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The global distribution of the burden of road traffic injuries: Evolution and intra-distribution mobility

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ABSTRACT

This research examines the evolution of the distribution across 187 countries of mortalities per 100,000, disability-adjusted life years (DALYs), years of life lost (YLL) and years lived with disabilities (YLD) due to road traffic injuries between 1990 and 2010 using the distribution dynamics approach. Fatal and non-fatal burdens of road traffic injuries display contrasting external shape dynamics and intra-distribution mobility. The results show that while the shape of the global distribution of YLD due to road traffic injuries (RTIs) has become tighter over time, the cross-country distributions of mortalities, DALYs, and YLL from road crashes have become more dispersed. The implication of the results is that international efforts should make a priority of targeting the prevention of a greater spreading out of the distribution of the burden of fatal RTIs. The exchange of relative positions within the distributions is substantial, but there is no linear relationship between a country's change in its relative position for the burden of fatal and non-fatal RTI distributions. Thus, further research is needed to determine whether policy interventions dealing with the burden of fatal RTIs also alleviate the burden of non-fatal RTIs and vice versa.

1. Introduction

This research employs the Global Burden of Diseases, Injuries, and Risk Factors Study 2010 (GBD, 2010) to present the evolution and intra-distribution mobility for the global distribution of the burden of road traffic injuries (BRTIs) between 1990 and 2010, using the following four metrics from 187 countries: mortalities per 100,000 due to road traffic injuries (RTIs), years of life lost (YLL) per 100,000 due to premature mortality lost to RTIs, years of life lived with disability (YLD) per 100,000 due to RTIs, and disability-adjusted life years (DALYs) per 100,000 from RTIs, which is the sum of YLL and YLD. YLL was calculated from country-time-specific estimates of mortality by cause, with death standardized by lost life expectancy at each age. YLD is defined as the sum of prevalence multiplied by the general public's assessment of the severity of health loss and is used to explore patterns. Specifically, YLD is calculated as the prevalence of 1160 disabling sequelae by cause, and weighted by disability weights for each health state (Murray et al., 2012a, 2012b; Murray and Global Burden of Disease Study 2010 Collaborators, 2012). The GBD 2010 Study was carried out by the Institute for Health Metrics and Evaluation (IHME), World Health Organization (WHO) and five partner universities (Horton, 2012). The GBD Study has systematically and extensively collected and evaluated data on disease, injuries, and risk since 1990. In 1990, the GBD Study first proposed DALYs to measure disease and injury burden. By 2010, the GBD Study began to assess mortality rate and the three metrics of disease and injury burden for 235 causes of death and 67 risk factors in 187 countries. This current paper particularly focuses on the evolution of the shape of the distributions of the four BRTI metrics and countries' mobility within these distributions.

RTIs are an issue of major public health importance and are projected to be the third leading cause of DALYs by 2020 (Murray and Lopez, 1996). In 2010, about 1.24 million people lost their lives in road traffic crashes, making RTIs the eighth leading cause of death globally. Additionally, 20–50 million people were non-fatally injured on the road (World Health Organization (WHO), 2013). For those who have survived serious crashes, their lives are usually less productive and enjoyable than before due to a resulting disability. One noteworthy pattern that emerged recently is that while the total number of road deaths in the world plateaued in the period 2007–2010, the growth rate of road traffic fatalities over the same period differed substantially across countries. Between 2007 and 2010, 88 countries saw a drop in the number of deaths on their roads, whereas 87 countries witnessed an increase in that number (WHO, 2013). This evokes the following questions: Is the gap in BRTIs between safe and dangerous countries diminishing? Which countries are catching up or falling behind? Is there evidence of churning and overtaking? How does one reveal and summarize the evolution of the entire cross-country distribution of BRTIs?

The performance of countries in terms of road safety relative to each other is worth studying for a number of reasons. First, existing evidence

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suggests that the extant of economic development is a key determinant of RTI fatality per person (Kopits and Cropper, 2005, 2008; Yannis et al., 2011; Commandeur et al., 2013; Antoniou et al., 2016). Given the fact that the cross-country distribution of income per capita is twin-peaked (Quah, 1996a, 1996b, 1997; Johnson, 2005) and that countries with similar initial conditions converge to similar levels of income per capita, i.e., there exists convergence clubs in income (Durlauf and Johnson, 1995; Canova, 2004; Phillips and Sul, 2007; Anderson et al., 2016), a natural question to ask is: Has the cross-country distribution of BRTIs become more dispersed or more concentrated?

Second, Nghiem et al. (2013) argue that since technology adoption is less costly than technology innovation, as technologies in vehicles, roads, and health infrastructures diffuse from technologically advanced countries to technologically backward ones, the burden of RTIs will fall faster in the latter countries. Examining the empirical validity of this argument is of great theoretical interest.

Third, understanding whether countries with high RTIs indeed catch up is essential for assessing the effectiveness of national and international efforts in narrowing the cross-country road safety gap. Reversals in BRTI rankings could signify that the motorization rate increased so rapidly that the existing road safety measures have reached their limit. By identifying and studying countries whose relative positions in the world distribution of BRTIs deteriorated, we can learn much about those factors that prevented countries from catching up with the best practice in road safety.

Fourth, Sen (1999) argues that human well-being is a multidimensional concept composed of not only income and wealth, but also personal development, social participation, health, and safety. Maasoumia et al. (2007) advocate that understanding the dynamics of the cross-country distribution of non-income dimensions of well-being is a direction worth pursuing. Road accidents result in not only the loss of lives, but the loss of jobs and quality-of-life of victims and their families. While there is a preponderance of evidence that the cross-country gap in material living standard has declined, a persistent difference in road safety across countries would indicate that disparities in human well-being remain.

Ever since the seminal contribution of Oppe (1989, 1991) who models road traffic fatality rate per person as a function of risk and exposure, substantial research efforts have been devoted to identifying trends and breakpoints of road traffic fatality and its two components - exposure and risk - for the average country and for individual countries. Recent research on road safety development has found that the pattern of road traffic fatality per person along the economic development path is on average an inverted-U shape (Grimm and Treibich, 2013). Using cross-country panel data for 88 and 79 countries, Kopits and Cropper (2005, 2008) and Anbarci et al. (2009) find that on average traffic fatality per person first rises and then falls with income per capita. Bishai et al. (2006) identify an inverted-U shaped relationship between road traffic fatalities and the level of economic development among a panel of 41 countries, but find no such relationship for injuries and crashes. Law (2015) and Law et al. (2011) notes that the Kuznets curve exists across 60 countries for road traffic fatality rate and nonfatal injury rate. The finding that road traffic fatality rate follows an inverted-U shaped relationship with income implies that as long as incomes converge, BRTIs will also converge across countries in the long run. However, since panel data models approximate only the conditional mean of road traffic fatality rate, the Kuznets curve estimated using panel data models masks the heterogeneity across individual countries.

Time series analyses of road safety data from individual countries confirm that while most countries have seen their exposure to traffic risk, i.e., the motorization rate, increases as their income have grown, they have exhibited divergent trends in traffic risk, as measured by fatality per vehicle and in road traffic fatality rate per person. Yannis et al. (2011) estimate the relationship between motorization rate and road traffic fatality rate per person using a piece-wise linear regression model and find that the number and location of breakpoints and the slope of the road fatality trend differ substantially among countries. Commandeur et al. (2013) and Dupont et al. (2014) respectively use a time-series technique that explicitly accounts for serial dependency in the fatality data and a latent risk time series model that treats exposure and risk as unobservable latent variables, presenting that data from different EU countries exhibit heterogeneous properties and traits and suggesting that one road traffic fatality model does not fit all. Brüde and Elvik (2015) analyze time series data for six countries and confirm that road traffic fatality rate first increases and then decreases over time. Antoniou et al. (2016) report that European countries differ significantly in their long-term elasticity of road traffic fatalities to GDP per capita.

The existing studies on road safety development surprisingly focus exclusively on either the average country or a particular country and entirely overlook the whole cross-country distribution, although the external shape dynamics and intra-distribution mobility of the BRTI distribution may reveal whether less safe countries are catching up with safer ones and the ways whereby less safe countries catch up. In light of the findings in the aforementioned studies that the pattern of development in road traffic fatality varies across countries, and that road safety development depends not only on the level of economic development, but also on slow-moving factors such as climate, demographics, and road safety culture, it would be illuminating to identify the characteristics of the cross-country BRTI distribution such as polarization, convergence clubs, and criss-crossing using methods that are able to present a picture of the behavior of how the entire BRTI distribution evolves. Moreover, although RTIs are an escalating problem in emerging economies, no previous research has quantified the BRTI gap between emerging and industrialized economies. The only study on cross-country convergence in road traffic crash fatality rates is Nghiem et al. (2013), who focus on convergence among OECD countries. This current paper considers the BRTI distribution across a much more diverse group of countries and pays special attention to the change in the BRTI disparity between geographic regions and between emerging and industrialized economies.

Cross-country convergence in road traffic crash fatality rate has been examined using strategies from the economic growth literature, i.e., β-, σ-, and club convergence analyses. In a nutshell, β-convergence refers to a negative correlation between the growth of a variable and its initial value, whereas σ-convergence measures convergence based on cross-sectional dispersion of the variable considered. For the concepts and methodologies for detecting β-convergence and σ-convergence, see Barro and Salai-i-Martin (1991, 1992), Sala-i-Martin (1996), and Young et al. (2008). For a discussion of the identification of catching up with one another within a club of countries, see Phillips and Sul (2007). The test for β-convergence involves testing the presence of a negative association between the initial level of road traffic fatality rate and its subsequent growth using cross-country regressions. The notion of σ-convergence refers to a reduction in the cross-country dispersion in road traffic crash fatality rate, measured by standard deviation, coefficient of variation, Gini coefficient, or Theil index. In short, the concept of β-convergence focuses on how the average country moves towards its steady state over time; in contrast, the concept of σ-convergence reveals whether road crash fatality rates are becoming increasingly similar.

Castillo-Manzano et al. (2014) apply the β- and σ-convergence approaches to data from EU-27 countries over the period 1970–2010. Their results confirm that, on average, road crash fatality rates in countries with a higher initial fatality rate decline faster and that cross-country disparity in road traffic fatality rates has declined over time. The test for club convergence aims at identifying groups of countries that converge to different steady states. Nghiem et al. (2013) carry out a club convergence analysis on 23 OECD countries between 1961 and 2007 and find that there is no overall convergence in road crash fatality rates. Nevertheless, countries form five clubs within which road crash fatality rates do converge.

Albeit informative, the notions of β-, σ-, and club convergences fail to address a key aspect of convergence in road fatality: Do BRTIs