THE INFLUENCE OF OVERALL CONSUMPTION LEVEL ON ROAD FATALITIES IN BRAZIL FROM 1996 TO 2017

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Abstract: Several studies in economics evidence the influence of economic activity on road accidents. This study contemplates this relationship for the case of Brazil, more precisely, we examine the relationship between road fatality rates and one measure of economic activity in particular: the overall level of consumption per capita. In Brazil, we observe a certain similarity in the evolutionary pattern between consumption and road fatalities. The empirical evidence presented in this paper suggests that most of the month-to-month variations in road fatality rates can be explained by seasonal fluctuations and variations in the consumption level of the current month and of a few preceding months. Controlling for seasonal fluctuations, variations in consumption answer for 22% of the month-to-month variations in road fatality rates according to the model proposed in this paper. These results preconize consideration of the level of economic activity when evaluating the effect of interventions in the Brazilian traffic context, under the risk of over or underestimation of their true effects. Equally important, the consideration of economic activity can contribute to the accuracy of forecasts related to traffic.

Keywords: road fatalities, road accidents, vehicle fatalities, consumption, economic activity.

JEL classification: R41; I12; O12

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1 INTRODUCTION

Road injuries claimed one over forty of all worldwide deaths in 2016, which represents 1.4 million deaths according to the World Health Organization. In Brazil, in the time span considered in this paper (from 1996 until 2017), more than 800 thousand people died due to vehicle accidents. In monetary terms, the annual cost of accidents in Brazilian roads lies around 1.2% of the GDP (IPEA, 2006), where most of the costs refer to the loss in production due to death or injury.

Figures like that highlight the importance of a better understanding of the dynamics propelling road fatalities. This work contemplates the relationship between road fatalities and the level of economic activity. For reasons elucidated ahead, we focus on one measure of economic activity of particular interest in the case of Brazil: the overall consumption level.

The influence of economic activity on road accidents is documented by the literature in the field of economics. On one hand, economic growth intensifies the transit of people and products. On the other hand, the higher the GDP per capita of a population, the better its emergency services and post trauma treatments; also, the newer and safer its vehicles fleet (Bishai et al., 2006). From the income perspective, wealth influences the frequency of the trips, the choice of transportation mode, and the demand for safety equipment (Grimm and Treibich, 2013). We can also presume a relationship between unemployment and alcohol consumption—especially its consumption outside the house (Ruhn, 1996).

Studies that associate road accidents to some measure of economic activity fulfill an essential hole assisting in the formulation of forecasts. Like the work of Bishai et al. (2006) that corroborates the thesis that economic growth rises road fatalities in low-income countries, but reduces fatalities in rich countries, imposing a transitory character to the conflict experimented by developing countries. The concavity of the relationship between economic prosperity and road fatalities is also evidenced by Grimm and Treibich (2013) in a comparison between different states in India. According to their study, in the initial stages of development, greater motorization allied with unstructured urbanization elevates road fatalities, especially among vulnerable users like motorcyclists and pedestrians. The authors recommend better planning in those stages, particularly, investments in policing and infrastructure to organize traffic. In a study for Brazil, Blumenberg et al. (2018) observe that states with forecasted GDP per capita below the national mean would be more prone to face a rise in road fatality rates.

Several economic papers focus on quantifying the impact of specific interventions or phenomena and consider some measure of economic activity just as a control variable. For instance, Ponicki et al. (2007) include income per capita in their regression equations when estimating the effect of different interventions implemented by some US states, among them: a rise in the minimum legal drinking age, a rise in alcohol taxes, and a reduction in the legal limit of alcohol in drivers' blood. Similarly, Ruhm (1996) controls for macroeconomic conditions to estimate the effect of more severe punishment for drunk drivers, drivers' license suspension for those who refuse to undergo alcohol testing, laws prohibiting establishments to sell alcohol to clearly intoxicated persons, in addition to liquor taxes and minimum drinking age. The author also recognizes some extreme cases of sale restrictions but ignores the nuances of the restrictions in place which in some locations are limited to particular days and hours. For Brazil, Silva and Kilsztajn (2003) include GDP per capita in its regression equation when evaluating the effect of a rise in the number of vehicles per inhabitant on the fatalities per vehicle.

Studies that aim to evaluate interventions without directly including some measure of economic activity still need to circumvent, or somehow control for its effects. This was the case in Pérez et al. (2007) which evaluates the effectiveness of newly installed radars in an important freeway of Barcelona. The authors pointed out that there were no newly installed radars in the arterial roads of the city and treated these roads as a control group. They infer that any other factor driving down the collisions when the radars were installed would also lead to a reduction in the collisions in the arterial roads. Similarly, Jackson and Owens (2010) use the method of differences-in-differences to evaluate the impact of an expansion of the metro working hours on Fridays and Saturdays nights in Washington DC. The authors compare the detentions for intoxicated driving on Fridays and Saturdays nights with Thursdays nights. In another almost-experimental situation, Hansey (2015) observes that the Washington state distinguishes intoxicated drivers from the severely intoxicated drivers and applies harsher punishment for second offenses. Exploring those differences in punishments and comparing offenders in the adjacencies of the legal limits for blood alcohol, the author finds evidence that hasher punishments reduce the incidence of repeated offenses.

In summary, the fluctuations in economic activity deserve some consideration when evaluating interventions, either including this variable directly in the model or somehow circumventing its effects. Furthermore, recognition of the influence of economic activity on road accidents can assist in the formulation of forecasts.

This paper examines in detail the relationship between road fatalities and a particular measure of economic activity: consumption. In Brazil, road fatalities seem to follow the movements of the overall level of consumption in the medium run. Such similarity in evolving patterns is not observed in the case of GDP, for instance, as shown ahead. For the sake of parsimony, we opt for a model in which road fatalities depends only on the overall level of consumption, besides the seasonal fluctuations. One distinction here is the more flexible relationship between economic activity and road fatality, one that allows for an immediate effect and also some delayed effect.

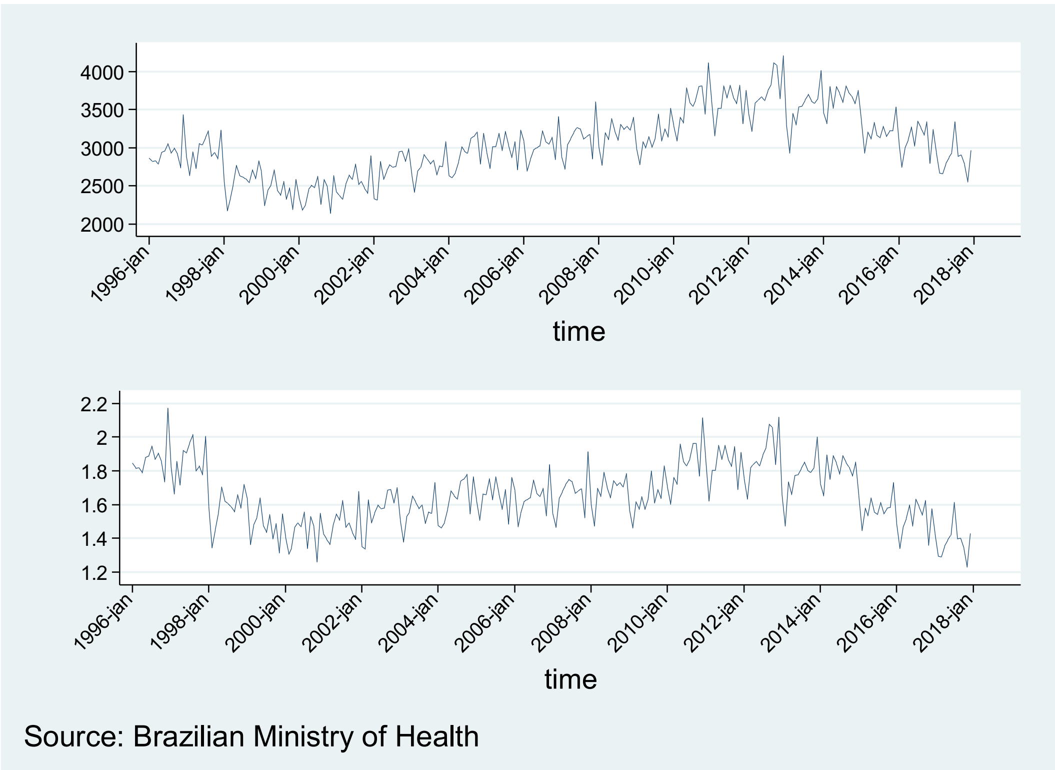
The data comprise the months between 1996 and 2017 and the sources are the Ministry of Health of Brazil and a well-known Brazilian government organization named Applied Economic Research Institute (IPEA). The original series was differentiated to deal with non-stationarity. Based on the model proposed here, we estimate that 80% of the month-to-month variations in road fatalities can be explained by seasonal fluctuations and variations in the overall level of consumption. Controlling for seasonal movements in fatalities, the regression results indicate that variations in the consumption level can explain approximately 22% of the month-to-month variations in the road fatalities.

In the next section, we present some basic statistics related to road traffic in Brazil. Some of them well documented in the literature, like the recent growth of the number of motorcycles on the roads, others less expected, like the existence of a peak in the fatality rates at elderly ages. In section 3, we present the model proposed in this work, test statistics, and regression results. In section 4, we apply the model proposed to estimate the impact of a particular intervention: the 2008 change in the law that implemented harsher punishments for drunk drivers, the so-called Dry Law (from the Portuguese Lei Seca). Last, we discourse upon some reflections reported in the literature about traffic-related interventions.

2 DESCRIPTIVE STATISTICS

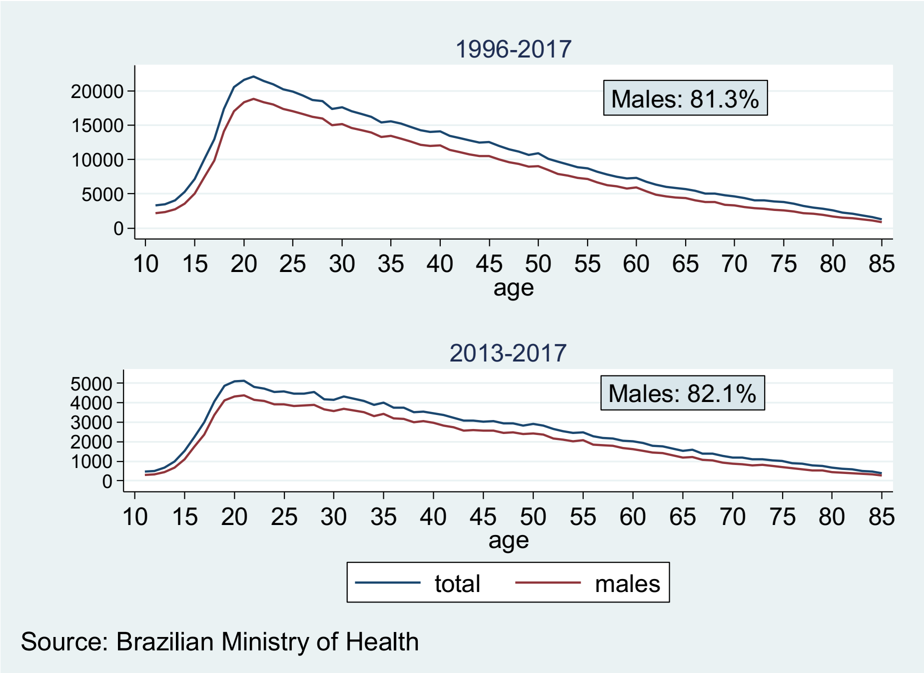
Examining the data on road fatalities from the Brazilian Ministry of Health, one can observe a downward trend after 2014 that persists until 2017, the last year considered in this work. Figure 1 presents the monthly fatalities (in the top) and the fatality rate (in the bottom), the latter defined as the number of fatalities per one hundred thousand inhabitants. The fatality and population data were extracted from the Mortality Information System (SIM) available on the Ministry of Health website. The data include all fatalities due to injuries in road accidents in Brazil, with deaths occurring at the same instant of the accident or in the course of one year after the accident.

Figure 1: The evolution of the road fatalities in Brazil from January of 1996 until December of 2017.



Disaggregating fatalities by gender and age, we perceive an overwhelming prevalence of males, around 81%, and a greater concentration of young adults, as shown in Figure 2.

Figure 2: Road fatalities by age for the entire population and the male population in Brazil from January of 1996 until December of 2017.



Despite the greater concentration of young adults among those who died on the roads, the greater fatality *rate* appears at elderly ages. Observing the fatality rates by age, we identify two peaks. One occurs in the youth, right after the individual reaches the minimum legal driving age, and the second, among the elderly. The existence of a second peak implies that the aging of the population will not necessarily help reducing road fatalities. Figure 3 presents the fatality rates by age for the last 5 years of the series and for all years available. The estimates of population size by age are available in the Ministry of Health website from 2000 onwards. It is worth mentioning that in the youth, most of the fatalities happen among motorcycle users, followed by automobile occupants. While, for the elderly, most of the victims are pedestrians.

Desegregating the fatalities according to the day of the week they occurred, we noticed a greater prevalence of fatalities on the weekends, with possible spillover effects on the adjacent days—Fridays and Mondays. As shown in Figure 4, the average number of fatalities on Sundays (the day of the week with the highest average) is almost twice as high as the Tuesdays' average (the day with the lowest average). Consistent with these statistics, Figure 5 shows that the number of fatalities per day is higher, on average, during holidays and extended holidays than during business days. The higher prevalence of fatalities during weekends and holidays reinforces the role of recreational activities in the determination of road fatalities. The last disaggregation related to the calendar will help to interpret the estimates of the next section. Figure 6 presents the average fatality per day for each month of the year. The highlight in this criterion is the month of December—a month with plenty of celebrations, get-togethers, and family reunions. There are about 8.5 more deaths per day in December than in the other month.

Figure 3: Road fatality rates by age in Brazil from January of 1996 until December of 2017.

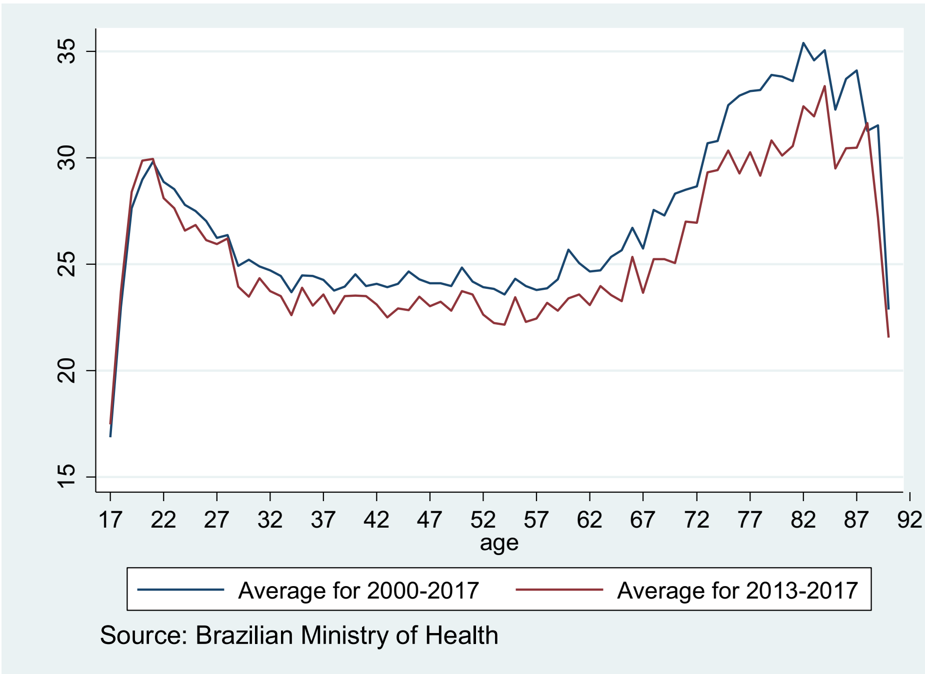


Figure 4: Average number of fatalities by day of the week in Brazil from January of 1996 until December of 2017.

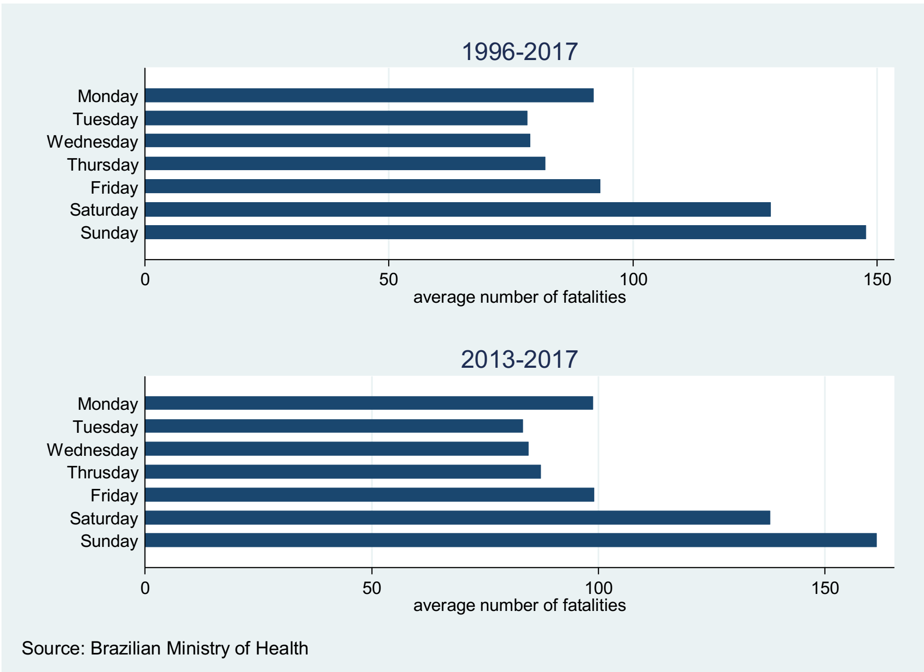
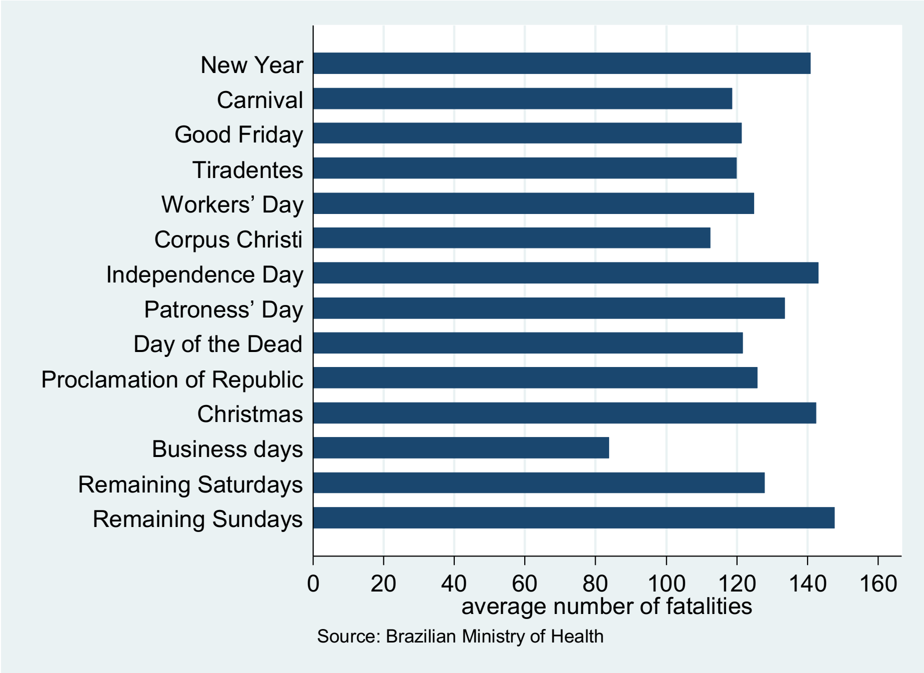
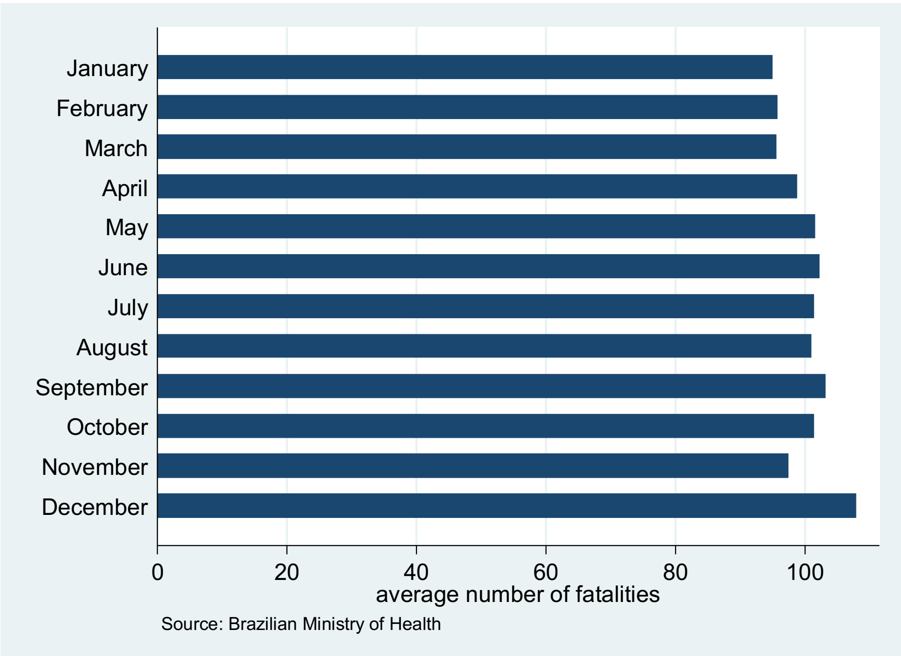


Figure 5: Average number of fatalities per day for holidays and extended holidays, remaining weekends, and business days in Brazil from January of 1996 until December of 2017.



Note: For an extended holiday, we considered the fatality daily average on the holiday and the weekend in the immediate adjacencies of the holiday. Applying the same logic, we considered Carnaval the period between Saturday of Carnival and the following Wednesday. Considering only the last 5 years of the series, we obtain a similar pattern to the one exhibited in the above figure.

Figure 6: Average number of fatalities per day by month in Brazil from January of 1996 until December of 2017.



Note: Considering only the last 5 years of the series, we obtain a similar pattern to the one exhibited in the above figure.

In recent years, one transportation means thrived in the roads: the motorcycles. As shown in Figure 7, in 2018, the number of motorcycles in Brazilian roads approached 22.3 million, nearly ten folders higher than the total in 1998, according to the Brazilian government traffic department—Denatran. This rise in the number of motorcycles in the roads was accompanied by a rise in the number of fatalities among motorcyclists, as shown in Figure 8.

Figure 7: Annual vehicle fleet in Brazil from 1998 until 2018.

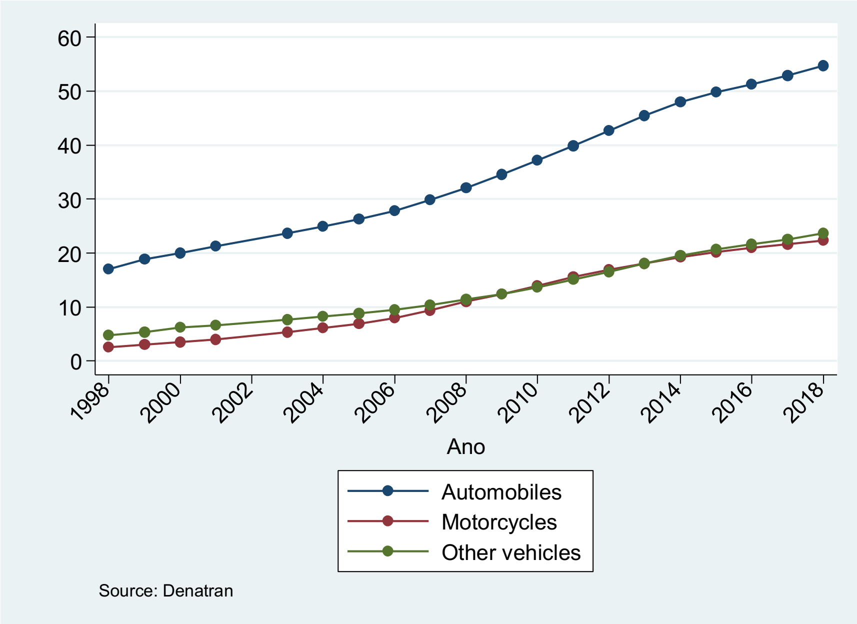
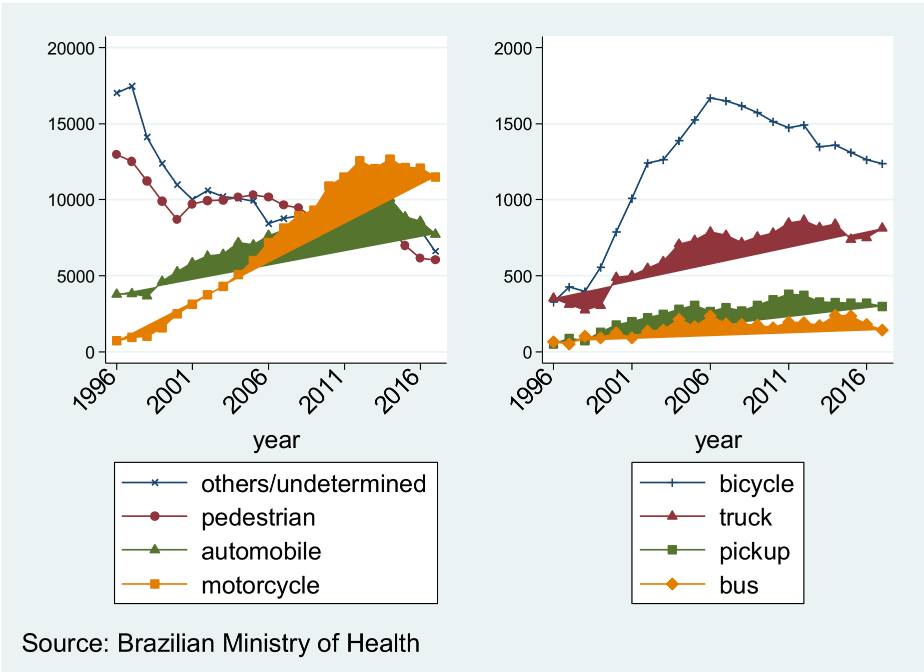


Figure 8: Annual road fatalities by vehicle type in Brazil from January of 1996 until December of 2017.



Since 2009, most of the people who died on the roads were motorcyclists. In 2017, they represented more than 1/3 of the fatalities on the roads. In second place, appear the automobile occupants (22.5%), followed by pedestrians (17.6%). Motorcyclists also top the rank of those in need of emergency care. In 2009, motorcyclists represented 50.9% of the road accident victims searching for public emergency care (Malta et al., 2012). Considering all accidents—with or without injuries—motorcyclists represent 30% of the cases in the years of 2007 and 2008 according to a nationally representative survey for Brazil (PNAD, 2010).

3 MODELS AND ESTIMATION

Several studies provide evidence of the relationship between the level of economic activity and road accidents. Some of the measures of economic activities considered are average income (accompanied or not by unemployment rate), gross domestic product, and consumption. See, for instance, Peltzman (1975), Ruhm (1996), Dee (1999), Ponicki et al. (2007), Bishai et al. (2006), and Grimm and Treibich (2013). For Brazil, Silva and Kilsztajn (2003) observe a similarity in evolution pattern between annual GDP per capita and road fatality rates. Yet, Blumenberg et al. (2018) find a strong correlation between the two variables considering the period from 2000 until 2013—period in which they use only official data—and a mild correlation considering a longer period of time, from 2000 until 2020—period in which they use official data as well estimated data.

The related literature, as well as the economic theory, conceive some causal relationships between road accidents and different measures of economic activity. For instance, it is inferred that a rise in production intensifies the transit of products, inputs, and labor. Also, from a theoretical approach in which a representative consumer chooses the consumption basket that maximizes her utility in her budget constraint, economic growth can be expressed by an increase in income, which can affect consumption and, consequently, the traffic on the roads. Under this framework, the association between income and traffic occurs in an indirect manner, through its effects on consumption. For instance, a rise in the purchasing power may prompt the consumer to go out more often, attend bars, restaurants, and parties, and/or drink more alcohol in those events, use individual transportation services, travel more (or to further places), get a driver´s license, buy a vehicle, consume safety equipment or a newer car, and a number of other consumption items that may be associated with traffic and, therefore, road accidents. Analogously, richer governments may improve road conditions and safety, police enforcement, emergency services, and trauma care.

In the long run equilibrium, the measures of economic activity mentioned are intertwined. After all, the sale of a product has a counterpart in the realization of an expenditure and in the formation of income. Despite the specificities of each measure, ceteris paribus, in the long run equilibrium, variations in one of these measures would be accompanied by variations in the others. Therefore, variations in any of these measures would capture the long run effects of the economic activity on traffic. Nevertheless, the adjustment the to long run equilibrium does not occur immediately. Consider, for instance, the recent credit expansion to households which boosted domestic demand in Brazil (Brazilian Central Bank, 2014 and 2019). The access to credit may rise consumption—with likely repercussions on traffic—even if no permanent and immediate rise occurs to income or production. Besides, road accidents in one location may be more directly related to either production activities or recreational activities depending on the specificities of its production logistics and the leisure habits of its population, which may lead the road fatalities to follow more closely the fluctuation in one particular measure of economic activity. For all those reasons, and respecting data limitations, the identification of which measure of economic activity better capture the effects of economic activity on traffic in each case may be an empirical question.

Alternatively, one could use all the main measures simultaneously. In this case, one would need to deal with the interrelation between those variables. Here, we opt for selecting one measure and keep the simplicity of the model.

Figure 9 shows the evolution of some measures of economic activity and road fatalities in Brazil. Precisely, we use the monthly index of apparent consumption of consumption goods devised by the Applied Economics Research Institute (IPEA). The apparent consumption is defined as domestic production plus the value of imported goods minus the value of exported goods. We also use the real average income from all jobs, the unemployment rate—both from the Brazilian Institute of Geography and Statistics (IBGE)—and GDP in current value from the Brazilian Central Bank deflated by the price index IGP-M from the Getúlio Vargas Foundation (FGV). Note that the series differ in time coverage. The figure presents fatalities, consumption, and production all in per capita terms. To facilitate comparisons, all series are converted to indexes with base in January of 2014. We present an enlarged version of some series in the Appendix.

Figure 9: The evolution of the road fatality rate and some measures of economic activity in Brazil.

Source: Brazilian Ministry of Health, IPEA, IBGE, Central Bank of Brazil, FGV

In the figure, road fatalities seem to follow the ups and downs of the overall consumption in the medium run. Given the similarity in behavior between those two series, we decided to focus on this relationship. Yet, there is some resemblance in movements between the series for fatality and GDP which will be examined in more detail in section 3.5.

We acknowledge here that the relationship between economic activity and fatality, not necessarily, manifests itself solely as an immediate effect. For instance, at the beginning of a consumption expansion cycle, people may prioritize projects they evaluate as more necessary or that were waiting for the right moment to be put in motion. Passed this first moment, they may start spending on items they consider less necessary, like trips and night outs, with different repercussions on traffic. In this case, the current composition of the consumption basket—and, therefore, the road fatalities—would depend on the previous levels of consumption. Specifically, we consider the following linear model:

$$F_t = \beta_0.C_t + \beta_1.C_{t-1} + \beta_2.C_{t-2} + \ldots + \beta_N.C_{t-N} + \alpha_1 + \alpha_2.Month02_t + \alpha_3. Month03_t + \ldots + \alpha_{12}. Month12_t + \mu_t, \quad (1)$$

where F represents road fatalities, C the overall level of consumption, and μ the residuals. The subscript t refers to time and N represents the maximum lag of the variable consumption. The model also includes dummies for each month of the year—except for the reference month, January—to capture the seasonality of the road fatalities. In the estimations that follow, we use the natural log of the fatality rates and of the per capita consumption indexes, both variables of monthly frequency.

First, we tested the stationarity of the series using the augmented Dickey-Fuller test. We use the Schwarz Bayesian Information Criteria to select the appropriate number of lags of the differenced variable to be included in the test specification. The criteria selected 14 lags for both variables—fatality and consumption—when the maximum number allowed was 36 lags. According to the test, we cannot reject the null hypothesis of a unitary root for the variables fatality and consumption. Next, we test the stationarity of the differentiated series. Following analogous criteria and considering a significance level of 5%, we reject the null hypothesis of unitary root for the differentiated series. We conclude, therefore, that the series are integrated of order one. The test statistics and critical values for each variable are presented in Table 1. The final specifications do not include trend variables since they are not statistically significant in any specification considered. We used the program STATA to compute all statistics and estimates presented in this work.

Table 1: Augmented Dickey-Fuller unit root test.

Variables (in ln)	Number of lags of the differentiated variable	Test statistics	Critical values		
			1%	5%	10%
Fatality	14	-1.639	-3.460	-2.880	-2.570
Consumption	14	-2.435	-3.460	-2.880	-2.570
$Fatality_t$ - $Fatality_{t-1}$	11	-5.952	-3.460	-2.880	-2.570
$Consumption_t$ - $Consumption_{t-1}$	13	-3.117	-3.460	-2,880	-2.570

Note: We use the Schwarz Bayesian Information Criteria to select the number of lags of the differentiated variable in the test specification.

Given that the series are integrated of order 1, we test for the existence of a long run equilibrium relationship between those variables, or the existence of a cointegrating vector. In case a cointegrating vector exists, one can estimate a Vector Error Correction (VEC) model. The first step consists of selecting the number of lags of the differentiated variables in the Vector Error Correction. This mechanism includes dummies for each month of the year to control for seasonality. According to the Bayesian Information Criteria, the appropriate number of lags would be 3, when the maximum allowed is 36. The statistics and critical values of the Johansen cointegration test are presented in Table 2. As shown in the table, we cannot reject the null hypothesis of the non-existence of a cointegrating equation between the variables consumption and fatality.

Table 2: Johansen cointegrating test.

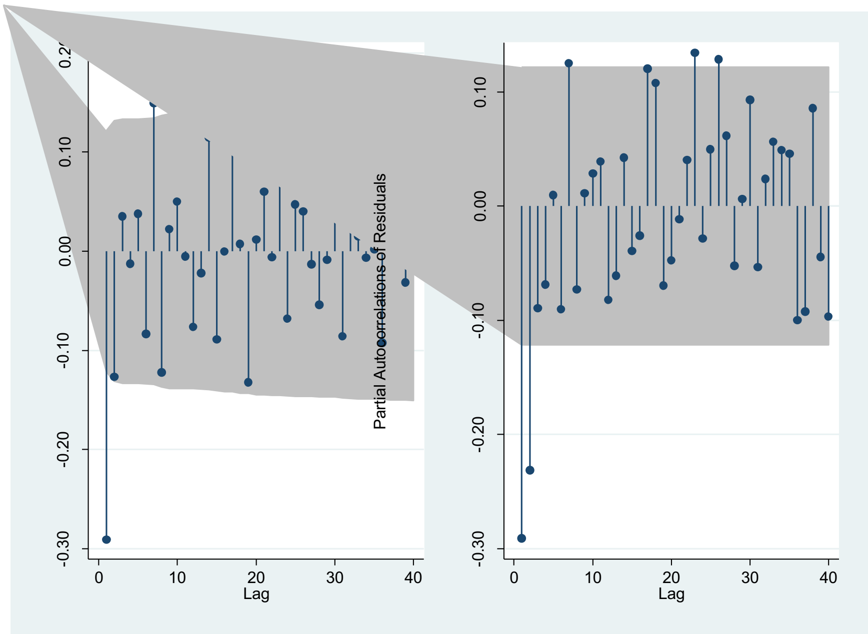
The null hypothesis about the number of cointegrating equations	Test statistics	Critical values at 5% significance level
0	11.966	15.410
1	1.994	3.760

Given that there is no cointegrating equation to be estimated, we differentiated the series to deal with the non-stationarity. Applying a lag to Equation (1) and subtracting the resulting equation from Equation (1), we find the Equation (2) below.

$$\Delta F_t = \beta_0.\Delta C_t + \beta_1.\Delta C_{t-1} + \beta_2.\Delta C_{t-2} + \ldots + \beta_N.\Delta C_{t-N} + \alpha_2.(Month02_t - Month02_{t-1}) + \alpha_3.(Month03_t - Month03_{t-1}) + \ldots + \alpha_{12}.(Month12_t - Month12_{t-1}) + \Delta\mu_t . \quad (2)$$

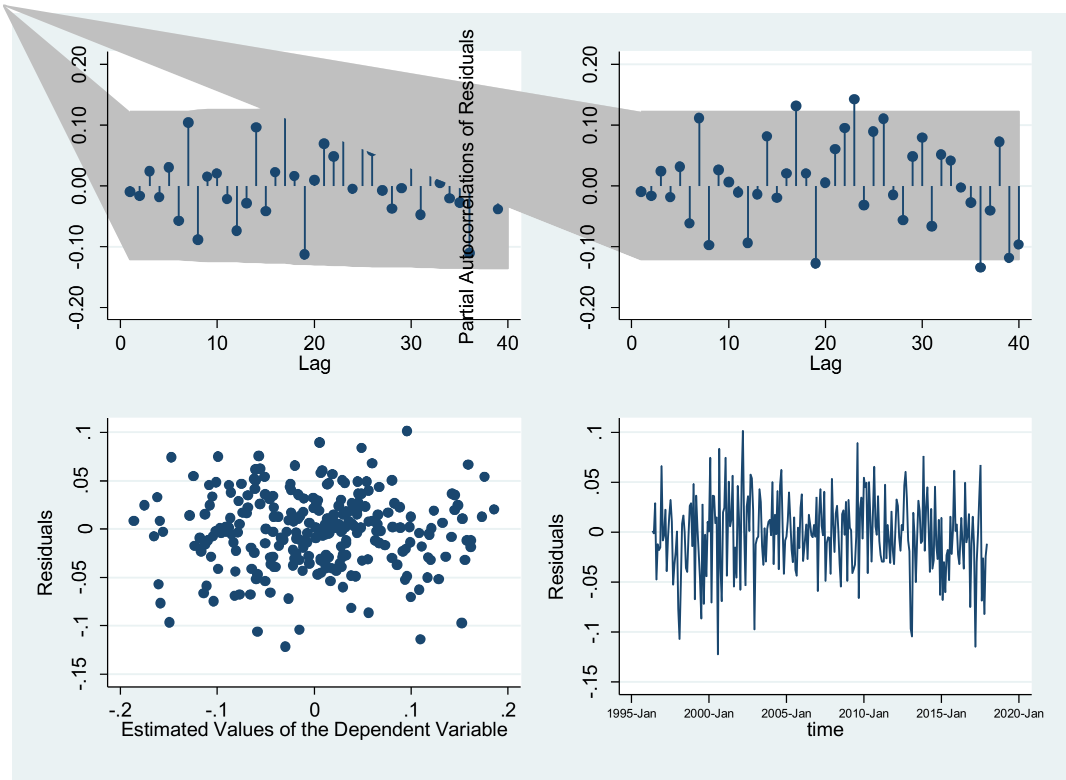
Initially, we did not include autoregressive or moving average terms in the specification of the residuals (i.e., we estimate the specification ARIMA(0,1,0) which differentiate the original variables). However, according to the graphs of autocorrelation (AC) and partial autocorrelation (PAC) of the residuals, the residuals for this specification are not independent. Figure 10 presents the case of a specification with up to 3 lags for consumption. We consider, then, specifications for the residuals with up to 2 lags for the moving average and the autoregressive terms. According to the Bayesian Information Criteria, the specification that better fits the data includes the first and second lag of the moving average in the specification of the residuals, and no autoregressive terms. The AC and PAC graphs of the residuals in the specification ARIMA(0,1,2) are presented in Figure 11. The figure also shows the graphs of the residuals over estimated values, and residuals over time. Next, we test for the presence of variability in the residual volatility over time. For that, we considered the autoregressive conditional heteroscedasticity models ARCH(1) and GARCH(1,1). Given that the coefficients of the lagged terms in the variance specification are not statistically significant individually, nor collectively in the case of GARCH(1,1), with the p-values in all tests above 20%, we conclude that there is no evidence of variability in the residuals' volatility. Similarly, we do not reject the null hypothesis of homoscedasticity of the residuals according to the Breusch–Pagan test ($R^2.N=0.572$; $\chi2$ with df=1) and the White test ($R^2.N=1.612$; $\chi2$ with df=2). Despite the results for the different tests, the residuals still might not be identically distributed over time. For this reason, we add robust estimates of the standard deviations to the results.

Figure 10: Autocorrelation and partial autocorrelation of the residuals for the specification ARIMA(0,1,0) with up to 3 lags of the variable consumption.



Source: Elaborated by the authors.
Note: 95% confidence intervals in the shaded area.

Figure 11: Autocorrelation and partial autocorrelation of the residuals, residuals over fitted values and time for the specification ARIMA(0,1,2) with up to 3 lags of the variable consumption.



Source: Elaborated by the authors.

Note: 95% confidence intervals in the shaded area.

The number of lags of the variable consumption was selected based on the statistical significance of the coefficient, and 6 was the maximum number of lags considered. We also experimented dealing with the seasonality through some SARIMA specifications (instead of the dummies for each month), but those specifications were disfavored by the Bayesian Information Criteria.

The coefficient estimates are presented in Table 3, column (A). As shown, the coefficients for the current consumption and for the previous three months' consumption are all statistically significant, meaning that fluctuations in economic activity, measured here as the overall level of consumption, are relevant to explain road fatalities in Brazil. Fatalities in a given month are positively affected by the consumption levels of 1 and 2 months preceding that, and negatively affected by the current level of consumption and its level 3 months before. As mentioned before, consumers may prioritize different items as the consumption expansion cycle evolves, with different implications for traffic, and road fatalities. Nevertheless, at the end of the 4 months adjustment period, the final effect of a rise in overall consumption is positive. Ceteris paribus, a 1% increase in the overall level of consumption leads to a 0.18% increase in the road fatality rate.

Table 3: The effect of consumption on road fatality rates in Brazil.

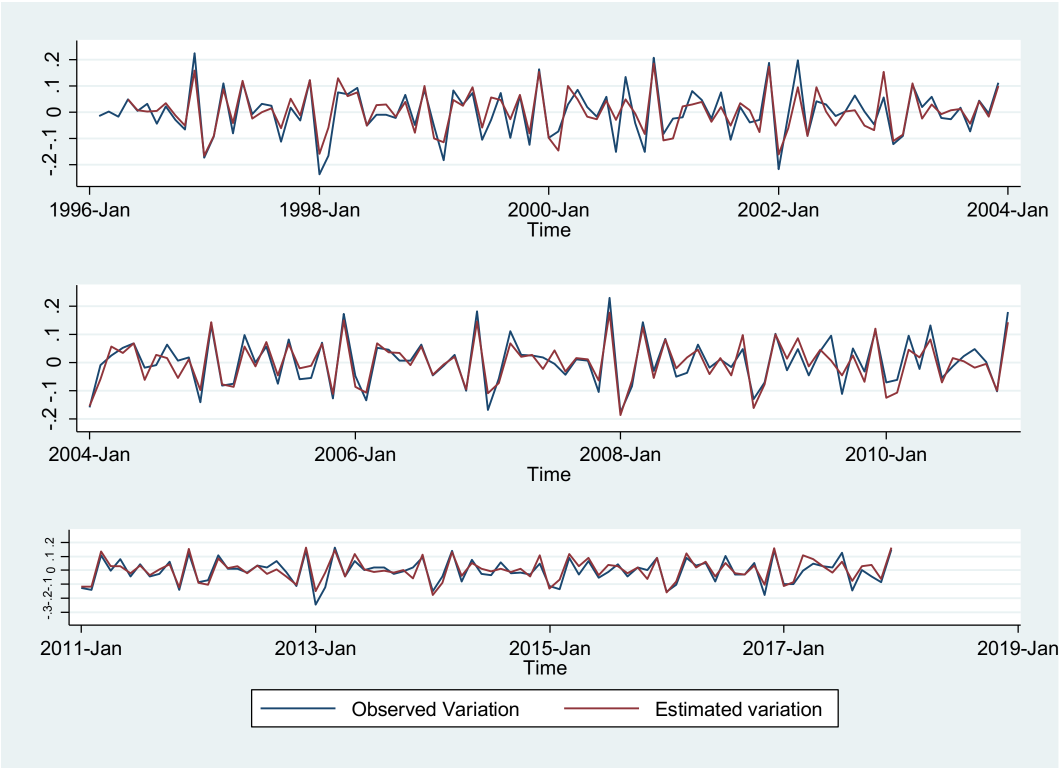
Dependent variable: Road Fatality Rate					
	(A)	(B)	(C)	(D)	(E)
Per capita current consumption index	-0.246***	-0.246***	-0.245***	-0.245***	-0.243***
	[0.068]	[0.065]	[0.069]	[0.065]	[0.065]
Per capita consumption index — 1 Lag	0.322***	0.322***	0.319***	0.319***	0.321***
	[0.062]	[0.071]	[0.062]	[0.070]	[0.071]
Per capita consumption index — 2 Lags	0.288***	0.288***	0.293***	0.293***	0.295***
	[0.068]	[0.068]	[0.068]	[0.068]	[0.068]
Per capita consumption index — 3 Lags	-0.179**	-0.179***	-0.179**	-0.179***	-0.182***
	[0.078]	[0.058]	[0.080]	[0.057]	[0.058]
February	-0.048***	-0.048***	-0.048***	-0.048***	-0.047***
	[0.014]	[0.016]	[0.014]	[0.016]	[0.016]
March	0.073***	0.073***	0.073***	0.073***	0.073***
	[0.026]	[0.024]	[0.026]	[0.024]	[0.024]
April	0.029	0.029	0.03	0.03	0.029
	[0.031]	[0.023]	[0.031]	[0.023]	[0.023]
May	0.069**	0.069***	0.069**	0.069***	0.068***
	[0.031]	[0.022]	[0.031]	[0.022]	[0.022]
June	0.047*	0.047***	0.049**	0.049***	0.048***
	[0.024]	[0.017]	[0.024]	[0.017]	[0.017]
July	0.069***	0.069***	0.070***	0.070***	0.069***
	[0.025]	[0.020]	[0.026]	[0.019]	[0.019]
August	0.074***	0.074***	0.075***	0.075***	0.074***
	[0.025]	[0.021]	[0.025]	[0.021]	[0.021]
September	0.024	0.024	0.024	0.024	0.023
	[0.026]	[0.022]	[0.026]	[0.022]	[0.022]
Octuber	0.058**	0.058***	0.058**	0.058***	0.057***
	[0.024]	[0.022]	[0.024]	[0.022]	[0.022]
November	-0.026	-0.026	-0.025	-0.025	-0.026
	[0.022]	[0.022]	[0.022]	[0.022]	[0.022]
December	0.070***	0.070***	0.071***	0.071***	0.070***
	[0.015]	[0.015]	[0.015]	[0.015]	[0.015]
Dry Law			-0.036	-0.036**	
			[0.080]	[0.017]	
First and Sencond Year of the Dry Law					-0.035**
					[0.017]
After the Second Year of the Dry Law					-0.018
					[0.026]
moving average — 1 Lag	-0.397***	-0.397***	-0.401***	-0.401***	-0.404***
	[0.059]	[0.073]	[0.059]	[0.074]	[0.073]
moving average — 2 Lags	-0.133**	-0.133*	-0.126*	-0.126*	-0.129*
	[0.066]	[0.072]	[0.066]	[0.073]	[0.074]
Constant	0.039***	0.039***	0.038***	0.038***	0.038***
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Number of Observations	260	260	260	260	260

Source: Elaborated by the authors.

Note: Standard deviations in brackets. * indicates that the coefficient is significant for the significance level of 10%, ** indicates significance at 5%, and *** significance at 1%. We applied the natural log to the variables fatality rate and consumption per capita. We use the specification ARIMA(0,1,2). Columns (B), (D), and (E) present robust standard deviations for the case of residuals not identically distributed over time.

As shown in Figure 12, the model can explain a great portion of the month-to-month variations in the dependent variable. Dividing the variance in the dependent variable explained by the model by its total variation, we find that the model can explain approximately 80.49% of the month-to-month variations in the dependent variable. Controlling for seasonal fluctuations, variations in the current level of consumption, and in the previous 3 months levels of consumption can explain 22.42% of the month-to-month variations in the dependent variable.

Figure 12: Observed and estimated month-to-month variations in the natural log of the road fatality rate in Brazil.

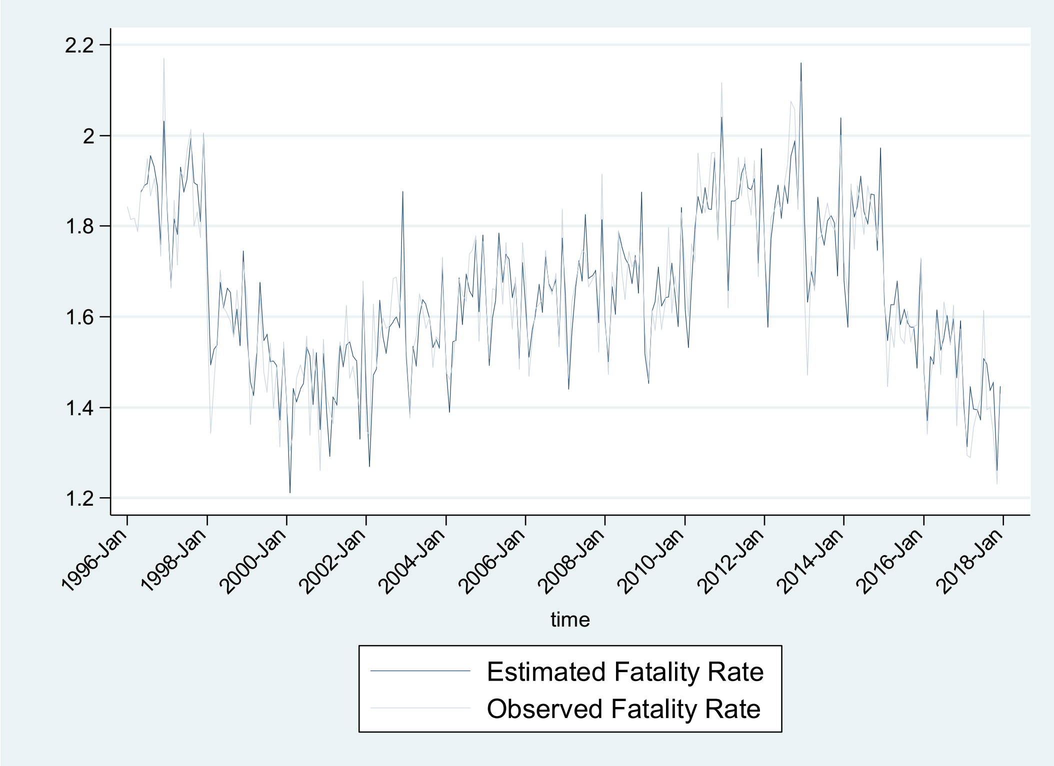


Source: Elaborated by the authors.

Based on the previous period fatality rate, we can calculate the current period fatality rate estimated by the model. Figure 13 shows the evolution of the fatality rate estimated this way and the actual rate. This procedure enables us to explain 91.83% of the variations in the fatality rate. Besides, this procedure can explain the fall in fatalities that happened after 2014.

Table 3, column (B) presents the estimates of the robust standard deviations in case the residuals of the regression are not independently and identically distributed. Notice that the conclusions remain the same. Last, the interpretation of the dummies coefficients requires some caution. Shorter months may have a lower number of fatalities simply because they have fewer days for the accidents to happen. That is the case of February relative to January. Despite the proximity of the daily fatality averages of those two months (see Figure 6), February has fewer days than January, which reduces the total number of fatalities in February relative to January.

Figure 13: Observed and estimated road fatality rate in Brazil.



Source: Elaborated by the authors.

In the next section, we use the model proposed here to evaluate the effect of a specific intervention in the Brazilian traffic context.

3.1 THE CHANGE IN DRUNK DRIVING LAW

In a complex and consistent study, Levitt and Porter (2001) estimate that drunk drivers are at least 7 times more likely to cause an accident involving fatality. Finds like that motivate the implementation of more strict laws against intoxicated driving, like the 11.705 Law of June 19th of 2008 (the so-called Dry Law). The law reduced the maximum legal level of alcohol in drivers' blood from 0.6 to 0.2 grams per liter. Thereafter, offenders with an alcohol level between 0.2 and 0.6 can be punished with tickets, driver's license suspension, and vehicle impoundment. Offenders with an alcohol level above 0.6 continued to face criminal charges. Simultaneously to the change in law, there was an intensification in enforcement and in awareness campaigns.

Empirical evidence suggests the Dry Law was successful in reducing road accidents right after its implementation. Malta et al. (2010), for instance, compare data from one year before and one year after the law and find a 7.4% drop in road fatalities for Brazil as a whole and an 11.8% drop for Brazilian capitals. Abreu (2012) compares data from July of 2007 with July of 2008 and finds a 12.9% drop in road fatalities in Rio de Janeiro city. Andreuccetti et al. (2011) use data from January of 2001 until June of 2010 and estimate a 7.2% drop in road fatality in São Paulo state and a 16% drop in its capital. Salgado et al. (2010) compare data from 2005 until

2009 and find a 50% drop in the number of drunk drivers in the city of Belo Horizonte. Moura et al. (2009) observe an immediate positive effect, yet temporary. The authors monitored by phone 27 Brazilian cities and observed a reduction in the number of drunk drivers only in the months immediately following the change in the law.

To estimate the effect of the Dry Law, we include in the model a dummy that takes the value of 1 for the period after the law came into force and zero otherwise. The results are presented in Table 3, column (C), and (D). Using robust estimates of the standard deviations, we find a significant effect of the law on road fatality rates. Nevertheless, when we separate the period the law has been in effect into the first 2 years and the subsequent period, we find a significant effect only for the first 2 years. This last estimation is presented in Table 3, Column (E). Maybe, a cooling in enforcement aligned with the widespread use of apps and social media that facilitates the disclose of the sobriety checkpoints attenuated its effect over the years. This hypothesis is consistent with the results in Nodari and Bottesini (2011)´s paper. Using sample data for a Brazilian city, they find evidence that the probability of being caught along sided with punishment is the main deterrent to misconduct.

3.2 GDP

In this section, we replicate the previous analysis using the GDP series instead of consumption. First, we do not reject the hypothesis of a unit root for the variable GDP (Augmented Dickey-Fuller test statistics=-0.77; critical value for a 5% significance level=-2.88). Yet, we reject this hypothesis for the differentiated series (test statistics=-3.79; critical value at 5%=-2.88). Next, we test the existence of a cointegrating vector between fatality rate and GDP. Following a procedure analogous to the previous one, we cannot reject the null hypothesis of the non-existence of a cointegrating equation between the variables fatality rate and GDP (Johansen cointegrating test statistics for the null hypothesis of zero cointegrating equations=5.87; critical value for a 5% significance level=15.41). Last, we estimate the regression equation for the differentiated series. The autocorrelation and partial autocorrelation graphs are similar to the previous case, and the same correction formula for the residuals proved itself suitable. Analogous to the previous case, the effects of the GDP of 4, 5, and 6 preceding months were not statistically significant, only the current level of GDP and the previous three months' levels of GDP have a significant effect on fatality rates. The signs are also the same: fatalities in a given month are negatively affected by the current GDP and the GDP of 3 months before, and positively affected by the GDPs of 1 and 2 months before. Nevertheless, the final GDP effect on fatalities is smaller than the consumption effect. Ceteris paribus, a 1% increase in GDP per capita leads to a 0.02% increase in the fatality rates—for consumption, this percentage is 0.18%. These results are consistent with the hypothesis that variations in road fatalities in Brazil are more directly tied to activities related to consumption than production. The model still can explain a great portion of the variations in the dependent variable, around 78.37%. Controlling for seasonal fluctuations, variations in the current GDP, and the preceding 3 months GDP can explain 16.67% of the month-to-month variations in the dependent variable. (For consumption, those percentages are higher, 80.49% and 22.42%, respectively.)

4 FINAL REMARKS

The estimation results provide evidence of the influence of the economic activity on road fatalities in Brazil. Seasonal fluctuations and variations in the levels of overall consumption of the current and a few preceding months can explain about 80% of the month-to-month variations in road fatality rates. Controlling for seasonal fluctuations in fatalities, variations in the economic activity can explain more than 22% of the month-to-month variations in the road fatality rates from 1999 until 2017 in Brazil. Ceteris paribus, an 1% increase in the overall level of consumption lead to a 0.18% increase in the road fatality rate, after a few months of adjustment.

These results preconize some consideration of the economic activity when evaluating the impact of interventions. The omission of this relevant variable may lead to an overestimation of the medium run effect of efforts aiming to contain fatalities during economic downturns and underestimation of this effect in periods of economic growth. Furthermore, the results in this paper suggest that measures of economic activity can contribute to the accuracy of fatality forecasts, which can facilitate preventive actions.

Still, the estimates presented here might underestimate the real effect of economic activity on road accidents. First, the accidents levy a cost in terms of future production of the injured or deceased. Second, anticipating a rise in fatalities, the government may raise investments in road safety measures. In the opposite direction, neglected roads or a decline in the quality of health care services or policing might affect fatalities as well as economic activity. These different factors might contribute to attenuate the positive relationship estimated here. On the other hand, there are plausible limits for the relative sizes of different effects, and to estimate them would require a more complex model.

Potentially, the consumption of items more directly related to road traffic, like average consumption of alcoholic beverages in bars and restaurants or distance traveled by inhabitant in different transportation modes, would enhance the predictive power of the model, but we could not find a time series data for those variables. We could find data for fuel consumption, however, advances in vehicle efficiency and changes in the fleet's composition and age probably compromised its relationship with road fatalities. In fact, the fall in fatalities from 2014 onwards was not accompanied by a fall in fuel consumption. Despite all that, there are some advantages to prioritizing the series of overall consumption. First, specific consumption items may gain or lose relevance in its association to road traffic over time, while a comprehensive consumption basket will always comprise items related to traffic. For instance, the consumption of cell phones and mobile internet may become relevant to road traffic issues when real-time navigation apps become accessible. Second, the overall consumption is a long series at a nationwide level and easily accessible.

The identification of the most suitable set of interventions for the case of Brazil lies beyond the scope of this paper. That said, we end this paper highlighting a few reflections reported in the literature about traffic interventions.

First, as pointed out by Ponicki et al. (2007), any specific intervention may exhibit a decreasing marginal return. For instance, a continuous rise in the minimum legal drinking age would, eventually, lead to smaller reductions in the road fatality rates. Second, the more diversified and stricter the regulatory portfolio of a government, the lower the effectiveness of any particular intervention. The authors present empirical evidence that the higher the legal drinking age, the lower the impact of an increase in alcohol taxes, and vice versa. A corollary of those two reflections is that cost-benefit analyses of different interventions would be limited to marginal changes from the regulatory context examined in the corresponding study.

Last, some improvements in road safety may be undermined by a risk compensation behavior of road users, which is commonly called the Peltzman effect. Albeit the diversity of contexts it has been applied, Peltzman introduced his idea in a 1975 paper about mandatory safety equipment, among them the seat belt. On one hand, seat belts reduce the gravity of injures in case of an accident. On the other hand, this extra protection may induce drivers to incur more risks on the road. Using data for North America, Peltzman finds an ambiguous effect on automobile occupants' fatalities. Unfortunately, the number of run overs increased with the new regulation. The idea is that rational individuals may take into consideration the probability of serious injuries when making risk decisions which may partially offset the effects of safety improvements. Several changes in the Brazilian traffic scenario might have been partially offset by a risk compensation mechanism or by other unanticipated reaction of road users. For instance, the widespread use of apps and social media to escape the sobriety checkpoints.

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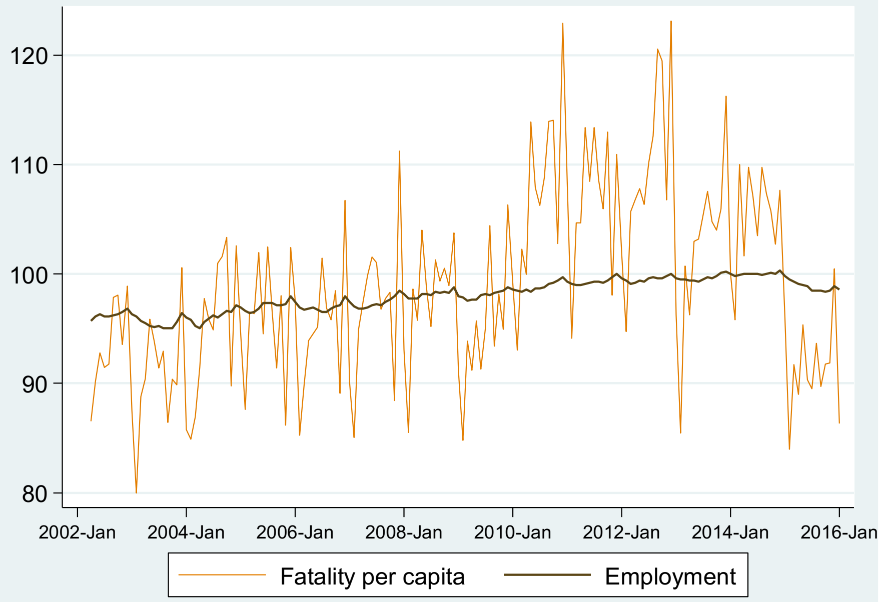
APPENDIX:

Figure A.1: The evolution of the road fatality rate and average income in Brazil.

Figure A.2: The evolution of the road fatality rate and employment level in Brazil.



Source: Brazilian Ministry of Health and IBGE