https://doi.org/10.1590/1980-549720210017.supl.1

ORIGINAL ARTICLE / *ARTIGO ORIGINAL*

Relationship between GDP per capita and traffic accidents in Brazilian municipalities in 2005, 2010 and 2015

A relação entre PIB per capita e os acidentes de transporte nos municípios brasileiros, em 2005, 2010 e 2015

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ABSTRACT: ***Objective:*** The main objective of this paper was to analyze the relation between GDP and three variables linked to traffic accidents in Brazilian municipalities: traffic accident mortality, deaths per vehicle; and vehicles per inhabitant. ***Methods:*** 2005, 2010 and 2015 traffic accident (TA) mortality rates were estimated using a three-year moving average and were standardized; then, we applied the empirical Bayes estimator (EBE). Fatality rates (deaths per vehicle) were also based on EBE. The variable vehicles per inhabitant considered the ratio between the fleet and the population at municipal level. For every studied year, we estimated linear regression models between GDP and the interest variables. ***Results:*** The variables distribution indicates that, between 2005 and 2015, GDP and vehicles per inhabitant kept the same rising relationship. Fatality rates show a decreasing association with GDP. The distribution of mortality by TA had an inverted U-shaped pattern. The model coefficients practically did not change for the vehicle per inhabitant. Estimated association between deaths per vehicle and GDP kept the same sign, but diminished between 2005 and 2015. Model coefficient sign changed in 2015 for TA mortality. ***Conclusion:*** Similar to what was observed in developed countries, the relation between mortality by traffic accidents and GDP changed in the analyzed period.

Keywords: Mortality. Accidents, traffic. Gross domestic product. Cities.

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Conflict of interest: nothing to declare – **Financial support:** Small Areas Project, Health Surveillance Secretariat of the Brazilian Ministry of Health (TED 148-2018).

RESUMO: ***Objetivo:*** O artigo pretende analisar a relação entre o produto interno bruto (PIB) per capita e três variáveis relacionadas aos acidentes de transporte (AT) nos municípios brasileiros: a mortalidade por AT, as mortes por veículo e o número de veículos por pessoa. ***Métodos:*** As taxas de mortalidade por AT foram estimadas (2005, 2010 e 2015) por meio do estimador bayesiano empírico (EBE). A taxa de mortalidade por veículo foi também estimada pelo EBE. O número de veículos por pessoa foi baseado na razão entre a frota de automóveis e a população residente. Para os três anos em análise, estimamos um modelo de regressão linear entre o PIB per capita municipal e as três variáveis de interesse. ***Resultados:*** A distribuição das variáveis mostra que a relação entre o PIB e o número de veículos por pessoa se manteve crescente ao longo dos anos e foi sempre negativa, considerando-se as mortes por veículo. A taxa de mortalidade por AT apresentou distribuição próxima a um U invertido. Os coeficientes do modelo de regressão praticamente não variaram para a relação entre PIB e os veículos por habitante. O sinal para o modelo com a taxa de mortalidade por veículo manteve-se o mesmo (negativo), mas apresentou diminuição. A taxa mortalidade por AT, por sua vez, apresentou inversão do sinal em 2015. ***Conclusão:*** De modo similar ao observado nos países desenvolvidos, parece ter havido inversão na relação entre mortalidade por AT e PIB nos municípios brasileiros entre 2005 e 2015.

Palavras-chave: Mortalidade. Acidentes de transporte. Produto interno bruto. Cidades.

INTRODUCTION

The occurrence of deaths from road transport accidents is a consequence of both the number of vehicles per person and the fatality per vehicle[1,2]. It depends, at the same time, on the motorization rates (vehicles/person) and the mortality rate per vehicle (deaths/vehicle)[1]. In low-income levels, the relation between economic development and mortality by traffic accidents (TA) (deaths/people) is positive[1-4].

In the countries of the Organization for Economic Cooperation and Development (OECD), the transversal relationship between prosperity and the mortality rate by traffic accidents (TA) changed between 1960 and 1990[2]. From 1970, this association became negative. The protective effect of income may be a consequence of adaptation mechanisms such as improve in infrastructure and medical assistance[2]. Noland[5] points out the advancement of technology and medical treatments as one of the factors associated with the reduction in mortality by TA after the 1970s in developed countries. In the city of Monterrey (Mexico), the implementation of new points for ambulance exits decreased the average emergency response time[6].

Bishai et al.[4] present, in addition to improving assistance to the injured, other lines of argument that intend to explain the difference between economic development and mortality by TA in developed and developing countries. In the first line, economic development is understood as a prerequisite for the implementation of institutional capacity to regulate the transportation system and hold offenders accountable. The second view deals with competitive risks. In other words, investment in developing countries would be concentrated on priorities (infectious diseases, nutritional risks, etc.), neglecting, due to limited resources, measures to contain transport risks. Another view concerns the composition of the fleet—in the highest levels of income, the proportion of vulnerable users would be lower.

The findings of Bishai et al.[4] indicate that only technological and medical advances would be able to decrease mortality rates. However, the authors reported that institutional advances, changes in the fleet composition and competitive risks influence the occurrence of accidents and injuries. As the relationship between the occurrence of accidents and injuries was not associated with the increase in gross domestic product (GDP), the authors understand that the main cause behind the lower mortality by TA in rich countries would be the greater capacity to provide care to the victims.

For Paulozzi et al.[3], the main reason for the inversion of the relation between mortality by TA and income is the change in the composition of users of means of transportation. The initial growth and subsequent decline in mortality rates were a consequence of changes in the proportion of vulnerable users (motorcyclists, cyclists and pedestrians). The results by Paulozzi et al.[3] do not indicate, for higher levels of income, greater security in displacement.

The complexity of GDP as an explanatory variable relates to it being a proxy for other measures that are difficult to measure, such as urbanization, fleet composition, availability of assistance and quality of roads[4]. The models estimated by Bishai et al.[4] suggest that these unmeasured phenomena impact mortality by TA in rich and poor countries, and are related to the institutional capacity of the health and legal systems.

The short-term economic dynamics is also related to the mortality rate by TA[7-10]. Law et al.[11], for example, when assessing the impact of a public policy aimed at reducing motorcycle accident mortality in Malaysia, reported that, in addition to the effects of the measures implemented, the economic slowdown also negatively impacted motorcycle mortality. The heating of the economy causes more people to circulate more frequently and, consequently, there is an increase in exposure to risk. The opposite is also true. Scuffham and Langley[9] stated that, in the short term, the increase in unemployment and the decrease in GDP were associated with the reduction of TA with fatal victims in New Zealand. Brazil, in recent years, has shown a dynamic of economic growth (2003–2008; 2009–2014) and recession (2015 and 2016)[12]. These dynamics are likely to have affected the circulation of people and, consequently, the mortality rate by TA as well.

For Wegman[13], road safety is achieved through measures capable of adapting the infrastructure, vehicles and regulation of the transport system to the characteristics of users. In addition to adequate infrastructure, the author argues that road safety depends on traffic rules, vehicle requirements, driver training and education, regulation and planning. Especially in developing countries, legislation and the regulatory system fail to achieve the proposed objectives[13].

In Brazil, the institutional capacity of health systems and transport regulation, in addition to the quality of roads, varies substantially between municipalities. Naturally, these differences influence the capacity for inspection and regulation and, consequently, the safety of cities. Despite being responsible for traffic management in their territory, according to the legislation, most municipalities are not prepared for this assignment[14].

The portal of the National Traffic Department (Denatran)[15] shows that, in March 2020, only 1,695 (30.4%) municipalities had municipalized traffic management. According to França and Jacques[16], the main reasons for the non-integration of municipalities in the National Traffic System (NTS) are: lack of qualified manpower to implement and manage traffic in the municipality; lack of resources to equip and maintain the transit agency; lack of systematic assessment of the management of the bodies already integrated into the NTS and capable of indicating the effectiveness of the municipalization process to those who have not yet adhered to it.

The mortality rate due to TA in Brazil has had different movements in the last decades. Between 1990 and 2015, Ladeira et al.[17] reported a reduction in mortality in Brazil. On the other hand, the period between 2000 and 2010 was marked by an increase in mortality by TA[18-21]. In recent years (2012 and 2013), the mortality rate by TA has decreased compared to 2010[21]. The regional dynamics, however, are quite different. Between 2000 and 2010, the States of the North and Northeast regions had the highest increase in mortality, mainly due to the increase in the number of deaths of motorcyclists[19,22,23].

The mortality rate of motorcyclists increased significantly, especially after 2000[19,20,23]. Unlike TA in general, Ladeira et al.[17] pointed an increase in the mortality of motorcyclists between 1990 and 2015. Naturally, there is an important regional variation, with special emphasis on the Midwest, Northeast and North regions[19,22,21, 24].

That being said, the objective of this paper is to analyze the association between the GDP of Brazilian municipalities, at three points in time (2005, 2010 and 2015), and the mortality rate by TA (deaths/people), with the number of vehicles per person (vehicles/people) and the mortality rate per vehicle (deaths/vehicles). Given the socioeconomic and institutional diversity of municipalities, as well as the different dynamics of income, the relationship between GDP and measures of interest are also expected to be different. The results can contribute to a better understanding of a phenomenon that annually kills and incapacitates thousands of Brazilians, and to a greater range of instruments for the prevention of these deaths.

METHODS

The number of deaths by TA in each municipality, per year, was collected from the Mortality Information System (SIM)[25]. The municipal population in 2005 and 2015 was based on estimates from the Interagency Health Information Network (Ripsa)[26], and in 2010, on the 2010 Census[27]. Information about the municipal fleet, considering all types of vehicles, was collected from the database of Denatran[28], having as reference the month of July of each year of interest. For the same three-year period (2005, 2010, 2015), the municipal GDP was collected from estimates of the Brazilian Institute of Geography and Statistics (IBGE)[29].

Deaths with ignored age and/or municipality were redistributed proportionally. Mortality rates due to TA were constructed considering, in the numerator, the three-year moving average around each base year (2004–2006; 2009–2011; 2014–2016). Then the rates were standardized by the direct method, using the Brazilian population in 2010 as standard. The last step was the smoothing of rates based on the empirical Bayesian estimator (EBE)[30], adopting the 15 closest municipalities in each year as the neighborhood structure. The use of a fixed number of neighbors ensures that each observation has a structure in the same size as the others. Bayesian smoothing is necessary due to random fluctuation and small numbers in the denominator, which can distort the risk estimates associated with events of interest[30-32].

The Bayesian estimator takes the rates observed in small municipalities towards the average of their neighbors, in an inversely proportion as to the size of the population[30-32]. In other words, more populous municipalities will have a Bayesian estimator closer to the gross rates. On the other hand, in smaller municipalities, which are more subject to the effects of random fluctuation and small numbers in the denominator, EBE will be closer to the average rate of neighboring municipalities[30-32]. More in-depth discussions about this method to be found in a series of studies[30-34].

The mortality rate per vehicle—the number of deaths divided by the size of the fleet—was also smoothed by EBE, with the same neighboring structure. In this case, the same numerator for TA mortality rate was used, as previously described. Naturally, the municipal fleet is also subject to the same problems of random fluctuation and small numbers in the denominator, which is why Bayesian smoothing was necessary. It is worth mentioning that, in 2005, 89 municipalities did not have information on fleet size in the Denatran database[26], with a large concentration in Alagoas (81).

Once TA mortality rates (deaths/population), the mortality rate per vehicle (deaths/vehicles) and the motorization rate (vehicles/population) for each year were estimated, they were used as dependent variables in models of linear regression by ordinary least squares (OLS), with GDP per capita as an explanatory variable. The idea was to analyze, at different points in time, the relationship between GDP and each of the rates. Some improbable values of mortality rate per vehicle, most likely due to problems in the quality of information about the fleet, were excluded from the analysis using observations above the 99.5 percentile as a cut-off point. Most of the excluded observations (82) were from 2005 and only two were from 2010. No values were excluded in the 2015 analysis.

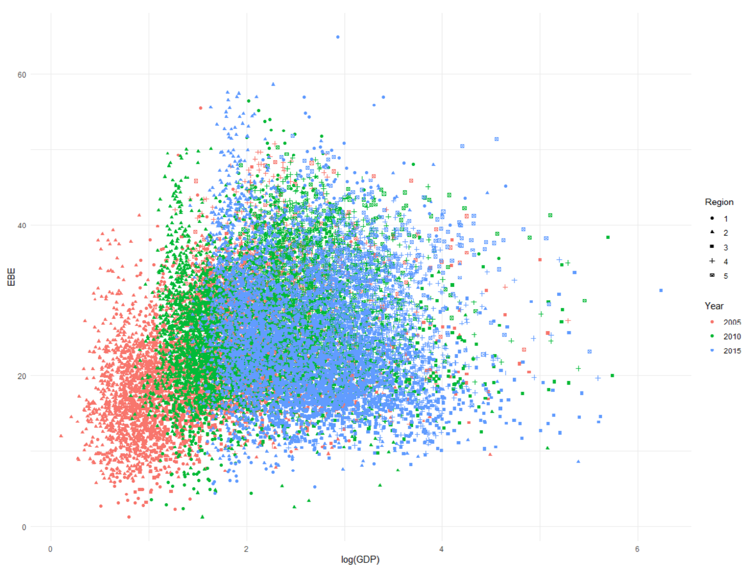
RESULTS

In the three years analyzed, the relation between TA mortality rate and GDP was distributed in an inverted U-shape graph (Figure 1). In other words, apparently, for lower levels of GDP, there is a positive relation between income and TA mortality rate up to the middle of the distribution. From that point on, municipal income appears to be associated with lower mortality rates. However, in the three years, there was a concentration of lower income municipalities with high TA mortality rate. In 2010 and 2015, this concentration was higher than in the first year of the series. These municipalities, almost exclusively, are from the Northeast region. Figure 1 shows that higher-income municipalities, in general, are not among those with the highest TA mortality rates.

Another regional characteristic in Figure 1 is a concentration of municipalities in the Midwest region among the ones with the highest per capita income and, at the same time, with high mortality. This can be observed in all years, but with more clarity in 2015. At the top of the distribution, mainly from 2010, the municipalities with the highest mortality rates were, in most cases, in the North and Northeast regions.

Figure 2 shows that, in the three-year timeframe, the increase in income was associated with the increase in the number of vehicles per inhabitant. At the beginning of the distribution, rates grow at a fast pace and then start to grow at a less accentuated pace. Also of note are some higher income municipalities that are further away from the main concentration of municipalities, that is, not among those with the highest rate of motorization. In Figure 2, there is no clarity as to a regional pattern of the relation between GDP and the number of vehicles per inhabitant. There were no major changes in the pattern of the relation between GDP and the motorization rate between 2005 and 2015.

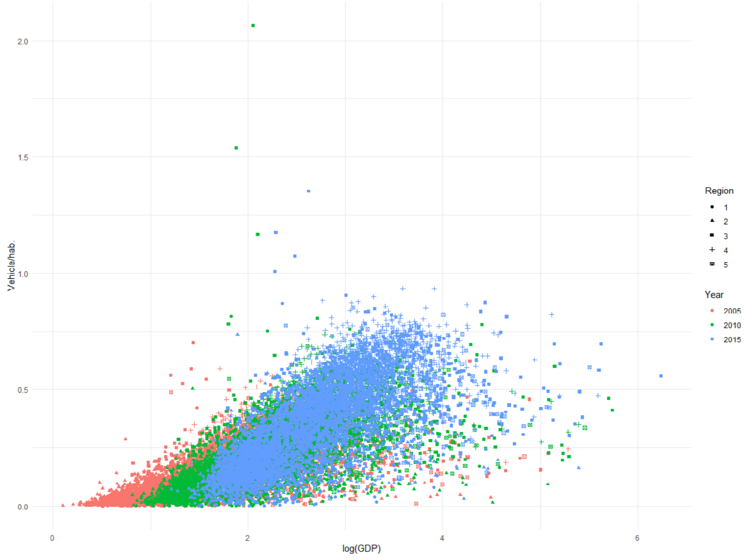
The analysis of the mortality rate per vehicle and the municipal income per capita shows a clear decreasing relation throughout the period (Figure 3). In all three years, higher levels of income are associated with a lower mortality rate per vehicle. Figure 3 suggests an improvement in the quality of information about the fleet over time, since the number of extreme values in 2015 is less than that observed in 2005 and in 2010.



GDP: gross domestic product.
Source: SIM[25]; RIPSA, 2005 and 2015[26]; 2010[27] Census; GDP of municipalities, IBGE[29].

Figure 1. Mortality rates in traffic accidents (empirical Bayesian estimator – EBE) × GDP per capita, municipalities in Brazil, both sexes, 2005, 2010, 2015.

Figure 3 also shows an important concentration of municipalities in the Northeast and North regions among those with the highest mortality rate per vehicle and with the lowest income. As in Figure 2, over time, there are no signs of a change in the relation between GDP and the mortality rate per vehicle in Brazilian municipalities.



GDP: gross domestic product.
Source: RIPSA, 2005 and 2015[26]; 2010[27] Census; Denatran[28]; GDP of municipalities, IBGE[29].
Figure 2. Ratio vehicle per person × GDP per capita, municipalities in Brazil, 2005, 2010, 2015.

GDP: gross domestic product.
Source: SIM[25]; Denatran[28]; GDP of municipalities, IBGE[29].
Figure 3. Bayesian mortality rate per vehicle (deaths/vehicles) × GDP per capita, municipalities in Brazil, both sexes, 2005, 2010, 2015.

Table 1 lists, for each year, the estimated regression coefficients between GDP per capita and the three estimated rates (mortality, motorization, mortality per vehicle) as dependent variables. As Figures 2 and 3 already suggest, between 2005 and 2015, the increase in GDP was associated with a reduction in the mortality rate per vehicle and an increase in vehicles per person. Between 2005 and 2015, the estimated coefficient for the association between GDP and the number of vehicles per inhabitant little changed, indicating a positive association with statistical significance.

Considering the mortality rate per vehicle, the association with GDP remains negative and with statistical significance over time. However, there was a decrease in the magnitude of the coefficient. In each year, the model indicates a decrease in the protective effect on mortality rate per vehicle associated with increased income. It should be noted that there are clear signs of improvement in the quality of information about the fleet over the period, which may have influenced the estimates.

Regarding TA mortality rate, between 2005 and 2010, there was a decrease in the impact on mortality associated with increased income, but it remained positive. In other words, in 2005 and in 2010, the impact associated with the increase in municipal GDP per capita was an increase in the TA mortality rate. In 2015, however, there was an inversion in this relation. The estimated model points to a negative association. Thus, in 2015, there appears to be a negative association between GDP and TA mortality rate.

DISCUSSION

The analysis of the relation between the TA mortality rate in Brazilian municipalities and GDP per capita show that, as in developed countries[1-4], there seems to have been an inversion in the transversal relation between these variables over time. In 2005, the coefficient was positive and more expressive than in 2010 (also positive), while in 2015, it becomes negative. In the case of vehicles per inhabitant and mortality per vehicle, the trend of the association was maintained over the years, although a decrease is seen in the intensity of the effect.

Table 1. Regression coefficients of the three dependent variables analyzed by municipal GDP per capita.

	2005	2010	2015
TA mortality	0.195**	0.018*	-0.044**
Deaths per vehicle	-5.09**	-2.304**	-1.186**
Vehicle per inhabitant	0.005**	0.004**	0.004**
N	5,392	5,562	5,570

GDP: gross domestic product; TA: traffic accidents; *significant at the 0.01 level; **significant at the 0.001 level.
Source: SIM[25]; RIPSA, 2005 and 2015[26]; 2010[27] Census; Denatran[28]; GDP of municipalities, IBGE[29].

Analyzing the OECD countries, Van Beeck et al.[2] stated the inversion of the association between TA mortality rate and GDP per capita, as well as the non-alteration in the relation considering the number of vehicles per person and deaths per vehicle. The inversion of the trend of association, according to the authors, could relate to the improvement in infrastructure and health care for the injured. In Brazil, Carvalho[21] pointed out that hospital admissions for TA increased between 2007 and 2014, but, at the same time, hospital mortality decreased—that is, mortality after hospitalization by TA. In the author's view, this shows an improvement in the structure and assistance to the injured. This improvement might also be related to the negative association between GDP and TA mortality rate in 2015[2,5,21].

It is also likely that the change in the composition of the fleet has influenced the dynamics of TA mortality rate[3]. Between 2005 and 2010, there was an expansion in the relative size of the motorcycle and scooter fleet from 18.6 to 25%. Between 2010 and 2015, the participation of motorcycles increased at a slower pace, rising to 26.5%[28]. However, this dynamic has regional differences. Motorcycles account for an important part of the fleet, mainly in the States of the North and Northeast regions. Maranhão and Piauí (2015) have the lowest GDP per capita and, at the same time, have motorcycles and scooters represent the most expressive portion of the vehicle fleet: 59.3 and 56.1%, respectively. The Federal District, on the other hand, has the highest GDP per capita and the smallest motorcycle fleet (11.4%). The increase in the proportion of vulnerable users is one of the possible explanations for the association between TA mortality rate and GDP[3,4].

The negative association between GDP per capita and TA mortality rate identified in 2015 might also be related to the slowdown in economic activity in recent years. In 2015 and 2016, GDP in Brazil retracted[12]. Periods of economic slowdown are associated with decrease in TA mortality in several countries[7-10]. Naturally, there is regional variation in the indicators of economic activity that influence the measures analyzed.

Mortality differentials between municipalities are also related to the ability to manage and regulate the transportation system. Schmidt[35] notes that, in Brazil, inspection and punishment stand out as a preponderant bias for putting traffic rules into practice, to the detriment of awareness and education. In the author's view, it undermines the identification by mayors of the accountability of the municipality in implementing traffic policies. The implementation of inspection measures imposes a series of difficulties on municipalities, such as the lack of a police force and a municipal registry of vehicles and drivers[35]. In addition to inspection and punishment, the education of users and the quality of roads are related to the economic development and investment capacity of the municipalities and can be associated with the results. In addition, Schmidt[35] points out that the mayors of small municipalities also bear the political burden of eventual penalties for traffic violations.

Souza et al.[36] highlight the trend of increasing mortality rates in small municipalities and a reduction in larger and wealthier municipalities, in the South and Southeast regions in recent years. This phenomenon could be explained by regulatory policies, better care for victims, greater investment in improving roads and road safety in these regions, since it all increases the inequity in the distribution of TAs across the country.

Different public policies have helped to reduce TA mortality rates, including the implementation of the Brazilian Traffic Code[37] in 1998, the Dry Law in 2008[38], and the New Dray Law in 2012[39], as well as regulatory measures related to vehicle safety[40]. The implementation of the Mobile Emergency Care Service (SAMU, acronym in Portuguese for "Serviço de Atendimento Móvel de Urgência") in 2003, the expansion of Emergency Care Units and of emergency care in hospitals, the creation of violence prevention policies[41], health promotion policies[42] and the Life in Traffic Project are initiatives that contributed to the reduction of traffic-related morbidity and mortality rates[19].

Among the study's limitations, the improvement of SIM data in recent years stands out, thus improving the capture of events and the reduction of ill-defined causes. This can affect trends, especially in the North and Northeast regions, which have had significant improvements in the registry of deaths and a reduction in records of ill-defined causes[43].

Separating the short and long-term effects of the relation between GDP per capita and TA mortality in Brazil may be an interesting research agenda for the future. Other authors had already identified the recent reduction in TA mortality in some States of Brazil[19,21], as well as in female mortality due to motorcycle accidents, especially in the South and Southeast regions[23]. It is likely that, in recent years, both effects have acted simultaneously. In addition, the use of other variables to control the effects of the association between the variables analyzed and TA mortality will help to better understand this relation.

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Received on: 07/22/2020
Revised on: 12/04/2020
Accepted on: 12/11/2020
Preprint on: 12/15/2020

Authors' contribution: PCP, RAT, ALPR, DCM conceived and designed the study. PCP carried out data management, exploration and analysis, the elaboration and interpretation of results, and discussion. All authors critically reviewed the manuscript and contributed to the entire process. All authors read, contributed to the final manuscript and approved it.