstration projects can support the process of catching up with best practice in road safety performance and are an essential part of building national and local capacity with a focus on results. These projects can provide useful benchmarks for rolling out a modern road safety program to the rest of the country with support of governments, private sector, civil society, and the international community.

The World Bank's Role

To advance the road safety agenda, the World Bank established the Global Road Safety Facility in 2006 funded by external donors. The Facility works with international partners to provide funding and technical assistance to scale-up LMIC capacity to implement cost-effective road safety programs.

Road safety is now routinely a key component in World Bank road infrastructure projects. For example, some projects include pilot measures (and monitoring), such as road safety reviews, strengthening capacity of national road safety authorities, improving safety features of road infrastructure, tightening enforcement, and public campaigns for safer driving.

The Bank's results-oriented Safe System" approach encourages governments to develop a systematic approach, as evidenced by the Argentina Road Safety Project. This precedent encompasses several innovative features that can guide the design and implementation of transformative road safety investment projects in other countries, aimed at achieving sustainable improvements in results. Key features of the Argentine initiative include (Raffo and Bliss, 2012):

- Empower the Lead Agency. The National Road Safety Agency (Agencia Nacional de Seguridad Vial, ANSV) was envisioned as the lead agency in the Federal Agreement on Traffic and Road Safety between the federal government, the provinces, and the City of Buenos Aires. The federal government's decision to empower and resource the ANSV confirmed the agency's "ownership" of the nation's road safety and its management of targeted partnerships.

- Collaborate and Partner with the Health Sector. The project was prepared as a collaborative effort and partnership

Table 2. Examples of Proven and Promising Road Safety Interventions Implemented in LMICs[7]

Interventions Proven in HICs	Implementation and Evaluation in LMICs		
	Country	Study Design	Results
Providing and encouraging use of alternative forms of mass transportation	Guadalajara Mexico	Before-and-after study of the impact of Macrobus on crashes.	46 percent reduction in crashes after Macrobus was implemented.
Increasing the visibility of pedestrians and cyclists	Seremban and Shah Alam, Malaysia	Time series study of the use of daytime running lights for motorcycles.	29 percent reduction in visibility-related motorcycle crashes.
Supervising children walking to school	Kuala Teregganu, Malaysia	Case–control study assessing the risk of injury to children walking or cycling to school who were supervised by parents	Risk of injury was reduced by 57 percent among supervised children.
Separating different types of road users	Selagor, Malaysia	Video observational study of crashes and out comes after introduction of an exclusive motorcycle lane.	39 percent reduction in motorcycle crashes, and 600 percent decrease in fatalities
Reducing average speeds through traffic calming measures	China	Before-and-after study of simple engineering measures (such as speed humps, raised intersections, and crosswalks) on speed and casualties	Average speed dropped by 9 percent in three of four intervention sites; overall number of casualties dropped by 60 percent.
Setting and enforcing speed limits appropriate to the function of roads	Londrina, Brazil	Time series study on enforcement of speed control, seat belt use, new traffic code, and improved prehospital care.	Reduction in mortality to 27.2 per 100,000 population after one year of implementing a new traffic code.
Setting and enforcing blood alcohol concentration limits	Kampala, Uganda	Time series study on enforcement of alcohol-impaired driving and speed laws	17 percent reduction in traffic fatalities after intervention
	Villa Clara, Cuba	Time series study on enforcement of alcohol-impaired driving during weekends	9.9 percent reduction in traffic crashes, 70.8 per cent reduction in deaths, and 58.7 percent reduction in injuries, compared with previous year (2002).

[7] Adapted from (Mock, Nugent, Kobusingye, and Smith 2017), Table 3.3, pp. 42-43. See the source text for citations.

Table 2. Con't

Interventions Proven in HICs	Implementation and Evaluation in LMICs		
	Country	Study Design	Results
Setting and enforcing the use of seat belts for all motor vehicle occupants	Iran, Islamic Rep.	Before-and-after study of seat belt and helmet enforcement and social marketing.	Death rates reduced from 38.2 per 100,000 population in 2004 to 31.8 in 2007 ($p < 0.001$); death rate per 10,000 vehicles reduced from 24.2 to 13.4.
	Guangzhou, China	Before-and-after study of enhanced enforcement and social marketing on seatbelt wearing.	12 percent increase in prevalence of seat belt use ($p = 0.001$).
Setting and enforcing motorcycle helmet use	Cali, Colombia	Time series analysis of fatalities following implementation of mandatory helmet law, reflective vests, restrictions on when motorcycles can be used, and compulsory driving training.	52 percent reduction in motorcyclist deaths.
	Thailand	Before-and-after survey using trauma registry data following implementation of helmet law.	Helmet use increased 5-fold, injuries decreased by 41 percent, and deaths decreased by 20.8 percent.
	Vietnam	Time series observational study in three provinces following introduction of mandatory motorcycle helmet law.	16 percent reduction in injuries, and 18 percent reduction in deaths.
	Malaysia	Time series study of motorcycle-related crashes, injuries, and fatalities following implementation of a Motorcycle Safety Program using annual police statistics.	25 percent reduction in motorcycle-related crashes, 27 percent reduction in motorcycle-related casualties, and 35 percent reduction in motorcycle fatalities.
Encouraging helmet use among child bicycle riders	Czech Republic	Case-control study of helmet enforcement, education, and reward campaign at schools	100 percent increase in helmet use, and 75 per cent reduction in head injury admission rates

between the transport and health sector teams in the Argentina World Bank Country Office and their counterparts in the relevant government agencies. This partnership deepened the understanding of road deaths and injuries as a public health priority and led to more effective and efficient data management initiatives. The partnership improved emergency response capacity by a regional emergency network with response training, assessment of trauma capabilities, and emergency care. In addition, a new data collection structure improved the reporting of deaths and injuries by health centers and hospitals.

- Establish a Road Safety Observatory. To build the results management platform, the project invested in road safety monitoring systems and analysis tools in the National Road Safety Observatory and related interventions in demonstration corridors. The Observatory established a new data collection system for road crashes. Surveys of seat belt usage, lights, helmet usage, and distractive factors provided baseline data and monitor progress in reducing road traffic injuries and fatalities.

- Engage Provincial and Local Governments, NGOs, and the Private Sector. The project's inclusive approach delivers road safety interventions in the demonstration corridors and elsewhere. Several initiatives are proving to be highly effective in developing a unified approach, a sense of shared responsibility, and a strong commitment to achieving the ANSV's mission and ensuring its success as a lead agency. Funding and technical support encourage NGOs and the private sector to participate. An incentive fund (Result Based Financing to implement a specific set of Road Safety Interventions) catalyses provincial and municipal engagement in the delivery of the strategy. From an institutional perspective, now Road Safety is on top of municipalities concerns and the country develop a coordinated work on that also within the Healthy Municipalities strategy of the government. Thus, road safety advocacy efforts have been strengthened and victim's groups have become more engaged in working with government partners to improve safety outcomes. The incentive fund brings the issue of road safety to the forefront of provincial and municipal government agendas.

- Target Police Engagement. A crucial aspect of the ANSV's powers concerned enforcement of traffic safety laws. Legal reforms assigned to the ANSV the responsibility to promote and coordinate traffic control and supervision of police and security forces at the federal, provincial, and city levels. On national highways, provincial roads, and urban streets, ANSV cooperates with the agencies with jurisdiction for traffic safety enforcement.

- Develop Global and Regional Knowledge Partnerships. To assist the development of the National Road Safety Observatory, the project takes advantage of global and regional knowledge partnerships. The IRTAD, in partnership with the World Bank's Global Road Safety Facility (GRSF), supports a twinning opportunity between its Spanish member agencies and agency partners in Argentina to provide data management services. Similar initiatives with the International Road Policing Organization (RoadPOL) and the International Road Assessment Programme (IRAP) also support the law enforcement agencies and enhance safety measures in the demonstration corridors.

The marked improvement in road safety indicators in Argentina shows the positive impact of project activities. Over the 2010-2016 implementation period, the number of road traffic fatalities along the demonstration corridors was reduced by 45 percent, and the total number of reported non-fatal road traffic injuries was reduced by 11 percent (Raffo, 2016).

In Vietnam, another World Bank-supported road-safety project, complementing related initiatives supported by other international agencies, helped the government improve a number of key metrics (WBG internal document, 2013). For example, unprecedented enforcement of a new law mandating motorcycle helmet use is contributing to striking reductions in road traffic fatalities). The project outcome data showed that road traffic crashes were reduced from 39 to 25 per 100 million vehicle-km (smashing the target of 29/100m v-km), while the fatality rate was lowered from 13 to 5 fatalities per 100 million vehicle-km. (beating the target of 6/ 100m v-km).

The lessons learned from country experiences in implementing a multisectoral approach that includes institution—and capacity strengthening, physical road improvements, user education, emergency medical services, both pre-hospital and in-hospital care, and monitoring and evaluation, are being adapted with World Bank support in other countries across different regions. It is worth noting that the efforts in reducing RTIs are well aligned with the World Bank Group's twin goals of ending extreme poverty and promoting shared prosperity. In this regard, the World Bank Group has a specific comparative advantage – the ability to potentially address this issue comprehensively across sectors (e.g., transport, health, urban planning, governance) and as part of the broader dialogue at the country level.

Why now?

The time to support concerted efforts to make roads safer has arrived. Growing urbanization, poor road conditions, accelerating growth in the number of vehicles, patchy efforts to build institutional capacity for managing road safety improvements, and increases in the rate of road injuries and fatalities, present a real threat. Investing in effective interventions under a safe systems approach would reduce premature mortality and disability, and their associated economic and social costs. As discussed in Box 3, averting preventable road traffic injuries and premature deaths, will also contribute to human capital accumulation, a key factor for sustainable economic growth and the enhancement of the total wealth of countries.

Conclusion

The large reductions in RTI mortality and morbidity estimated as part of the modelling work done for this report are within the reach of an increasing number of countries.

RTIs and their associated burden are largely preventable, if governments adopt and enforce and sustain over the medium term proven strategies, incorporating smart institutional management, evidence-based interventions, and a steady focus on results. Many countries have already chosen this path. Between 1990 and 2015, average RTI mortality rates among all OECD countries declined by more than 50 percent, from 22 to 8 (per 100,000 population). Change is possible, and progress can be swift.

The road is open for leaders who commit to achieve or surpass such results, securing healthier lives for their people and boosting national economic growth and welfare.

BOX 3:

Prevention of road traffic injuries and premature deaths contributes to human capital accumulation

Reduction of RTI as analysed in this study actively supports WBG's recently launched Human Capital Project, which focuses on the relationship between economic growth and improvements in human capital, and emphasizes that investing in people is investing in economic growth. As evidenced in WBG analysis (2006), the answer to the question *Where is the Wealth of Nations?* yields important insights into the prospects for sustainable development across the world. Wealth is more than produced capital (buildings, machinery, equipment, and infrastructure), it includes natural resources, land, and intangible capital (labor, human capital, social capital, and quality of institutions). WBG estimates show that unaccounted "intangible capital"--human capital and the value of institutions, constitutes the largest share of wealth in virtually all countries accounting for 58 percent, more than produced capital (16 percent) and natural resources (26 percent).

As shown in this report, the social costs of preventable road traffic injuries and premature death are terrible high, while the costs of effective interventions are surprisingly low. Investments in the prevention of road traffic injuries and premature deaths will pay off maximizing healthy life years, free of injuries and disabilities, contributing to build health capital (the value of a person's lifetime health), and hence to human capital (the sum of knowledge, skills, and know-how possessed by the population), which have a positive effect on a country's total wealth.

As argued by Jim Y. Kim, the WBG President at the 2017 WHO-IMF Annual Meetings, investing in health, education, and social protection, is putting in place the capital that is needed to grow the economies of countries. Indeed, investments in human capital have had a huge impact on economic growth. The difference between the top quartile – the top 25 percent of countries that have improved human capital the most, compared with the bottom 25 percent – countries that have improved human capital the least – is enormous. Between 1991 and 2016 – the difference in economic growth was 1.25 percent of GDP each year over 25 years. investments in human beings have had a huge impact on economic growth. Looking forward, investing in people will become more important in the increasingly digital economy of the future.

Source: WBG 2006, Kim, JY, 2017ab

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APPENDIX 1. THE IMPACT OF RTIs ON ECONOMIC GROWTH

Background and assumptions

To address the question of RTIs' impact on economic growth, policymakers must begin by estimating the impact of RTI-attributable mortality and morbidity on growth, to evaluate the macroeconomic gain, in terms of gross domestic product (GDP), that would be expected to accrue if they managed to decrease RTI mortality and morbidity according to a stylized set of future scenarios. We focus on RTI mortality and morbidity among the working-age population (aged between 15 and 64) in the five study countries of China, India, the Philippines, Tanzania, and Thailand, because the main effect of mortality or morbidity on economic growth depends on individual participation in economic production.

As noted in the body of this report, the proportion of RTI-related deaths and disability-adjusted life years lost in these five countries is relatively small compared to their respective all-cause mortality and morbidity (around 5 percent on average). Previous literature has found scant (if any) effect of mortality and of other population health measures on economic growth (see Appendix 5). Accordingly, ex ante, we expect to obtain relatively small effects on projected future income, even for major reductions in RTI mortality and morbidity.

Across this section, we assume that the effect of RTI mortality and morbidity and the effect of all-cause mortality and morbidity on economic growth are similar. We label this the "same-effect assumption." Although this is a strong assumption, we believe it is acceptable approximation since, after all, "a death is a death", independently of its cause, and its immediate effect is a loss of potential labor supply.

In fact, there are reasons to believe that the effect of RTI mortality and morbidity might be either larger or smaller than the all-cause effect, because RTI mortality is concentrated among young individuals and among males. On the one hand, younger people have great potential in terms of contribution to national production. Similarly, morbidity among younger people might be more detrimental to the prospects of economic growth than morbidity among the more senior, because injured or disabled young people would require support from the health care system for a longer time. On the other hand, younger people are also those with less experience in the labor market, and can be easily replaced at the workplace by drawing from the reserve of youth unemployment that exists in many countries.

Furthermore, while in many societies men tend to be household breadwinners and typically are more attached to the labor market than women, over recent decades women have been participating increasingly in the labor force. In many developed countries, women's labor market participation rate is now at par with their male counterparts. Moreover, the proportion of women with high education levels is growing, and often females are, on average, more educated than males.

Thus, whether the effect of RTI mortality and morbidity on economic growth can be assimilated to the effect of all-cause mortality and morbidity is an empirical question, especially because economic growth results from a complex system of determinants and mechanisms, many of which are affected by health conditions and by the distribution of health conditions by age among the population of a given country.

The main motivation for the same-effect assumption is the lack of reliable data on RTI mortality and morbidity, given that especially in LIMCs road crashes are under-reported and RTI mortality and morbidity is often mis- or under-registered. Compared to RTI mortality and morbidity, data on total (i.e. all-cause) mortality and morbidity are more reliable.

Thanks to the same-effect assumption, RTI mortality and morbidity can be omitted from the empirical models as their effect is entirely accounted for by all-cause mortality and morbidity. Hence, more parsimonious empirical models can be defined that require much less in terms of sample size and identification strategy.[6]

A regression-based approach is not the only theoretically feasible way of assessing the growth impact of health. One potential alternative that has been used in some recent attempts to assess the growth consequences of certain health issues has been the WHO's EPIC model (see Appendix 6 for a brief discussion of the EPIC model as a potential alternative approach).

Model Specification

We estimate the effect of mortality rates and the effect of DALYs on economic growth, using a sample of 135 countries. Compared to previous studies[7] this is the largest and, hence, the most representative set of countries used to date, mainly because the period considered, i.e., from 1990 to 2014, is recent, and data availability has increased compared to earlier years.

We estimate, first, an income dynamics model and, second, a long-run growth model. Each model rests on different identification assumptions. The purpose of this two-tier strategy is to assess whether our estimates are robust to alternative empirical models and underlying assumptions. The income dynamics model, as adopted in Suhrcke and Urban (2010), is defined as follows:

$$y_{it} = \alpha_0 + \rho y_{it-1} + \alpha_1 R_{it} + X_{it}\beta + \mu_i + \varepsilon_{it} \quad (1)$$

where y_{it} is real per-capita GDP in country i at time t, with t=1,…T, y_{it-1} is the same variable lagged by one period, R_{it} is all-cause mortality rates (resp. DALYs), X_{it} are time-varying country controls and μ_i are country fixed effects. Finally, ε_{it} is the usual zero mean error term that we allow to be heteroskedastic. Model (1), where current inputs combine with past income to predict current income, can be derived from a standard Solow model of capital accumulation.

The long-run growth model, as proposed by Lorentzen (2008), is defined as

$$g_i = \pi_0 + \pi_1 \log(y_{i1}) + \pi_2 \bar{R}_i + \pi_3 \bar{X}_i + \mu_i + \varphi_i \quad (2)$$

where $g_i = \frac{y_{iT} - y_{i1}}{y_{i1}}$ is the long run growth rate of real per-capita GDP from period 1 to period T, $\bar{R}_i$ and $\bar{X}_i$ are the all-cause mortality rate in country i and the time-varying country controls averaged over the period from t=1 to t=T. Furthermore, country fixed effects are parametrized as $\mu_i = \gamma W_i$ where W_i includes time-invariant country characteristics.

Rather than describing how income evolves from period to period, as in the income dynamics model, the long-run growth model directly relates long-run growth to the

[6] As RTI mortality (resp. morbidity) rates are correlated with mortality (resp. morbidity) rates attributable to all other causes, a correctly specified model needs to include both RTI and non-RTI mortality (resp. morbidity) rates among the regressors, unless the effects of RTI and non-RTI mortality (resp. morbidity) are equal.

[7] Rocco et al. (2014) use 119 countries, Lorentzen et al. (2008) use 88 countries, Suhrcke and Urban (2010) include 61 countries, and the sample in Acemoglu and Johnson 2007 comprises 47.

initial level of income and a summary of the determinants from period 1 to T. However, equation (2) can also be derived from the Solow model, suggesting that the results obtained by the income dynamics model (1) and the long-run growth model (2) ought to be comparable, even though the two models represent the process of income growth in different ways.

Indeed, we show that R is related to long-run income growth, albeit indirectly, also in the income dynamics model (1). By recursive substitution of y_{it} in (1) we get

$$y_{iT} = \rho^{T-1} y_{i1} + \alpha_1 \sum_{j=1}^{T-2} R_{ij}\, \rho^t + \left(\sum_{j=1}^{T-2} X_{ij}\, \rho^t \right) \beta + \sum_{j=1}^{T-2} (\alpha_0 + \mu_i + \varepsilon_{it}) \rho^t$$

Next, by subtracting and dividing both sides by yi1 and by approximating R_{it} with a constant over the period from t=1 to t=T, so that $R_{it}=\bar{R}_i$, we obtain

$$g_i \sim (\rho^{T-1} - 1) + \left(\frac{\alpha_1}{y_{i1}} \frac{1-\rho^{T-1}}{1-\rho} \right) \bar{R}_i + \left(\sum_{j=1}^{T-2} \frac{X_{ij}}{y_{i1}} \rho^t \right) \beta + \sum_{j=1}^{T-2} \left(\frac{\alpha_0 + \mu_i + \varepsilon_{it}}{y_{i1}} \right) \rho^t$$

(3)

which is equivalent to equation (1), excepting that now the outcome variable is g, the long-run growth of real per capita GDP between the initial and the final periods (time t=1 and t=T). This is the same outcome of the long-run growth model defined in equation (2). Hence equation (3) allows determining the marginal effect of R on long-run growth and the semi-elasticity of long-run growth with respect to R, starting from the estimates of the income dynamics model. These two quantities mirror those promptly obtainable in the long-run growth model.

[10] To illustrate, consider the case of China. China's observed long-run growth between 1990 and 2014 was 441 percentage points. Suppose that the semi-elasticity is -0.35. Then a reduction of 10 percent in R, every-thing else being equal, would increase long-run growth by 3.5 percentage points [(-10)*(-0.35)], bringing it to 444.5 percentage points (441+3.5).

Specifically, from equation (3), the semi-elasticity of long-run growth with respect to R is defined as

$$\epsilon_i = \frac{\partial g_i}{\partial \bar{R}_i} \frac{\bar{R}_i}{100} = \left(\frac{\alpha_1}{y_{i1}} \frac{1-\rho^{T-1}}{1-\rho} \right) \frac{\bar{R}_i}{100}$$

The semi-elasticity yields the effect on long-run growth (expressed in percentage points) of reducing R by 1 percent.[10] By estimating (1) we obtain estimates for α_1 and ϱ that can be used to compute the semi-elasticity.

The semi-elasticity of the long-run growth rate with respect to R is immediately computed from model (2) as

$$\epsilon_i = \frac{\partial g_i}{\partial \bar{R}_i} \frac{\bar{R}_i}{100} = \pi_2 \frac{\bar{R}_i}{100}$$

In what follows, we will always refer to the semi-elasticities to discuss and compare the results derived from the two alternative models.

Estimating the Income Dynamics Model

To estimate model (1) – the income dynamics model – we adopt the classical Arellano-Bond (1991) GMM method (AB). This estimator recognizes the dynamic nature of the model and the necessary endogeneity of the lagged income variable, which is correlated with country fixed effects. The AB estimator extends the original intuition of Anderson and Hsiao (1981) that further lags of income could be used as instruments when the model is taken in first-differences. Hence, AB expands the set of instruments by adding all available lags and, as a result, improves efficiency and consistency. The necessary assumption for any dynamic panel model to provide consistent estimates is that the residuals are serially uncorrelated. We shall test this assumption.

As mortality and morbidity depend on economic development, we consider R as endogenous and treat it as the lagged income (i.e., lags of R are used as instruments for R). A distinctive feature of the AB estimator is that it does not require external instruments and so is easier to implement. However, it might suffer from the weak-instrument problem, as lagged levels could be poorly correlated with first-differences. As is common in the literature, we compare AB estimates with two benchmarks, the panel fixed effect estimates and the OLS estimates. The former accounts for country fixed effects while the latter does not. The OLS model is thus the least reliable among the three methods used. Although both benchmarks have proven to be inconsistent (Nickel 1981; Trognon 1979), they are still informative, because their estimates have smaller standard errors.

To remove short-run fluctuations due to the business cycle, we average data in periods of three or four years. As a result, T turns out to be equal to 8 and time is defined as follows: t=1 corresponds to the years 1990-1992, t=2 to 1993-1995, …, t=7 to 2008-2010 and t=8 to 2011-2014. To each t correspond the period-average controls X_{it} detailed below.

Estimating the Long-Run Growth Model

We specify the long-run growth model (2) as in Lorentzen et al. (2008). Real per capita GDP growth over the period 1990-2014 is regressed on initial log income, log(yi1), over-time average mortality/morbidity R, and averaged controls. As mortality and morbidity are likely to be correlated with country characteristics that influence economic growth, and as economic development feeds back to mortality and morbidity, R is endogenous. To address endogeneity of R and provide consistent estimates of the effect of mortality/morbidity on income growth, Lorentzen et al (2008) proposed to instrument R with climatic and geographic characteristics of the countries, based on the argument proposed by Acemoglu and Johnson (2007) and references therein that these variables do *not directly* determine economic growth. We follow this approach, and we instrument R with the malaria falciparum index prevailing in 1966, i.e., more than two decades prior to our period of analysis. This index measures the proportion of the population at risk of infection. Malaria falciparum is a type of malaria transmitted by *Plasmodium falciparum*, a parasite. It is the most prevalent type of malaria, especially in Africa, and it is responsible for most malaria deaths globally, while other types of malaria are not deadly in general. Malaria develops in tropical and subtropical areas all over the equatorial belt, but its distribution is not homogenous and depends on land elevation, humidity, presence of water pools, and the effectiveness of eradication campaigns. Hence the tropical and subtropical countries are not equally affected by malaria.

An instrumental variable is valid if it satisfies two requirements: 1) relevance, i.e., being strongly correlated with mortality and morbidity; and 2) excludability, i.e., the instrument should not have any direct effect on economic growth beyond that mediated by mortality and morbidity. While the first requirement is testable, and we will show that the 1966 malaria index is strongly correlated with mortality and morbidity, the excludability condition is untestable, and plausible arguments should be provided to support its validity and dismiss concerns. A possible problem is that, with *Plasmodium falciparum* being concentrated in Sub-Saharan Africa, our index could be correlated with characteristics specific to Africa that have historically reduced the continent's propensity to growth, such as climatic conditions, poor institutions, and a recent past of colonial domination. Although Acemoglu and Johnson (2007) argue that climatic and geographical conditions are not the cause of poor economic performances, to support the assumption of excludability we control for the proportion of each country area that is defined as polar, dry temperate, wet temperate, tropical, and subtropical. Furthermore, we control for an index of civil liberties, the diffusion of internet in the country, and the condition of being member of OECD in 1990, variables that we consider proxy institution quality. Importantly, the model includes income in 1990, a variable that could be considered at least in approximation a sufficient statistic for the factors that determined income growth in the past, including socio-cultural factors. Hence, conditional on these controls, we argue that the effect of the malaria index acts on economic growth only through its effect on mortality and morbidity, and it does not exert an autonomous impact on growth.

Beside IHME data that we already described, we exploit other sources of information. We derive malaria indices and climatic zones from Harvard University's Center for International Development (CID).[11] Real per-capita GDP, population, government spending, exports and imports measured in constant 2011 national prices converted in US$ are drawn from the latest version 9.0 of the Penn World Tables (PWT).[12] These data are available yearly up to 2014. The proportion of urban population and the proportion of people with access to the internet are drawn from the World Development Indicators (WDI), available from the World Bank.[13] Finally the index of civil liberties derives from the Freedom in the World (FIW) data, version 2002, available from Freedom House. We group these controls in the two vectors X_{it} and W_i as follows. X_{it} includes time-varying controls: log population, the proportion of urban residents, the proportion of residents with internet access, government spending, and an index of openness to the global economy, defined as the ratio between the sum of imports and exports and national GDP. Wi includes time-invariant controls: a set of variables accounting for the proportion of the country area in polar, temperate, subtropical, and tropical zones, the index of civil liberties, and a dummy reporting the OECD membership in 1990. Overall, data on Xit and Wi are available for 135 countries and from 6 to 8 periods per country. Summary statistics are reported in Table 9.

Results

We turn now to the actual results of our simulations. First, we discuss the effects of the all-cause mortality rate. Then, we discuss the impact of DALYs.

The Impact of Higher Mortality on Economic Growth

For increases in all-cause mortality, the estimates of the income dynamics model are reported in Table 10 and those of the long-run growth model in Table 11. Reassuringly, both provide similar indications. The effect of a higher mortality on economic growth is statistically significant and negative. Specifically, looking at the semi-elasticities reported at the bottom of the two tables, we find that, in our sample of 135 countries, a 10 percent decrease in all-cause mortality will increase the long-run growth rate by 3.6 percentage points according to the income dynamics model and by 4.6 percentage points according to the long-run growth model. Taking as reference the latter, the corresponding country-specific figures are 3.5 in China, 5.6 in India, 4.3 in Philippines, 5.1 in Thailand, and 6.4 in Tanzania. (Note that Table 10 and Table 11 also provide the results of the coefficients on the other control variables, despite the focus of interest being on the mortality variables and their interactions. We note that the precise sign and significance of the control variables should

[11] http://www.cid.harvard.edu/ciddata/ciddata.html

[12] http://www.rug.nl/ggdc/productivity/pwt/

[13] http://data.worldbank.org/data-catalog/world-development-indicators

[14] https://freedomhouse.org/report-types/freedom-world

not be over-interpreted, as these are not the focus of the specific model, and their estimates may be biased by endogeneity.)[15]

The F test assessing the strength of the instrument in the long-run growth model largely exceeds 10, which is considered the level below which an instrument is weak. The autocorrelation test AR (2) reported for the income dynamics model does not reject the hypothesis of absence of auto-correlation in the disturbances. [16]

By using the long-run growth model, we have also tested whether there is a differential effect of mortality in high-income countries (defined as those in the top quartile of income distribution) and whether there is a differential effect in East and South-East Asia, the region that China, Thailand, and Philippines belong to, in South Asia (the region of India), or in East Africa (the region of Tanzania). For this purpose, we include in model (2) an interaction between R and, alternatively, a dummy variable for high-income counties, East and South East Asia, South Asia, and East Africa. We treat the interaction as endogenous, and the additional instrument is the malaria index in 1966 interacted by the corresponding dummy variable. Results are reported in columns 3 to 7 of Table 11. In no case, no evidence of a statistically significant differential effect was found, and the point estimates of the interactions are very small. We thus reject the hypothesis of differential effects and conclude that our baseline model (2) is correctly specified.

The Impact of DALYs

We now use the results discussed in the previous sections to predict the expected gains in terms of long-run economic growth that would be expected to result from reducing the RTI mortality rate and RTI DALYs according to a stylized set of scenarios, starting from their 2014 levels.

Referring to the estimates of the long-run growth model, first, it is predicted what would be the real per capita GDP growth between 2014 and 2038, if all covariates, including mortality and morbidity, would remain at their 2014 level. This is what it is defined as the status quo scenario. The 2014 starting point is chosen because 2014 is the most recent year for which we have complete information regarding all covariates included in model (2). The length of the prediction period, 24 years, matches that used in the baseline estimation of model (2). Next, it is considered three hypothetical scenarios, where average[17] RTI mortality rate and DALYs are reduced by 25, 50, or 75 percent. These are the three intervention scenarios that we refer to as the moderate, median, and optimistic scenario, respectively.

Growth Gains From Reducing RTI Mortality

Reducing RTI mortality by n percent implies a reduction in all mortality of *n*(RTI mortality)/ (All-cause mortality)*. The predicted long-run growth will then be increased by *semi-elasticity * n *(RTI*

[15] We obtained practically indistinguishable results when we controlled for the share of oil rents on national GDP (data obtained by the World Bank World Development Indicators). Likewise, results are qualitatively similar when we estimate the long-run growth model by OLS without instrumenting. The latter evidence (i.e., the fact that OLS and 2SLS estimates are comparable in sign and magnitude) helps support the validity of the proposed instruments. We have also tested whether the effect of all-cause mortality is constant or varies at different levels of mortality by including the squared all-cause mortality rate in the long-run growth model. To maximize the statistical power of the test, we have estimated the model via OLS without instrumenting. This test does not reject the hypothesis that the relationship between economic growth and mortality is linear.

[16] Autocorrelation of first order, tested by AR(1), is physiological because of the presence of the country fixed effect, and it is removed by first-differencing.

[17] The average is taken over the period 2014-2038.

mortality)/ (All-cause mortality). To illustrate, for China the predicted long-run growth from 2014 to 2038 in the status quo scenario is 258 percent, equivalent to 5.4 percent annually. A reduction in RTI mortality of 50 percent will imply a reduction of all-cause mortality by 3.9 percent. With the semi-elasticity in China being -0.35 (i.e., the estimated marginal effect of all-cause mortality, -0.114, times the all-cause mortality rate in China in 2014, 308.48, divided by 100), the additional predicted growth is equal to 1.36 percentage points in the long run (0.35 * 3.9), corresponding to an additional yearly growth rate of about 0.02 percent.

In Figure 5 and Table 12 we report the results of the simulation of reducing RTI mortality, holding everything else constant. For each year between 2014 and 2038, we compute the additional income per capita that would result from moving from the status quo scenario to each intervention scenario (a reduction of 25, 50, or 75 percent in RTI mortality). Income gain is the result of the additional yearly growth rate, derived as in the example above. (For China and for a reduction of 50 percent in RTI mortality, the additional yearly growth rate would be 0.02 percent.)

Not surprisingly, more optimistic scenarios correspond to higher income gains and, since the effect of additional annual growth accumulates over time, income gains exponentially increase as they approach the end of the period. In the bottom part of Table 12 we have reported the discounted sum of all income gains, discounted at the 2 percent annual rate,[18] by intervention scenario, and, finally, we have compared such figures with the level of real per-capita GDP in 2014.

It turns out that reducing RTI mortality by 25 percent will produce a flow of additional income in the period between 2014 and 2038 that ranges between 2.5 percent of 2014 per-capita GDP in the Philippines and 7.3 percent in Thailand. The stronger reduction of RTI mortality implied by the median scenario will produce total income gains ranging between 4.7 percent in the Philippines and 14.6 percent in Thailand. Finally, in the optimistic scenario income benefits are between 7.0 percent in the Philippines and 21.9 percent in Thailand.

Benefits are consistently the smallest in the Philippines because RTI mortality in the country is already low, and there is little room for further reduction. The opposite is true for Thailand, which has the highest RTI mortality rate among the five countries under consideration (see Table 6).

Table 3 reports the estimated 95% confidence intervals of the total gain achievable by reducing RTI mortality, as a proportion of 2014 GDP per capita, by country and scenario. These intervals mirror the (ample) confidence interval associated with the marginal effect of reducing all-cause mortality, as reported in Table 11, column 2. On the one hand, their width is the result of the limited precision of our estimates, a feature that we have already emphasised and which is (inevitably) connected to the small size of the sample at hand. On the other hand, however, and more importantly, the large width of the confidence intervals is the result of the fact that that small changes in the effect of mortality on economic growth correspond to large variations in the expected income gains achievable by reducing mortality, given that the process of economic growth is exponential. This also implies that the benefit of investing in RTI reduction on economic growth could be much more limited than previously suggested, if the "same-effect hypothesis" were violated, and in particular, if the effect of reducing RTI mortality were smaller than the effect of reducing all-cause mortality.

[18] See Box 2 for sensitivity analysis on the model discount rate.

Table 3. Total GDP per capita gain associated with a Reduction of RTI Mortality, by Intervention Scenario. Proportion of 2014 GDP per capita. 95% confidence intervals

RTI mortality reduction scenario	China	India	Philip-pines	Tanza-nia	Thailand
Total GDP pc gain / 2014 GDP pc 25% reduction scenario	0.6%-8.8%	0.6%-9.4%	0.3%-4.4%	0.3%-5.4%	0.9%-13.7%
Total GDP pc gain / 2014 GDP pc 50% reduction scenario	1.1%-17.7%	1.2%-18.7%	0.6%-8.8%	0.7%-10.8%	1.7%-27.5%
Total GDP pc gain / 2014 GDP pc 75% reduction scenario	1.7%-26.5%	1.8%-28.1%	0.8%-13.2%	1.0%-16.2%	2.6%-41.2%

Growth Benefits of Reducing RTI DALYs

Turning to RTI DALYs, Table 13 reveals that the benefits of reducing both RTI mortality and morbidity are significantly larger than the gains estimated above when looking at RTI mortality only. Specifically, the moderate scenario yields returns in terms of faster economic growth that range between 3.5 percent of 2014 real per-capita GDP in Tanzania and 11.1 percent in Thailand. These numbers double and triple in the median and in the optimistic scenario.

Also in this case, cross-country differences depend on the different starting levels of RTI DALYs and on the variation in the importance of RTI compared to other causes of mortality and morbidity.

By comparing results in Table 13 with those in Table 12 we can have a rough idea of the economic value of reducing RTI morbidity. To illustrate, take the median scenario. The economic value of reducing RTI morbidity can be obtained by subtracting the total gains as reported in the bottom part of Table 13 and Table 12: hence, for China this value corresponds to 5.6 percent of 2014 GDP, while we find 4 percent in India, 2.5 percent in the Philippines, 1.4 percent in Tanzania, and 7.6 percent in Thailand.

To neutralize the heterogeneity due to different initial mortality and morbidity rates, we consider an additional scenario that consists of an absolute reduction of 10 units in the RTI mortality rate, corresponding to an equivalent reduction in all-cause mortality. Again, using the long-run growth model's estimates (Table 11), such a reduction will add 1.14 percentage points to future growth in all countries, which is equivalent to a discounted flow of additional income that ranges between 7.7 percent of 2014 GDP in China and 8.5 in Tanzania, a much narrower range than under the intervention scenarios discussed above. The residual heterogeneity is due to the different economic initial conditions and the different economic growth potential. A similar experiment, where RTI DALYs are reduced by 100 units in all countries, causes an additional growth of 0.48 percentage points, while the economic benefit ranges between 3.3 percent of 2014 GDP in China and 3.6 percent in Tanzania and Thailand. The size of the economic effects increases approximately linearly with the size of the reduction in mortality rate and DALYs.

Conclusions and Limitations

In this analysis, we have estimated the contribution of reducing RTI mortality and morbidity to economic growth in China, India, Philippines, Tanzania, and Thailand. While RTIs are not one of the leading causes of total mortality and morbidity, what makes them a highly appealing policy target in principle is that they are avoidable. Policies have a great potential for reducing the probability of road crashes and their severity, as illustrated by the experience of many high-income countries. Thus, it is not unreasonable to hypothesize large reductions in RTI mortality and morbidity in the future and evaluate their economic benefits in terms of additional long-run growth rates. Our results indicate that halving RTI mortality and morbidity has the potential to produce an additional flow of income of 7.1 percent of 2014 GDP in Tanzania, 7.2 in the Philippines, 14 in India, 15 in China and 22.2 percent in Thailand, the country with the largest scope for reducing RTIs.

Our analysis has several limitations and rests on certain assumptions, all of which need to be borne in mind when interpreting the findings. First, predictions are – unavoidably – based on past performances and assume a stable structural relationship between economic growth and its determinants over time. Second, and more importantly, predictions for a single country are extrapolated from the average past performance in the sample of 135 countries. While our tests exclude the presence of differential effects of mortality and morbidity in high-income countries or in the world regions where our countries of interest are situated, we cannot exclude the possibility that the relationship between mortality and morbidity on the one hand and economic development on the other hand follows country-specific patterns.

Third, because of lack of reliable data on RTI mortality and morbidity, we have assumed that reducing RTI mortality and morbidity has the same effect on growth as reducing all-cause mortality and morbidity (what we have termed the "same-effect assumption"). While this assumption is an acceptable starting point, further research is necessary to assess its validity when better data will be available.

A fourth point to be noted is that mortality and morbidity data are estimates and could be subject to measurement errors. Only if such errors were classical, then our instrumental variable strategy would still produce consistent results. Fifth, although the number of countries included in the sample is large compared to other studies, many countries are left out due to missing data. It is difficult to assess to what extent such lack of data threatens the representativeness of our sample. Sixth, the validity of the malaria index as instrument could be questioned if important controls were omitted from our models. While this is possible, estimates obtained by an alternative procedure, depending and not depending on external instruments, are rather similar, supporting our confidence in the (at least approximate) validity of our results.

APPENDIX 2. THE WELFARE IMPACT OF RTIs

Background: Assigning Value to a "Statistical Life"

To decide whether an intervention is cost effective, policy makers must assess whether the gains obtained will at least equal the costs of implementing the measure. While the costs (at least the direct costs) are usually comparatively straightforward to measure, estimating benefits can be difficult. A tool created to quantify the likely benefits of a risk reduction intervention or health policy is the value of a statistical life (VSL).

The theory underlying the VSL is that we can assign a monetary value to a life by considering how much an individual is willing to pay to decrease her risk of dying, or alternatively how much monetary compensation an individual requires to accept an increased risk of dying. By giving a value to an increase in survival probability, we can calculate a value for the whole life. In turn, if a policy decreases the mortality risk that people face and thus helps save lives, the benefits of such a policy can simply be computed by multiplying the number of lives saved by the value of a (statistical) life.

Pre-empting Misinterpretations

Much of the reservation about putting a monetary value on life and health stems from a misunderstanding of what such a value means. In fact, economists cannot – and do not seek to – place a monetary value on any identified person's life. That is why economists do not measure the value of a life, but the value of a statistical life. Although less elegant, rather than discussing the "value of a life," it would be more appropriate to speak of "the value of small mortality risk reductions." What is really being valued is comparatively small changes in the risk of mortality, rather than life as a whole. While normally no one would trade his or her life or health for money, most people weigh safety against cost in choosing safety equipment, or safety against time when crossing a busy street.

Approaches to Estimating the VSL

Despite its theoretical simplicity, the willingness to pay approach is not free of problems, because individual preferences are not observable, and thus people's willingness to pay is not directly measurable. To overcome this problem, economists have tried to estimate the needed values. The two main approaches used are the stated preferences (SP) and the revealed preferences (RP) method. In what follows we briefly discuss their main strengths and weaknesses.

The stated preferences approach assumes that people can judge the value of their own life and of changes in survival probabilities. Hence, one possibility is to directly ask people to assess the value of improved health, and to compute the VSL based on the analysis of survey data that includes such information. While typically high, the VSL derived using this method is not infinite, since people do not give up everything in exchange for better health.[19] This approach assumes that individuals are able to correctly assess probabilities. If this is not the case, the estimates will be biased.

The revealed preference approach assumes that people are not fully conscious of their preferences and thus that they cannot directly reckon the value of an incremental increase or decrease in their likelihood of survival.

[19] This refers to situations where people face marginal trade-offs between health and other goods, not the far less representative situation where people face immediate death, which would probably yield an infinite readiness to pay.

However, even if real preferences are not observed, individuals' choices about risk can indirectly reveal their implicit trade-off between risk (of mortality or ill-health) and money. Such preferences can be inferred from wage differences on jobs with different levels of risk. People employed, for example, in mining will demand a wage premium in return for accepting greater risk. People obviously act as if life were not "priceless" and, in making these choices, are implicitly putting a price on (i.e., attributing a value to) changes in the risk of mortality.

Knowing these premia/prices and the risks associated with them makes it possible to calculate the VSL, which can then be used to place a value on changes in the risk of mortality. This method has usually led to VSL estimates of around US$ 5.5-7.5 million. (See Viscusi and Aldy 2003 for estimates of the VSL in the United States in 2004 dollars.) However, the revealed preferences approach has its disadvantages, too. Indeed, it is not always straightforward to define the job-risk variable in the wage equation (for a discussion see Viscusi 2004 and Ashenfelter 2006). For example, it is difficult to find two jobs that have the same characteristics but that differ just with respect to their degree of risk. In addition, it is not clear whose preferences are being elicited. Rather than measuring the preferences of the median worker, it is more likely that the studies measure the preferences of risk-loving individuals. Indeed, the estimates are derived using work choices of people involved in risky jobs and thus on average more risk-loving than the median worker. Finally, the revealed preferences approach implicitly assumes that there are no transaction costs when changing jobs, which is not always the case.

A third approach to estimating VSL consists in using a mathematical model in which a representative individual maximises her lifetime expected utility. The VSL is derived by choosing a particular utility function and by calibrating it using estimates of the parameters (e.g., elasticity to intertemporal substitution) taken from empirical studies or imposing parameters that make the consumption pattern simulated in the model similar to the actual consumption pattern (see e.g., Becker et al. 2005; Murphy and Topel 2006; Soares 2007).

The ideal approach to estimate welfare benefits for any given country would use VSL estimates derived within the country of interest. A most useful database of worldwide VSL estimates is available from the OECD's recent major work on mortality risk valuation in health, transport, and environment. (See OECD 2012 for the overall report, including the meta-analysis of global VSL studies.[20]) However, direct VSL estimates from LMICs are generally hard to find.[21] Since estimates for all the countries analyzed in this report are not available, we will use four different but related rules of thumb to generate estimates of the VSL that, together, may provide a "ballpark sense" of the range within which the actual figure would fall.

Model Specification and Scenarios

The estimation of the welfare impact of future reductions in RTI mortality needs two measures: a) the average number of lives saved per year, and b) the VSL for the countries considered. We computed the number of lives hypothetically saved between 2014 and 2038 as follows. We considered a linear trend in mortality reduction

[20] More information on background reports and related materials is available on the OECD's dedicated website: www.oecd.org/environment/tools-evaluation/valuingmortalityimpacts.htm (accessed 18/04/2016), which also includes an Excel file with all country-specific studies (and VSLs) included in the meta-analysis.

[21] Out of the five countries of particular interest for the proposed planned work (India, China, Thailand, Philippines, and Tanzania), VSL estimates appear to exist only for India, China and Thailand (at least according to the OECD's meta-analysis referred to above).

from 2014 to 2038, i.e. we assumed that the reduction in mortality takes place linearly and it reaches a 25, 50, 75 percent reduction at the end of the period considered. We thus computed the average lives saved per year under the three scenarios considered (i.e., 25, 50, and 75 percent reduction in RTI mortality). The number of lives that can be saved in the three scenarios ranges from 883 in Tanzania in the most pessimistic scenario to 123,250 in China in the most optimistic one. Finally, we computed the total value of lives saved per year, multiplying the VSL by the average number of lives saved per year.

Since VSL estimates in LMICs are scarce, as noted, we will use our four different rules of thumb to try and identify the upper and lower bounds for the VSL in the study countries. We consider four measures. The first is based on Milligan et al. (2014), who suggest a VSL for LMICs to be used for applications in transport safety. Second, we use the International Road Assessment Programme (iRAP) rule of thumb, proposing a VSL of 70 times the GDP per capita of the respective country. We chose these two methods because they have been developed and used in the context of road traffic crashes. Third, we suggest a rule of thumb that combines GDP per capita and life expectancy to take into consideration the difference in survival probabilities between countries. Fourth and finally, we use, as upper bound, the values of US$3 and 5 million, which are more in line with the values estimated by Viscusi and Aldy (2003) for the United States. These figures could be meaningful at least for the richest and fastest-growing countries in our sample.

Milligan et al. (2014) interpolate estimates of VSL from estimates obtained for a set of LMICs using transfer functions (benefit-transfer process). The method involves deriving a (non-linear) relationship between the VSL and GDP per capita. To create the transfer function, the authors perform a meta-analysis based on stated preferences estimates of VSL. Their analysis is based on 856 VSL estimates included in OECD (2012) and another 6 estimates taken from Svensson (2009), Lee et al. (2011), Hoffman et al. (2012), and Viscusi et al. (2013). The 123 studies from LMICs included in the analysis had to pass a quality screening. These studies were conducted between 2003 and 2010. The VSL estimates in the sample range from US$3138 to US$1.5 million. The coefficients for the transfer function are derived by means of a robust MM weighted regression with weights equal to the inverse of the number of estimates in a given survey.

The VSL is computed as a function of GDP using two different transfer functions for high-income countries and LMICs. Since our report covers LMICs only, we will focus on the latter transfer function. The transfer function for LMICs is a convex function of GDP per capita and it is defined as follows:

$$\mathrm{VSL} = 1.372 \times 10^{-4}\mathrm{gdpcap}^{2.478}$$

where gdpcap is the GDP per capita in international prices (expressed in 2005 prices). Table 14 reports our estimates for the VSL in the five countries we considered. Data on GDP per capita in international prices have been obtained using the information in the International Monetary Fund World Economic Outlook database (IMF 2017). In particular, GDP per capita in international prices for each year/country has been computed using the formula

$$gdppcap(in\ international\ prices\ in\ 2005\ prices) = \mathrm{gdpcap(in\ current\ prices)(PPP)}^{-1}\left(\frac{\mathrm{GDP\ deflator\ in\ 2005}}{\mathrm{GDP\ deflator\ in\ the\ year\ considered}}\right).$$

The value of the total GDP in 2014 has been computed by multiplying the value of GDP per capita used for the construction of the VSL by the country's population in millions (in 2014). The number of lives saved has been computed as explained above.

Results

Table 14 reports the estimates obtained using the Milligan et al. (2014) approach. The estimates of the VSL are in line with those obtained by the Milligan team and range from $1.81 million in Thailand to $5,283 in Tanzania. Such values are quite low compared to the levels estimated for developed countries. This result that can be explained by the shape of the transfer function for LMICs, which is convex and, hence, quite flat for the GDP per capita values considered. Consequently, the value of the gain obtained by reducing the mortality by 25, 50, or 75 percent as a share of GDP goes from 0.19 percent for Tanzania in the most pessimistic case to 45.7 percent for Thailand in the most optimistic case.

The results in Table 14 suggest a very low estimate of the VSL for poor countries. To overcome this problem and in order not to underestimate the VSL in particular in Tanzania and in India, we also compute the VSL using the iRAP rule-of-thumb (Table 15). As mentioned above, this entails computing the VSL as a linear function of the GDP per capita, i.e., as the GDP per capita (in 2005 international prices) multiplied by 70. The linearity of the transfer function implies that the estimates of the VSL for the poorest country in our sample are likely to be higher than those obtained using Milligan et al. (2014) methods and reported in Table 14. On the other hand, the VSL estimates for the richest countries in our sample (China and Thailand) are likely to be lower than the previous ones.

The gains in terms of GDP now range from 2.9 percent in the most pessimistic case in Tanzania to 21.4 percent for the most optimistic case in Thailand. These estimates have been obtained using estimates of the VSL ranging from around US$ 80,000 (in Tanzania) to around US$ 850,000 in Thailand.

As a third estimate, we propose a rule of thumb that takes into consideration both the level of economic development and the population health level of a country (see Table 16). We compute the VSL as the 2014 GDP per capita (in international prices expressed in 2005 dollars) multiplied by life expectancy at birth in that country in 2014. The life expectancy at birth ranges from 65 years in Tanzania to 76 years in China. These estimates are of the same magnitude and comparable to the iRAP case, since in many LMICs life expectancy at birth is around 70 years. In addition, it is also similar to Becker et al. (2005) who consider life expectancy an important determinant in the computation of the VSL. Indeed, if we compare two equally rich countries, it appears obvious that the VSL should be lower in the one with the lower life expectancy. If we assume that an individual would be willing to pay an annual sum of money to increase her life expectancy, and that this annual compensation depends on how rich the individual is, the lifetime compensation (and thus the VSL) would be greater whenever the life expectancy (and thus the years the individual is willing to pay the compensation) is longer.

The gains in terms of GDP now range from 2.7 percent in the most pessimistic case in Tanzania to 22.7 percent for the most optimistic case in Thailand. These estimates have been obtained using a VSL ranging from around US$75,000 (in Tanzania) to around US$898,000 in Thailand.

Since the VSL we computed may appear rather low, we also provide an estimate of the welfare benefits using two less conservative values of the VSL, US$3 million and US$5 million. These two values are proposed because they are similar to the lower bound of the VSL estimated by Viscusi and Aldy (2003) for the USA in 2000 dollars. Results are reported in Table 17. Considering a VSL equal to $3 million, the gains in terms of GDP in 2005 international prices now range from 0.83 percent in the most pessimistic case in China to 15.20 percent for the most optimistic case in Tanzania. Adopting a VSL of $5 million, the gains in terms of GDP range from 1.66 percent in the most pessimistic case in China to 22.81 percent for the most optimistic case in Tanzania.

RTI crashes not only represent a cost in terms of lives lost, but the morbidity they cause similarly produces a welfare loss that ought to be captured in any welfare benefit assessment. To capture this effect, it is computed the number of DALYs saved due to a reduction of 25, 50 and 75% of DALYs using the same method used to compute the changes in mortality. We then evaluate the benefits by giving to each DALY gained the value of either the GDP per capita (in 2014, in 2005 international prices) or three times the GDP per capita in 2014, as suggested in WHO (2001).

Results are presented in Table 18. Estimated gains for the entire period range from around 3% of the GDP for China and the Philippines in the most pessimistic scenario using the more conservative rule of thumb, to 144% of the GDP for Tanzania in the most optimistic scenario using the least conservative rule of thumb. The results thus suggest that the welfare lost due to RTI crashes is much bigger than that measured just taking mortality into account, in particular for Tanzania, the poorest country in our sample.

Conclusions and Limitations

We have assessed the welfare gains of a decrease of RTIs in five developing countries: China, India, Philippines, Tanzania, and Thailand. The measure of the welfare gains is needed in order to assess whether the policy proposed represents "value for money", i.e., if its benefits are greater than its costs. To estimate the benefit side (which has been the sole focus here), we followed various approaches using at their core the value of statistical life for each country, largely following the methods commonly used in the RTI literature. Due to the scarce availability of original VSL estimates from LMICs, we had to make strong assumptions about the range of the VSL in the five countries considered. Not surprisingly, the assumptions made about the VSL of a given country have considerable repercussions for the overall effect size, as the variability of the results has shown.

Likely the single biggest limitation that plagues any welfare benefit assessment of reducing RTIs in LMICs is the fact that no reliable measures of the VSL are available for most LMICs, including the five countries investigated here. Proper measures of the VSL ought to be derived by asking individuals their willingness to pay for a marginal reduction in mortality or by inferring such willingness to pay from their behavior. In either case, the evaluation of the VSL requires the collection of extensive, suitable microdata. Unfortunately, this information is unavailable for the countries under study, and we had to extrapolate countries' VSL from the relationship between VSL and per capita GDP that can be derived from countries where proper estimates of VSL are available, meaning in most cases high-income countries. Such an extrapolation, proposed, for example, by Milligan et al. (2014), produces very low figures, especially for poor countries such as Tanzania. These extrapolations should be regarded with caution. They are likely to be significant underestimates of the true VSLs in LMICs. For this reason, to provide more of an upper boundary estimate, we reported in Table 16 welfare estimates based on VSLs that are of the same order of magnitude as in high-income countries.

Interestingly, the extrapolation proposed by Milligan et al. (2014) produced VSLs that are close to those that could be derived from the so-called "human capital approach," where the VSL coincides with the value of the economic production during individual life. It is thus clear that in poor countries where GDP per capita is far smaller and life expectancy considerably shorter than in upper middle-income and high-income countries, VSL will be "mechanically" smaller. However, while economic production (and mostly the corresponding income earned by the individual) is certainly part of the VSL, by no means does it represent the entire monetary value of the utility enjoyed over the life cycle, which would include many non-monetary components.

Not only are the estimates of the VSL used here likely underestimates, but also the figures on RTI mortality could be underestimated or at least incomplete for the countries we focus on, adding to the concern that the resulting welfare benefits are distorted downwards.

Finally, the estimates mainly focus on RTI mortality while less emphasis is given to morbidity, which is certainly a major component of the total RTI burden. We tackled the problem of morbidity by complementing our analysis with an estimate of the welfare gains evaluated using two simple rules of thumbs: i.e., the value of a DALY equal to the country GDP per capita and three times as much. More research is needed to provide a more rigorous basis for the valuation approaches applied in the welfare assessment of RTI mortality and morbidity.

APPENDIX 3. EXTERNAL DATA SOURCES FOR MACRO-ECONOMIC MODELLING

The analysis underlying both the growth and welfare impact assessments used data from several different sources. The sources and time periods of each dataset are given in Table 4.

Table 4. Datasets Used in the Analysis

DATABASE	VARIABLES	TIME PERIOD	REFERENCE
1. IHME GHDx	RTI and All-cause Deaths (numbers and rates), DALY, YLL, YLD, LE, HALE	1990-2015	http://ghdx.healthdata.org/gbd-results-tool. Access date: 16 November 2016
2. CID	Various geography	1998-1999 (some variables earlier, e.g. gdp from 1995 in physical geography file)	http://www.cid.harvard.edu/ciddata/ciddata.html. Access date: 28 November 2016
3. PWT	GDP and National Accounts	1990-2014	http://www.rug.nl/ggdc/productivity/pwt/. Accessed: 29 November 2016
4. WDI	Population density, urbanization	1990-2016	http://data.worldbank.org/data-catalog/world-development-indicators. Access date: 8 December 2016
5. FIW	Political rights and civil liberties	2002	https://freedomhouse.org/report-types/freedom-world. Access date: 2002 (sent by Lorenzo)

For health data – including RTI-attributable and all-cause mortality, morbidity and derived summary measures such as disability-adjusted life years (DALY) and health adjusted life expectancy (HALE) – we used information from the Institute for Health Metrics and Evaluation (IHME) global health data exchange (GHDx) GBD results tool.[22] The specific variables that were downloaded and constructed from IHME GHDx are shown in Table 5. For each listed variable, an estimate for each male, female, and both was extracted. Within each variable and sex combination, estimates for three age categories were then further specified: ages 15-64, aged over 65, and a final "all ages" category. All IHME GHDx data were available for the timespan 1990 to 2015. However, measures that incorporated morbidity (YLD, DALY, and HALE) were only available every fifth year. Missing data for the IHME GHDx data were only observed for the number of deaths and death rates for females. These were imputed using the nearest previous year estimate carried forward. If female deaths were missing at the beginning of the interval (e.g., in 1990), then the closest future mortality estimate was used.

Table 5. Variables Extracted from IHME GHDx Dataset

RTI	ALL CAUSE	AVAILABLE YEARS
Mortality Number	Mortality Number	1990-2015, inclusive
Mortality Rate	Mortality Rate	1990-2015, inclusive
YLD	YLD	1990-2015, every 5 years
YLL	YLL	1990-2015, inclusive
DALY	DALY	1990-2015, every 5 years
	LE	1990-2015, inclusive
	HALE	1990-2015, every 5 years

Note: YLD – years of life lived with disability; YLL – years of life lost; DALY – disability adjusted life year; LE – life expectancy; HALE – health adjusted life expectancy.

[22] http://ghdx.healthdata.org/gbd-results-tool

Further data was accessed from Harvard University's Center for International Development (CID).[23] We used six specific data files from CID's geography data repository. These include:

1. Agricultural data
2. Infectious disease areas
3. Population in infectious disease areas
4. Malaria (area and population)
5. Physical geography and population
6. Köppen-Geiger climate zones

For several types of data, we used the latest version 9.0 of the Penn World Tables (PWT).[24] This data is available yearly up to 2014. We used variables for real GDP as well as the national accounts data add-on for the following variables: investment, government consumption, exports and imports. All variables used were in constant 2011 national prices using US$.

We also drew upon the World Development Indicators (WDI), published by the World Bank.[25] The two variables extracted for use were the population density (people per square mile) and the percent urbanization (% population living in urban agglomeration greater than 1 million population).

Finally, we used the Freedom in the World (FIW) database from Freedom House.[26] The 2002 version of this database was used, and separate variables for political rights and civil liberties were extracted.

[23] http://www.cid.harvard.edu/ciddata/ciddata.html
[24] http://www.rug.nl/ggdc/productivity/pwt/
[25] http://data.worldbank.org/data-catalog/world-development-indicators
[26] https://freedomhouse.org/report-types/freedom-world


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APPENDIX 4. DESCRIPTIVE STATISTICS FOR STUDY COUNTRIES

Table 6. RTI and All-Cause Mortality Rates (x 100,000 Inhabitants)

YEAR	CHINA	INDIA	THAILAND	PHILIPPINES	TANZANIA	OECD
1990	24 403	24 652	30 369	10 368	18 647	22 342
1995	26 385	25 624	51 458	11 350	16 811	19 334
2000	29 367	26 597	48 500	10 358	14 892	15 295
2005	31 350	27 554	43 444	12 378	12 826	12 274
2010	28 319	26 523	37 431	12 384	13 632	9 253
2015	24 306	25 490	34 453	11 379	14 534	8 241

Table 7. RTI and All-Cause DALYs (x 100,000 Inhabitants)

YEAR	CHINA	INDIA	THAILAND	PHILIPPINES	TANZANIA	OECD
1990	883 16919	734 23588	1145 17026	326 15266	498 21898	894 15815
1995	955 16579	767 23268	1941 20690	356 14682	453 26526	799 15726
2000	1084 16397	812 23215	1821 22275	335 15101	395 28924	660 14801
2005	1200 16736	848 22527	1668 20615	405 15767	339 27062	537 14325
2010	1071 16044	834 21754	1378 19969	433 16391	352 21744	410 13677
2015	903 15334	804 21001	1217 20069	401 16394	382 18632	355 13471

Table 8. Real GDP per capita (National Constant Prices 2011)

YEAR	CHINA	INDIA	THAILAND	PHILIPPINES	TANZANIA	OECD
1990	2311	1801	6383	4078	1352	26150
1995	3443	2098	9165	4026	1400	26685
2000	4181	2536	8986	4298	1514	32210
2005	6333	3269	11167	4867	1852	35516
2010	9530	4531	13249	5733	2130	35060
2014	12524	5534	14642	6774	2439	36393
growth 1990-2014	441%	207%	129%	66%	80%	39%

APPENDIX 5. BRIEF LITERATURE REVIEW ON RECENT LITERATURE ASSESSING THE IMPACT OF HEALTH ON ECONOMIC GROWTH

A considerable literature has attempted to estimate the effect of mortality or of life expectancy on economic growth. From a macroeconomic perspective, the theoretical starting point, grounded in the classical Solow model, is that decreasing mortality (or increasing life expectancy) and a corresponding faster population growth is *not necessarily beneficial* to the GDP per capita growth rate, despite the unambiguously beneficial effects at the microeconomic level in terms of worker productivity, labor supply, and acquisition of human capital. Hence, whether the effect of reducing mortality on macroeconomic growth is positive or negative is finally an empirical question.

Early studies generally found a strong positive association between health and income growth or income level. For instance, Sala-i-Martin (1997) concludes that health variables (specifically life expectancy, malaria, and infant mortality) are among the most robust predictors of economic growth. However, as Weil (2007) pointed out, much if not all of the existing work on the subject "suffer(s) from severe problems of endogeneity and omitted variable bias. [...] More generally, the problem with the aggregate regression approach is that, at the level of countries, it is difficult to find an empirically usable source of variation in health, either in cross section or time series, that is not correlated with the error term in the equation determining income (p.1271)". In other words, the supposed positive causal effect of health on economic performance could in fact be just a spurious correlation due to the lack of adequate conditioning in the regression or due to the possibility that the causal relationship runs in the reverse direction, i.e., from economic growth and improvement in living standards towards health. The simple strategy of lagging explanatory variables, as suggested by Bloom et al. (2010), does not seem to be able to solve neither the problem of omitted variables nor that of reverse causation, as both income per-capita and health are quite persistent and slow-moving overtime. Arguably more acceptable is the approach followed by Suhrcke and Urban (2010), who not only lag their health variable (cardiovascular disease [CVD] mortality) by 5 years but estimate a Blundell-Bond dynamic panel data model with country fixed effects which account for country unobserved heterogeneity and exploit all lags and first differences as instruments.

Here we focus on the more recent literature which, acknowledging endogeneity problems, tries to uncover the causal effect of health on growth. There are two papers that have renewed the interest in this analysis. Both recognize the importance of a proper identification of the causal effect of health on economic growth or income level, adopting appropriate solutions. Nevertheless, they end up with opposite conclusions.

Somewhat pessimistic results are found by Acemoglu and Jonhson (2007) (AJ henceforth), who study the effect of life expectancy on income level, using an identification strategy that rests on an unprecedented improvement of health conditions around the 1940s in many countries (most of which are in the

LMIC category) due to the discovery of new chemicals and drugs and the diffusion of public health measures (the so-called international epidemiological transition). Results indicate that life expectancy has no significant effect on the total GDP level while it has a significant negative effect on per-capita GDP. The latter result is consistent with the significant positive effect of life expectancy on population size and number of births, as a larger population tends to reduce income per capita.

The second seminal paper we discuss is Lorentzen, McMillan, and Wacziarg (2008) (LMW henceforth). They also use an instrumental variable strategy, but they analyze the causal effect of mortality rates on per capita income *growth*. Their final sample covers 88 countries, and their regression model makes per capita income growth between 1960 and 2000 dependent on both the average adult and infant mortality registered between 1960 and 2000, the log of per capita income in 1960, and a number of country controls. Mortality rates are considered endogenous and are instrumented by the Malaria Ecology Index developed by Sachs et al. (2004), climatic variables (the percentage of a country's land located in each of the twelve climate zones, proportion of land with more than five days of frost per month in winter), and geographic characteristics (the distance of a country's centroid from the equator, the mean distance to the nearest coastline, the average elevation, and the log of land area). Results indicate a strong negative and significant effect of both adult and infant mortality on per-capita income growth, with the effect of infant mortality being considerably stronger than the effect of adult mortality.

AJ and LMW papers were developed more or less simultaneously, trying to answer a similar question, although their model specification is not identical. The former looks at the effect of life expectancy on GDP levels while the second examines the effect of mortality rates on per capita GDP growth. Moreover, their empirical approach is quite similar, as they turn to instruments to identify causal effects. Despite all these similarities, their conclusions seem to contradict each other. Such discrepancy has led to a substantial research effort in subsequent years to establish more coherent results.

Aghion et al. (2011) point out that the AJ model is mis-specified because the initial level of life expectancy is omitted. According to the so-called Nelson-Phelps approach to economic growth, a higher initial *level* of life expectancy will induce faster technological innovation and adoption, supporting economic growth. Estimating a model similar to LMW where growth between 1960 and 2000 is regressed on the change in life expectancy in the period and its initial level, they find a positive contribution of both variables on growth, even when they perform an IV strategy with the same instruments as LMW. A similar point has been raised by Bloom et al. (2014). They note that the negative effect in AJ is due to the fact that there is strong negative correlation between change in life expectancy and its initial level, and that it is the initial level of life expectancy that favors subsequent growth. Thus, by controlling only for the variation in life expectancy, AJ make a specification error, which drives their results. Bloom et al. note also that controlling for initial life expectancy largely reduces the strength of AJ's instrument, which essentially depends on mortality rates in the 1940s. Both Aghion et al. (2011) and Bloom et al. (2014) point out that not only the relation between the *level* of income and the *level* of life expectancy could depend on country-level heterogeneity (i.e., country fixed effects), but also the relation between their *growth rates*. Acemoglu and Johnson (2014) reply to Bloom et al. (2014) adopting the specification suggested by the latter by controlling for life expectancy in 1900 (rather than 1940) and using decadal observations between 1940 and

1980 rather than long differences, confirming their original result of a negative effect of life expectancy on per capita GDP level. In a recent paper, Hansen and Lonstrup (2015) extend the AJ dataset by adding an observation relative to year 1900 for 35 of the original 47 countries. They are thus able to compute two long differences for each country, one between 1900 and 1940 and one between 1940 and 1980, and in so doing they are able to introduce country fixed effect in the long differences model, which accounts for the Bloom et al. (2014) critique that initial life expectancy was omitted. Their results confirm and extend the original AJ conclusions. Not only the growth of life expectancy but also its initial level negatively influences the growth rate of per capita GDP.

Unfortunately, the number of observations both in AJ and even more in Hansen and Lonstrup (2015) is so small that one may wonder how estimates turn out to be statistically significant. Also, it would be useful to analyze more in depth whether results depend on the inclusion or exclusion of one or few observations. More importantly, countries for which data are available are not a random or a representative sample of all world countries, so that the degree of generalizability of these results is doubtful.

While AJ's instrument is intuitively appealing, and it formally varies by country and time, in practice it mainly depends on mortality in 1940, as pointed out by Bloom et al. (2014), i.e., on a country-specific characteristic which might be correlated with country unobserved heterogeneity (in that case, compromising instrument validity). Results in Hansen and Lonstrup (2015) tend to dispel the latter concern but, again, they refer to a sample of only 35 countries. Finally, the inclusion of long differences in health as explanatory variables raises the problem of measurement errors (Bleakley 2010). If mortality or life expectancy were measured with error and such error were classical, i.e., independent from the correctly measured health indicator, taking differences would increase the proportion of variation in the explanatory variable due to measurement error with respect to that due to the "true" information the indicator is expected to capture (i.e., the noise to signal ratio will increase). This fact would imply a downward bias in estimates.

Hansen (2014) develops an estimation strategy very similar to that of AJ to estimate the effect of life expectancy on per capita GDP across the U.S. states between 1940 and 1980. In line with AJ, the adopted instrument is the interaction between mortality from nine medically treatable communicable diseases registered before and after antibiotic discovery. The advantages of this within-country analysis include (1) comparing more homogenous economic systems than those entering in cross-country studies and (2) a smaller measurement error due to the adequate vital registration system already established in America after 1933. Results show that increased life expectancy has significant positive effects on population and total GDP, while the effect on GDP per capita is small and statistically insignificant.

Trying to reconcile AJ and LMW results, Cervellati and Sunde (2011a) redo the AJ analysis on the same data but distinguish between countries that in 1940 had already completed their demographic transition towards a low-fertility and low-mortality regime and those countries that had not done so. The key observation Cervellati and Sunde (2011a) report is that the introduction of new pharmaceuticals has the immediate effect of reducing mortality, which is not immediately accompanied by a reduction in fertility. It follows that, at least for a certain period, population grows much faster than usual, causing a fall in income per capita. Accordingly, among countries already on a trajectory of low mortality and low fertility, a further decrease in mortality might have supported growth of per capita income via its positive effect on labor productivity and investment in human capital, while in countries lagging behind in their demographic transition, the sudden reduction in mortality occurred in the early 1940s might have caused a reduction in income per capita due to the corresponding substantial expansion of their population.

Motivated by this observation, Cervellati and Sunde extend the AJ model and define a fully interacted model which allows different estimates between pre- and post-demographic transition countries. The authors use AJ and LMW instruments alternatively, and in both cases, they find that increasing life expectancy is beneficial to income in post-transition countries (the effect of life expectancy being positive and highly statistically significant) while it is generally negative, though not always significantly different from zero, among pre-transition countries. They conclude that the opposing results in AJ and LMW are not due to the alternative instrumentation strategies, but rather to a too-rigid specification that forced life expectancy (or mortality) to have the same effect in all countries.

In a subsequent short paper, Cervellati and Sunde (2011b) further increase the degree of flexibility of their empirical analysis by defining a mixture model that allows data to determine whether a country is to be considered pre- or post-demographic transition, rather than relying on an ex-ante classification that they had adopted in Cervellati and Sunde (2011a).

From a perspective close to that of Cervellati and Sunde (2011a), Bleakley (2010) notes that the response of income to health depends on the manner in which health improves. Whether health shocks mainly affect adults or children makes a difference for the magnitude and the timing of results. In the former case, the effect is mainly through a variation in population size, while in the latter case it is mainly through a variation in investments in human capital and indeed in the future supply of effective units of labor (i.e., hours of work weighted by workers' human capital). For instance, the 1918 pandemic flu in India reduced the working population, thereby increasing the amount of land available per worker, with the effect of reducing aggregate income but improving the future income dynamic (Shultz 1964). The eradication of tropical parasites in the Southern U.S. states mainly reduced childhood morbidity and favored human capital accumulation (Bleakley, 2007), with effects that become visible gradually as long as young cohorts entered the labor market.

An interesting source of exogenous variation to identify the effect of health on income growth has been exploited by Strittmatter and Sunde (2013). They instrument health (captured by mortality rates) by means of the progressive introduction of universal public health care in 12 European countries between 1820 and 2010. The empirical results indicate that the introduction of public health systems led to significant reductions in infant mortality and crude death rates that, in turn, had a significant positive effect on economic growth.

APPENDIX 6. BRIEF CONSIDERATIONS ABOUT THE EPIC MODEL AS AN ALTERNATIVE WAY OF ASSESSING THE MACROECONOMIC CONSEQUENCES OF RTIs

The WHO EPIC is a simulation model which assumes that the economy of a given country expands according to a simple and completely deterministic model of factor accumulation. The model analyses how the growth path obtained under given assumptions on population health (typically disease-specific mortality) compares to the growth path obtained in a baseline scenario.

The model has been largely inspired by the work of Cuddington and Hancock (1994), which aimed at predicting the economic impact of the HIV/AIDS epidemic in Malawi, which at the time of the study was in its early stages. The WHO EPIC model was first formulated in a WHO working paper (Abegunde and Stanciole 2006), with a focus on estimating the macroeconomic impact of chronic NCDs in nine countries. Perhaps because accompanied by a ready-to-use MS Excel tool (which is not readily publicly available), the model became rather popular, and it has been adopted in many publications, predominantly – though not solely – in the public health literature and in high profile public health reports.[27] In 2007, Abegunde et al. used a slightly modified version to estimate the costs of chronic diseases in low-income and middle-income countries. Results were published in The Lancet, as part of the first *Lancet* NCD series.

[27] See e.g. Bloom et al. (2011), Bloom et al. (2014), Alkire et al. (2015).

While the model is simple, clear and logical, it rests on several restrictive assumptions. Hence, its results, like those of any other approach discussed here, must be taken as a broad indication of the order of magnitude of the effect of particular health conditions in a given country. It is beyond the scope of this discussion to give a full account of the EPIC model. Overall, though, the EPIC model has strengths and weaknesses, like any other approach. It is useful to make them explicit, and we would submit that so far this has not been done in the literature using the EPIC model.

We start by the strengths: First, EPIC's internal logic is clear and its implementation is simple. It is a virtue that WHO has developed a user-friendly tool able to quickly produce illustrative results. Second, the simulation requires relatively little data: only to set the initial conditions and key structural parameters (the latter, however, might be quite hard to derive in practice and sometimes are arbitrarily assumed). It also requires little extrapolation from analysis carried out in other countries (which in any case would be difficult to justify). Third, and perhaps most importantly, it allows researchers to produce country-specific results, depending on actual country health and economic conditions.

As far as certain downsides are concerned, first, the Solow model, which is what the EPIC model is based on, has for many years been at the heart of the empirical analysis on convergence that aimed to test Solow's prediction that countries sharing the same structural parameters should converge to the same steady state, regardless

of their initial conditions (prediction known as conditional convergence) (Durlauf et al. 2001, 2005). We stress that the prediction of the model was tested and not the model itself. Indeed, it is far from obvious how to use the Solow model (or any variation of it) to describe the economic dynamic of one single country over time, because it is unlikely that a model that simple, deterministic, and rigid could replicate reasonably well the growth process of a complex system such as a national economy. We are not aware of studies which have analysed the fit of the Solow model to the GDP, capital, and labor time series of one particular country.
Second (but related to the first point), the reliability of the EPIC model results depends on how model parameters are specified and on the extent to which the assumed shape of the production function reflects the real relationship between inputs and outputs in the country under study.

Third, the EPIC model does not account for morbidity (though an extension of the model may allow for this, using certain assumptions), which is well known to have important effects on productivity, particularly in lower and middle-income countries where manual labor often predominates (Lopez-Cassanovas et al. 2005). However, the neglect of morbidity makes the macroeconomic impact estimated by the EPIC model more conservative and so, perhaps, preferable, recalling that the empirical evidence regarding the effect of health on growth is still mixed.

Fourth, in countries with excessive saving and under-optimal consumption per-capita (i.e., those in a condition of dynamic inefficiency, such as for instance China), the reduction in savings due to the need to finance the cost of illness might be beneficial private consumption (Bloom et al. 2014).

Fifth, and more important in our view, the EPIC model focuses on the effect of mortality reduction on total income and not on per capita income. As total income is assumed to positively depend on the size of population (or labor force), any health policy able to reduce mortality and increase population will produce large gains in total income, even if the marginal productivity of labor keeps declining as population grows. The only countervailing factor is the aggregate cost of the policy, which, however, will never be able to limit aggregate income expansion in the long run, according to the model specification. As we mentioned above, per capita income and not aggregate income should be the outcome to look at to evaluate the macroeconomic effect of any mortality reduction, and more generally of any health enhancement policy, as only per capita income gives an idea of average living standards in a given country.

Compared to the gain in total income associated with a given policy, a more acceptable measure of the effect of the policy is the sum of two components: 1) the number of averted deaths multiplied by per capita income, which accounts for the income benefit accrued to the additional population due to the policy, and 2) the variation between per capita income under the mortality reduction policy and under the status quo, multiplied by population under the status quo scenario, which accounts from the effect of better health on the living standards of the existing population. While the former component will certainly be positive, the latter could be positive or negative, depending on whether income per capita will grow or decline. A Pareto-improving policy that benefits everyone and that we expect will receive ample political support is one in which both components are positive. Less obvious will be the support for a policy with a negative second component, even if the sum of the components is positive.


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APPENDIX 7. ADDITIONAL DATA AND RESULTS FROM GROWTH IMPACT ESTIMATION – ALL AGES

Table 9. Summary Statistics. Variables Averaged Over the Period 1990-2014

VARIABLE	Obs	Mean	Std. Dev.	Min	Max
Real GDPpc growth 1990-2014 (percent)	135	64.13	65.90	-43.68	441.96
All-cause DALYs (years per 100,000 inhab.)	135	18.63	6.72	9.34	44.44
RTI DALYs (years per 100,000 inhab.)	135	0.73	0.34	0.25	1.93
All-cause Mortality Rate (deaths per 100,000 inhab.)	135	483.18	280.21	161.47	1407.69
RTI Mortality Rate (deaths per 100,000 inhab.)	135	21.59	10.61	6.38	56.56
Falciparum Malaria Index 1966 (% of resident population at risk)	135	32.65	42.47	0.00	100.00
Log Real GDPpc 1990	135	8.72	1.19	5.90	11.70
OECD 1990	135	0.14	0.35	0.00	1.00
Log population	135	16.39	1.37	14.06	20.97
Urban (% of urban population)	135	54.33	22.11	8.82	100.00
Openness	135	75.87	38.92	17.61	322.93
Government spending	135	17.15	11.27	3.68	101.75
Civil liberties (Freedom House Index)	135	3.72	1.68	1.00	7.00
Internet (% population with internet access)	135	18.05	15.60	0.47	56.44
Proportion area in polar zone	135	0.02	0.06	0.00	0.30
Proportion area in boreal zone	135	0.06	0.16	0.00	0.91
Proportion area in dry temperate zone	135	0.04	0.13	0.00	0.95
Proportion area in wet temperate zone	135	0.20	0.32	0.00	1.00
Proportion area in subtropical zone	135	0.29	0.33	0.00	0.98
Proportion area in tropical zone	135	0.17	0.26	0.00	1.00

Table 10. The Effect of Mortality Rate on GDP per capita Accumulation. Dynamic Panel Model. All Ages

VARIABLES	(8) AB	(9) FE	(10) OLS
lagged real GDPpc	0.735*** (0.067)	0.884*** (0.032)	0.977*** (0.022)
All-Cause mortality rate (per 100,000 inhab.)	-3.331* (1.947)	-1.756 (1.091)	0.198 (0.179)
log population	-8,035.590* (4,566.909)	-5,705.533* (3,302.417)	22.936 (43.190)
urban	146.684 (100.111)	53.115 (46.635)	14.108* (7.610)
openness	18.082*** (5.793)	4.540 (3.832)	5.559*** (1.972)
government spending	-86.286** (37.891)	-82.116*** (29.881)	-3.106 (5.122)
internet	36.347*** (9.179)	32.129*** (6.342)	41.871*** (7.664)
Great Recession (year>2007)	-2,832.510 (2,595.229)	-4,632.812** (1,803.225)	-2,704.055 (1,645.299)
Constant	130,707.178* (71,703.262)	95,197.633* (52,906.094)	-995.130 (967.145)
Interactions between Great Recession and Controls	Y	Y	Y
Number of countries	135	135	135
Observations	770	906	906
semielasticity	-1.400	-1.103	-0.163
AR(1) p-val	0.045		
AR(2) p-val	0.254		

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 11. The Effect of Mortality Rate on GDP per capita Growth. Long-Run Growth Regression. All Ages

	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV
All-Cause mortality rate (x 100,000 inhab.)	-0.076*** (0.016)	-0.086** (0.035)	-0.119*** (0.046)	-0.082** (0.035)	-0.095** (0.040)	-0.090*** (0.035)	-0.092** (0.038)
Log real GDPpc 1990	-40.547*** (10.746)	-41.186*** (9.772)	-55.722*** (18.120)	-41.886*** (9.753)	-41.272*** (9.865)	-40.891*** (9.470)	-41.477*** (9.648)
OECD 1990	-39.771*** (13.207)	-38.614*** (12.775)	-77.229** (33.173)	-38.291*** (12.768)	-38.816*** (12.888)	-27.841* (15.245)	-29.210* (15.989)
Log population	20.480*** (6.114)	20.127*** (5.931)	19.733*** (5.882)	20.018*** (5.835)	21.364*** (6.475)	15.534** (6.292)	16.898** (7.682)
Urban	-0.550 (0.437)	-0.585 (0.453)	-0.610 (0.521)	-0.639 (0.443)	-0.708 (0.486)	-0.508 (0.483)	-0.637 (0.539)
Openness	0.541*** (0.134)	0.535*** (0.129)	0.595*** (0.153)	0.516*** (0.129)	0.536*** (0.132)	0.443*** (0.136)	0.443*** (0.143)
Government spending	-1.441*** (0.198)	-1.417*** (0.207)	-1.547*** (0.238)	-1.460*** (0.224)	-1.457*** (0.217)	-1.286*** (0.211)	-1.360*** (0.260)
Civil liberties	-6.283 (4.336)	-6.283 (4.079)	-5.950 (4.532)	-5.503 (4.289)	-7.209* (4.050)	-7.625** (3.798)	-7.509* (3.871)
Internet	1.853*** (0.653)	1.806*** (0.630)	1.367** (0.675)	1.976*** (0.673)	1.686*** (0.616)	1.325** (0.665)	1.431** (0.705)
% Area in polar zone	-83.118 (110.772)	-83.870 (106.451)	-110.186 (103.427)	-84.576 (106.537)	-88.960 (107.838)	-86.059 (105.438)	-89.625 (106.404)
% Area in boreal zone	103.984*** (34.682)	110.037*** (36.835)	115.975*** (39.745)	107.975*** (36.973)	116.878*** (39.913)	103.161*** (36.981)	107.176*** (41.044)
% Area in dry temperate zone	57.513** (26.338)	62.032** (28.568)	76.301** (35.467)	61.952** (28.511)	62.178** (29.123)	58.062** (28.266)	58.641** (28.945)
% Area in wet temperate zone	59.669** (23.461)	66.018** (29.491)	71.081** (34.524)	64.368** (29.401)	71.281** (31.918)	61.484** (29.898)	64.426** (32.831)
% Area in subtropical zone	35.500* (20.214)	38.115* (21.196)	37.124 (22.769)	41.777* (21.873)	38.039* (21.581)	26.255 (20.890)	30.379 (22.879)
% Area in tropical zone	-12.911 (23.281)	-10.406 (24.268)	-18.200 (26.492)	-13.048 (24.684)	-10.106 (25.349)	-19.676 (25.518)	-20.072 (26.497)
All-Cause DALYs (x 100 inhab.) * Top quartile of real GDPpc 1990			0.095 (0.063)				
All-Cause DALYs (x 100 inhab.) * East Africa				-0.022 (0.022)			-0.015
All-Cause DALYs (x 100 inhab.) * South Asia					-0.041 (0.028)		-0.027
All-Cause DALYs (x 100 inhab.) * East and South-East Asia						0.078* (0.047)	0.068 (0.056)
Constant	128.181 (89.598)	147.893 (101.534)	301.918** (136.212)	151.942 (100.788)	149.292 (102.609)	239.606** (109.761)	230.927** (114.473)
Observations	135	135	135	135	135	135	135
Semielasticity	-0.666	-0.754					
F		38.02					

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 12. Estimated GDP per capita Gain Associated with a Reduction of RTI Mortality, by Year and Intervention Scenario. Note: Real GDP at constant national prices (in 2011US$)

YEAR	RTI mortality reduction scenario	China	India	Philippines	Tanzania	Thailand
2014	GDP pc in status quo scenario	12524	5534	6774	2439	14642
	GDP pc gain 25% reduction scenario	0	0	0	0	0
	GDP pc gain 50% reduction scenario	0	0	0	0	0
	GDP pc gain 75% reduction scenario	0	0	0	0	0
2019	GDP pc in status quo scenario	16332	7001	8378	2946	17747
	GDP pc gain 25% reduction scenario	7	3	2	1	14
	GDP pc gain 50% reduction scenario	13	7	4	2	29
	GDP pc gain 75% reduction scenario	20	10	6	3	43
2024	GDP pc in status quo scenario	21298	8858	10364	3558	21510
	GDP pc gain 25% reduction scenario	17	8	5	2	35
	GDP pc gain 50% reduction scenario	34	17	10	5	70
	GDP pc gain 75% reduction scenario	51	25	15	7	105
2029	GDP pc in status quo scenario	27775	11206	12819	4297	26072
	GDP pc gain 25% reduction scenario	34	16	9	4	64
	GDP pc gain 50% reduction scenario	67	32	19	8	127
	GDP pc gain 75% reduction scenario	101	48	28	12	191
2034	GDP pc in status quo scenario	36221	14178	15857	5189	31602
	GDP pc gain 25% reduction scenario	58	27	15	7	103
	GDP pc gain 50% reduction scenario	117	54	31	13	206
	GDP pc gain 75% reduction scenario	175	81	46	20	308

2038	GDP pc in status quo scenario	44792	17112	18797	6035	36858
	GDP pc gain 25% reduction scenario	87	39	22	9	144
	GDP pc gain 50% reduction scenario	173	78	44	19	288
	GDP pc gain 75% reduction scenario	260	117	66	28	432
2014-2038	Total GDP pc gain (discounted 2%)					
	Total GDP pc gain 25% reduction scenario	589	276	159	70	1070
	Total GDP pc gain 50% reduction scenario	1177	551	317	140	2139
	Total GDP pc gain 75% reduction scenario	1765	827	476	210	3207
2014-2038	Relative to 2014 GDPpc					
	Total GDP pc gain / 2014 GDP pc 25% reduction scenario	4.7%	5.0%	2.3%	2.9%	7.3%
	Total GDP pc gain / 2014 GDP pc 50% reduction scenario	9.4%	10.0%	4.7%	5.7%	14.6%
	Total GDP pc gain / 2014 GDP pc 75% reduction scenario	14.1%	14.9%	7.0%	8.6%	21.9%

Table 13. Estimated GDP per capita Gain Associated with a Reduction in RTI DALYs, by Year and Intervention Scenario

YEAR	RTI DALYs reduction	China	India	Philippines	Tanzania	Thailand
2014	GDP pc in status quo scenario	12524	5534	6774	2439	14642
	GDP pc gain 25% reduction scenario	0	0	0	0	0
	GDP pc gain 50% reduction scenario	0	0	0	0	0
	GDP pc gain 75% reduction scenario	0	0	0	0	0
2019	GDP pc in status quo scenario	16237	6936	8342	2952	17572
	GDP pc gain 25% reduction scenario	11	5	3	1	22
	GDP pc gain 50% reduction scenario	21	10	6	2	45
	GDP pc gain 75% reduction scenario	32	14	9	4	67
2024	GDP pc in status quo scenario	21051	8692	10274	3572	21090
	GDP pc gain 25% reduction scenario	28	12	8	3	54
	GDP pc gain 50% reduction scenario	55	24	15	6	107
	GDP pc gain 75% reduction scenario	83	36	23	8	161
2029	GDP pc in status quo scenario	27292	10893	12654	4323	25312
	GDP pc gain 25% reduction scenario	54	23	14	5	97
	GDP pc gain 50% reduction scenario	107	45	29	10	194
	GDP pc gain 75% reduction scenario	161	68	43	15	290

2034	GDP pc in status quo scenario	35384	13652	15584	5231	30379
	GDP pc gain 25% reduction scenario	93	38	23	8	155
	GDP pc gain 50% reduction scenario	186	76	47	17	310
	GDP pc gain 75% reduction scenario	278	113	70	25	465
2038	GDP pc in status quo scenario	43553	16354	18410	6094	35153
	GDP pc gain 25% reduction scenario	137	54	33	12	216
	GDP pc gain 50% reduction scenario	274	109	67	23	432
	GDP pc gain 75% reduction scenario	411	163	100	35	647
2014-2038	Total GDP pc gain (discounted 2%)					
	Total GDP pc gain 25% reduction scenario	938	387	242	86	1623
	Total GDP pc gain 50% reduction scenario	1875	774	485	173	3243
	Total GDP pc gain 75% reduction scenario	2812	1161	727	259	4861
2014-2038	Relative to 2014 GDPpc					
	Total GDP pc gain / 2014 GDP pc 25% reduction scenario	7.5%	7.0%	3.6%	3.5%	11.1%
	Total GDP pc gain / 2014 GDP pc 50% reduction scenario	15.0%	14.0%	7.2%	7.1%	22.2%
	Total GDP pc gain / 2014 GDP pc 75% reduction scenario	22.5%	21.0%	10.7%	10.6%	33.2%

APPENDIX 8. ADDITIONAL DATA AND RESULTS FROM WELFARE IMPACT ASSESSMENT

Table 14. Welfare Benefits Corresponding to a Permanent Reduction of RTI Mortality (Using the VSL Constructed Following Milligan et al. 2014)

Scenarios	Reduction in RTI mortality rate (over 100,000)	Population in 2014 (millions)	Total number of lives saved from 2014-38	VSL (2014) in 2005 international prices (in million)	GDP 2014 (international prices, 2005, in million)	% of GDP 2014
China		1,369.44		0.875979	12,395,562	
25%	6		985,992			6.97%
50%	12		1,971,984			13.94%
75%	18		2,958,000			20.90%
India		1,295.29		0.070518	4,241,565	
25%	6.25		971,472			1.62%
50%	12.5		1,942,944			3.23%
75%	18.75		2,914,392			4.85%
Tanzania		50.44		0.005283	58,046	
25%	3.5		21,192			0.19%
50%	7		42,360			0.39%
75%	10.5		63,552			0.58%
Thailand		67.73		1.811902	822,018	
25%	8.5		69,096			15.23%
50%	17		138,168			30.46%
75%	25.5		207,264			45.69%
Philippines		99.14		0.199805	494,239	
25%	2.75		32,712			1.32%
50%	5.5		65,424			2.64%
75%	8.25		98,160			3.97%

Table 15. Welfare Benefits Corresponding to a Permanent Reduction of RTI Mortality (Using the VSL Estimates Constructed According to the iRAP Approach)

Scenarios	Reduction in RTI mortality rate (over 100,000)	Population in 2014 (millions)	Total number of lives saved from 2014-38	VSL (2014) in 2005 international prices (in million)	GDP 2014 (international prices, 2005, in million)	% of GDP 2014
China		1,369.44		0.6336	12,395,562	
25%	6		985,992			5.04%
50%	12		1,971,984			10.08%
75%	18		2,958,000			15.12%
India		1,295.29		0.2292	4,241,565	
25%	6.25		971,472			5.25%
50%	12.5		1,942,944			10.50%
75%	18.75		2,914,392			15.75%
Tanzania		50.44		0.0806	58,046	
25%	3.5		21,192			2.94%
50%	7		42,360			5.88%
75%	10.5		63,552			8.82%
Thailand		67.73		0.8496	822,018	
25%	8.5		69,096			7.14%
50%	17		138,168			14.28%
75%	25.5		207,264			21.42%
Philippines		99.14		0.3490	494,239	
25%	2.75		32,712			2.31%
50%	5.5		65,424			4.62%
75%	8.25		98,160			6.93%

Table 16. Welfare Benefits Corresponding to a Permanent Reduction of RTI Mortality (Using the VSL Constructed by Multiplying the GDP per capita by the Life Expectancy)

Scenarios	Reduction in RTI mortality rate (over 100,000)	Population in 2014 (millions)	Total number of lives saved from 2014-38	VSL (2014) in 2005 international prices (in million)	GDP 2014 (international prices, 2005, in million)	% of GDP 2014
China		1,369.44		0.6336	12,395,562	
25%	6		985,992			5.47%
50%	12		1,971,984			10.94%
75%	18		2,958,000			16.42%
India		1,295.29		0.2227	4,241,565	
25%	6.25		971,472			5.10%
50%	12.5		1,942,944			10.20%
75%	18.75		2,914,392			15.30%
Tanzania		50.44		0.0748	58,046	
25%	3.5		21,192			2.73%
50%	7		42,360			5.46%
75%	10.5		63,552			8.19%
Thailand		67.73		0.8981	822,018	
25%	8.5		69,096			7.55%
50%	17		138,168			15.10%
75%	25.5		207,264			22.65%
Philippines		99.14		0.3390	494,239	
25%	2.75		32,712			2.24%
50%	5.5		65,424			4.49%
75%	8.25		98,160			6.73%

Table 17. Welfare Benefits Corresponding to a Permanent Reduction of RTI Mortality (Using Alternative VSLs Equal to US$3 Million and US$5 Million)

Scenarios	Reduction in RTI mortality rate (over 100,000)	Total number of lives saved	GDP 2014 (international prices, 2005, in million)	% of GDP 2014 (VSL=3mil) (international prices 2005)	VSL=3mil) (international prices 2005
China			12,395,562		
25%	6	985,992		23.86%	39.77%
50%	12	1,971,984		47.73%	79.54%
75%	18	2,958,000		71.59%	119.32%
India			4,241,565		
25%	6.25	971,472		68.71%	114.52%
50%	12.5	1,942,944		137.42%	229.04%
75%	18.75	2,914,392		206.13%	343.55%
Tanzania			58,046		
25%	3.5	21,192		109.53%	182.55%
50%	7	42,360		218.93%	364.88%
75%	10.5	63,552		328.46%	547.43%
Thailand			822,018		
25%	8.5	69,096		25.22%	42.03%
50%	17	138,168		50.43%	84.04%
75%	25.5	207,264		75.64%	126.07%
Philippines			494,239		
25%	2.75	32,712		19.86%	33.09%
50%	5.5	65,424		50.43%	66.19%
75%	8.25	98,160		59.58%	99.30%

Table 18. Welfare Benefits Corresponding to a Permanent Reduction of RTI DALYs (Using a value per DALY=GDP per capita)

Scenarios	Reduction in RTI Dalys (entire population)	Total number of DALYs	GDP 2014 (international prices, 2005, in million)	% of GDP 2014 (Value of a DALY=GDP per capita) (international prices 2005)	% of GDP 2014 (Value of a DALY=3*GDP per capita) (international prices 2005)
China			12,395,562		
25%	3,737,146	43,132,893		3.15%	9.45%
50%	7,474,292	86,265,786		6.30%	18.90%
75%	11,211,438	129,398,679		9.45%	28.35%
India			4,241,565		
25%	3,312,568	152,930,211		8.16%	24.48%
50%	6,625,136	305,860,422		16.32%	48.95%
75%	9,937,703	458,790,633		24.48%	73.43%
Tanzania			58,046		
25%	89,036	4,110,475		16.02%	48.07%
50%	178,071	8,220,950		32.05%	96.15%
75%	267,107	16,441,900		48.07%	144.22%
Thailand			822,018		
25%	241,965	2,792,686		4.12%	12.37%
50%	483,931	5,585,372		8.25%	24.74%
75%	725,896	8,378,058		12.37%	37.11%
Philippines			494,239		
25%	139,696	64,492,800		2.95%	8.86%
50%	279,391	128,985,600		5.91%	17.72%
75%	419,087	193,478,400		8.86%	26.58%