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MODELING SPEED LIMIT OFFENDERS IN MAURITIUS USING SYMMETRIC AND ASYMMETRIC GARCH MODELS: FROM FINANCIAL MODELING TO TRAFFIC MODELING

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Abstract: Many countries have adopted important policies in view of curbing the number of injuries/fatal road accidents with the most important being speed limit enforcement. In that respect, Mauritius has recently embarked on a strategy of using cameras in view of detecting violations to speed limits. However, the empirical literature on speed limit offenders is still very poor in terms of modeling. In essence, this paper constitutes the very first study that provides sound econometric modeling for speed limit offenders. Findings suggest that vanilla GARCH can be used to model the number of speed limit offenders. Above all, leverage effects are also noted, clearly showing the importance of the type of traffic flow of speed limit offenders which underpins the non-compliance/breach to speed limits. Furthermore, results show the presence of strong weekend effects as confirmed by the dummy variable. The research is expected to provide a momentum in the use of GARCH models for traffic modeling not only for Mauritius but also for other countries in the world.

Keywords: speed limit enforcement, GARCH models, econometric modeling, Mauritius.

1. Introduction

Nowadays, many studies have been conducted as to show that higher speed limits constitute one of the main causes for fatal accidents. The Organisation for Economic Co-Operation and Development (OECD) and the European Conference for Ministers for Transport (ECMT) (OECD/ECMT, 2006) report that speeding constitutes the number one road safety problem throughout the globe. Blincoe et al., (2006) find that for every one mile per hour fall in average speed in US, crashes would be scaled down in the range of two to seven %. The predominant method employed to gain control over driving speed is the application of speed limits with a two-pronged objectives. First, the aim is geared towards reducing the disparities in drivers' speed choices and thus scaling down the potential for vehicle conflicts. Second, the objective is to enforce speed limits in view of deterring reckless drivers in jeopardizing their lives, the lives of other drivers and pedestrians.

In Mauritius, the Ministry of Public Infrastructure, Land Transport and Shipping, has taken solid measures in view of curbing non-compliance with speed limits and thereby mitigate fatal road accidents, with an average of 140 fatal accidents recorded per year. To be more considerate and attentive, recourse has been made towards high resolution cameras, which has been placed at Pailles for traffic

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moving to the north and at Camp Chapelon for traffic moving in the opposite direction to detect excess speeding and thereby enforce speed limits, which are 40, 80 and 100 km/h in towns, highways and motorways, respectively. The penalty fees has been fixed at Rs 2,000/- for any violation noted and the usual lapse of time between the date that the infringement has been caused and the date that payment is effected, revolves around 30 days.

A conspicuous finding noted with respect to the number of speed limit offenders for the two places whereby the cameras have been fixed is that, the daily number of speed limit offenders has initially fallen to then hover around stable levels. The underlying rationale is that, these cameras started to operate in December where it is usually the festive season so that people tend to drive at higher speeds. Above all, just like any new technology introduced, there is a learning curve process.

However, as at date, the empirical literature on modeling of speed limit offenders is still deficient in terms of modeling the flow of speed limit offenders. Many important benefits emanate from having a proper model that could depict the flow of speed limit offenders in any country. First, a model that captures the essence of traffic offenders is useful for policy purposes like knowing the average number of speed limit offenders on a daily basis could be useful for government in taking more vigorous actions like scaling up the penalty fines for recurrent offenders. In the same vein, dummy variable has been employed to show the significance of weekend effects with a higher number of offenders being noted. Second, any econometric model used is powerful in terms of its forecasting ability which is particularly important for having an idea of the level of government revenues that could feasibly emanate from these speed limit offenders. Such a need is considered to be of paramount significantly, chiefly when the US Subprime crisis spectre has already enthralled most economies, developed and developing, with major stress being exerted on government purse on the back of the fiscal stimulus packages.

Results show that not only vanilla GARCH but also asymmetric GARCH models highly befit the data for the number of speed limit offenders. Above, the leverage effects noted are negative and highly accommodative of the practical fact that the volatility in the number of speed limit offenders is also a function of the state of traffic flow, like peak hours and off-peak hours. Weekend effects are also being confirmed through the statistically significant dummy variable.

The remainder of this paper is structured as follows. Section 2 discusses the theoretical and empirical foundation of the studies on speed limit violation. Section 3 describes the data and econometric model. Section 4 presents the empirical results. Finally, section 5 concludes with important policy implications.

2. Literature Review

The relationship between driving speed and injury or fatal road accidents has been studied in many countries with nearly most studies clearly pointing out a direct positive relationship (Aarts and Van Schangen (2006), De Pelsmacker and Janssens (2007)). Lui et al., (2005) conclude that 30 % of crashes in US is generated by speeding with more or less similar findings obtained for New Zealand (Oxley, 2006) and Australia (RTA, 2005). For Sweden, Warner and Aberg (2008) find that had drivers adhered to the speed limit, twenty % of the people killed on Swedish roads would have survived. In Grece, Kanellaidis et al., (1995) find that drivers who personally believe that speed limits can diminish accidents, are much more likely to adhere to those speed limits. Interestingly, they also note that speed limit compliance is induced by certain vital factors like elder drivers, higher the number of miles driven, let alone a higher education level. Aarts and Van Schagen (2006) find that speed limit reductions negatively impact on the occurrence of collisions to thereby lower the injury outcomes of the crashes.

There is another branch of empirical study which focuses on how injuries can be fostered when speed limits levels are being adjusted upwards. For example, Farmer et al., (1999) find a rise of 15 % in fatalities for 24 US states that scale up their speed limits during the period 1995 to 1996. Similarly, Patterson et al., (2002) note a much higher increase of 38% in fatality rate in states that rose their speed limits to 75 mph and a slightly lower rise in fatality rate of 35 % in case states increased their speed limits to 70 mph. In essence, there is growing evidence throughout the world that speed limits do represent the main element in case of road casualities. Interestingly, Farmer et al., (1999), Kockelman and Bottom (2006) and National Highway Traffic Safety Administration (1992) demonstrate some converging findings whereby the lower 55mph speed limits do save lives.

However, in some studies, a rise in speed limit ironically triggered a fall in fatality road. Lave and Elias (1994) analyse the impact of scaling up the speed limit from 55 mph to 65 mph to find a drop of 3.4 to 5.1 % in road fatality rates. The reason is that, with the rise in speed limit, resources used to enforce such speed limits are being judiciously used elsewhere in areas most sensitive to road accidents so that, there is a general fall in crash severities rates. Similarly, lower the speed limit does not automatically implied in having compliance from all drivers. For example, Goldenbeld and Van Schagen (2007) find that drivers speed in case they find that the speed limits are set too low.

The empirical literature has also focused on other forces, susceptible to impact on speed limit, like credibility, posted speed limit and political factors. Drivers are less susceptible to exceed the speed limit if they have the perceptions that speed limit imposed on a specific road is compatible with the features of the road and surroundings (Goldenbeld and Van Schagen, 2007). Recarte and Nunes (2002) find that there is an increase of 11 km/h on average when no speed limit is posted compared to cases when there is the presence of posted speed limits. Similarly, there is also the potential effect of political consideration with respect to speed limit enforcements. For instance, following the Emergency Highway Energy Conservation Act in the US in the 1974, which imposed a 89 km/h on interstate highways relative to the level set by engineers (112 km/h), highway engineers were concerned about a detrimental impact on the highway safety. Mannering et al., (2009) point out that important compliance problem can manifest whenever speed limits are set for political purposes without factoring in the major design-safety principles.

3. Econometric Model and Data

However, one of the major criticisms of the previous empirical research is that no model has been devised as such to capture the number of speed limit offenders prevailing. The issue is that no real modeling works have been envisaged in that area. This paper fills such a vacuum by applying the GARCH technique to traffic modeling. In essence, the GARCH model has been widely used in finance but the current research shows that it still rejoices over much larger application level.

3.1. GARCH (1,1)

The mean equation for the GARCH model is explained in Eq. (1).

$$FIX1_t = c + FIX1_{t-1} + FIX2_t + DUM \quad (1)$$

Where:
FIX1: Number of Speed Limit Offenders for Camera 1
$FIX1_{t-1}$: Number of Speed Limit Offenders for Camera 1 at time t – 1
FIX2: Number of Speed Limit Offenders for Camera 2
DUM: 1 if the violation occurs in a weekend, 0 otherwise

The above equation shows that the number of speed limit offenders caught under camera fixed at downstream flow of traffic at Port-Louis is a function of a constant C, the number of speed limit offenders lagged by one day, $FIX1_{t-1}$, the number of speed limit offenders found at camera two, $FIX2_t$,. A total of 272 observations were used for the analysis, all comprising of drivers who violated the stipulated speed limit. The underlying rationale for taking speed limit offenders under camera 2 is because being not far from camera 1, the capture of number of speed limit offenders at camera 2 is susceptible to exert some positive momentum on the capture of the number of speed limit offenders at camera 1.

$$\sigma^2_t = \alpha_0 + \alpha_1 u^2_{t-1} + \beta\, \sigma^2_{t-1} \quad (2)$$

The GARCH model is attributed to two famous names, namely Bollerslev (1986) and Taylor (1986). Eq. (1) states the formal standard, linear or symmetric GARCH model. In practical finance, it is believed that the GARCH (1,1) is sufficient to capture the essence of the data under investigation. The ones in the GARCH reflect the lagged coefficients by one period of the ARCH effect, u^2_{t-1}, and GARCH effect, σ^2_{t-1}. The parameters of the GARCH (1,1) process are restricted to be nonnegative, $\alpha_0 > 0$, $\alpha_1 \geq 0$ and $\beta \geq 0$. Furthermore, $\alpha_1 + \beta$ are required to be less than one to ensure that the unconditional variance is finite and positive.

3.2. GJR-GARCH

However, the plain vanilla GARCH model does not capture volatility asymmetry. The reason is that both positive and negative return shocks ($u_{t-1} > 0$, $u_{t-1} < 0$) entail the same impact on the conditional variance term because the residual appears in squared form. Technically speaking, GARCH (1,1) can merely capture volatility clustering but not leverage effects. To deal with leverage effects, asymmetric GARCH models are thereby employed. The TGARCH or GJR-GARCH model of Glosten et al., (1993) is used whereby the symmetric GARCH model is augmented with the leverage parameter which basically incorporates the volatility response emanating principally negative shocks.

$$\sigma^2_t = \alpha_0 + \alpha_1 u^2_{t-1} + \lambda\, I\,(u_{t-1} < 0)\, u^2_{t-1} + \beta\, \sigma^2_{t-1} \quad (3)$$

The indicator function I takes one if $u_{t-1} < 0$, and 0 otherwise. The term “leverage effect” emanated from the financial modeling environment. In brief, it reflects the inverse relationship between equity market returns and equity volatility whereby equity market volatility increases are more acute ensuing a large negative return than they are following a positive return, despite both being of the same magnitude. The underlying mechanism is that as returns fall, this leads towards a rising debt-to-equity ratio which eventually feeds inside into a higher level of volatility as investors perceive higher risk of investing.

The data has been obtained from the traffic branch unit in Mauritius and it is on a daily basis for a period of ten months, starting off as at December 2010 up to September 2011. Leverage effects are expected to hold in the case of speed limit offences[2]. As a matter of fact, with respect to the number of speed limit offenders recorded on a day, important leverage effects could potentially manifest. Indeed, the volatility in the number of speed limit offenders is susceptible to increase more following a rise in the number of speed limit offenders than a fall of the same magnitude. The rationale is that as there is an increase in the number of speed limit offenders, this is synonymous towards a smoother traffic flow which induces speedier driving and thereby scaling up the volatility in the number of speed limit offenders. The volatility in the number of speed limit offenders, for the same magnitude fall in the number of speed limit offenders, is likely to be lower on the back of a more congested traffic flow which deters speedier driving. Based on the fact that under leverage effects, the same change in the number of speed limit offenders entails a higher volatility effect if the shock is positive relative to when it is negative, leverage effect should be confirmed by a statistically significant and negative value for λ.

[2] Speed limit violation manifests in case the driver exceeds 80 km during off-peak hours. No violation occurs during peak hours since all cars are like concatenated on the roads.

4. Results

Table 1 shows the results for the first camera, labelled as FIX1. A one % change in the number of speed limit offenders of yesterday trails behind around 0.37 % in the number of speed limit offenders noted today. Interestingly, FIX2 at time t also generates a positive impact of around 0.42 % on the number of offenders witnessed today, showing some synchronicity in terms of traffic flowing to and from Port-Louis. Above all, the weekend dummy variable has been found to be statistically significant, with on average 37 additional offenders recorded during any weekend. The adjusted R^2 is comforting since it explains around 56% of the variation in the dependent variable. Since lagged value of the dependent variable has been employed, the Durbin-Watson test is not valid as a metric for gauging serial correlation. Breusch-Godfrey Serial Correlation shows that there is no serial correlation problem at the six % level, which is highly comforting.

Table 1
OLS Results for FIX1

Dependent Variable: FIX1	
Variable	Coefficient
C	19.74
	6.36*
FIX1(-1)	0.37
	9.18*
FIX2	0.42
	4.25*
DUM	31.79
	10.32*
R-squared	0.56
Adjusted R-squared	0.56
Durbin-Watson stat	2.05
Log likelihood	-1208.49
F-statistic	114.14
Prob(F-statistic)	0.00

Prior to embarking on any GARCH applications, it is of paramount significance to compute the Engle (1982) test for ARCH effects to ensure that this class of model is appropriate for modeling. In the case that the errors are heteroscedastic but considered homoscedastic, this would be symptomatic to wrong standard error estimation so that the use of ARCH is highly recommended. When the data on speed limit offences is analysed, strong evidence of autoregressive conditional heteroscedasticity in the residuals, prevails. In that recourse, the model is run as to see whether it befits the use of GARCH vanilla.

Irrespective of the GARCH models employed, it transpires that the GARCH error parameter is highly sensitive to traffic shocks or events. Similarly, the higher coefficients noted for the GARCH lag parameter signifies that there is significant persistent in volatility with respect with the number of speed limit offenders. The sum of the GARCH parameters sum to 0.938, with both the reaction and persistent parameters being statistically significant. Post fitting the model with the vanilla GARCH, re-testing of the variance shows that there are no more presence of ARCH effects, glaringly validating the use of GARCH models. However, it could be that volatility is different in the upward or downward move so that leverage effects should be given due consideration. Interestingly, the sign for the leverage effect is not only negative but also statistically significant, adding evidence to the fact that as the number of speed limit offenders rise, there is tendency to experience a heightened volatility in the number of offenders recorded based on a smoother flow of traffic. Above all, the unit root test for the residuals under both GARCH and TGARCH showed that they were stationary and the standardized residuals behave like normal distributions as depicted in Fig. 1. and Fig. 2.

Table 2

GARCH and TGARCH Results for FIX1

	GARCH (1,1)	**TGARCH**
	Mean Equation	
C	27.8104	28.3612
	8.61*	8.26*
FIX1(-1)	0.1987	0.1932
	5.14*	4.56*
FIX2	0.3473	0.3631
	3.77*	3.72*
DUM	31.0341	31.0830
	13.24*	11.74*
	Variance Equation	**Variance Equation**
C	16.1438	39.2594
	2.50**	2.54*
RESID(-1)^2	0.1048	0.1391
	3.99*	3.46*
RESID(-1)^2 * (RESID(-1)<0)		-0.1962
		-2.28*
GARCH(-1)	0.8332	0.7880
	29.77*	18.62*
Adjusted R-squared	0.4867	0.4897
S.E. of regression	22.2878	22.2221
Log likelihood	-1173.9650	-1171.0620
Durbin-Watson stat	1.4506	1.4581
F-statistic	43.8219	38.1508
Prob(F-statistic)	0	0

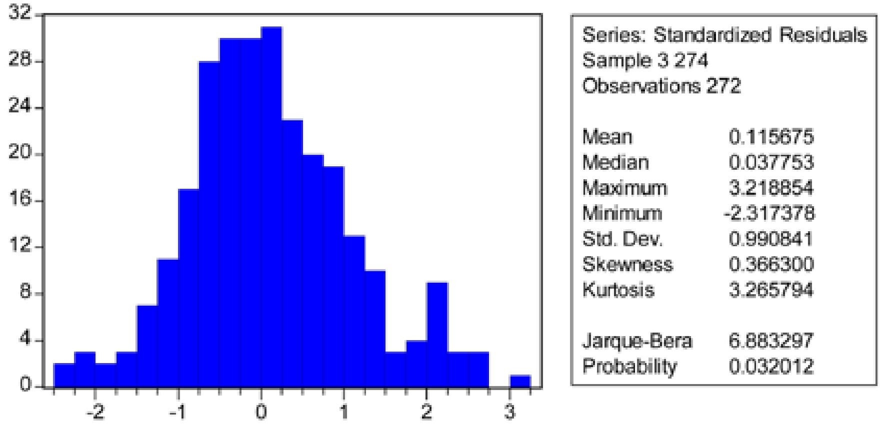

Fig. 1.
Standardized Residuals for GARCH

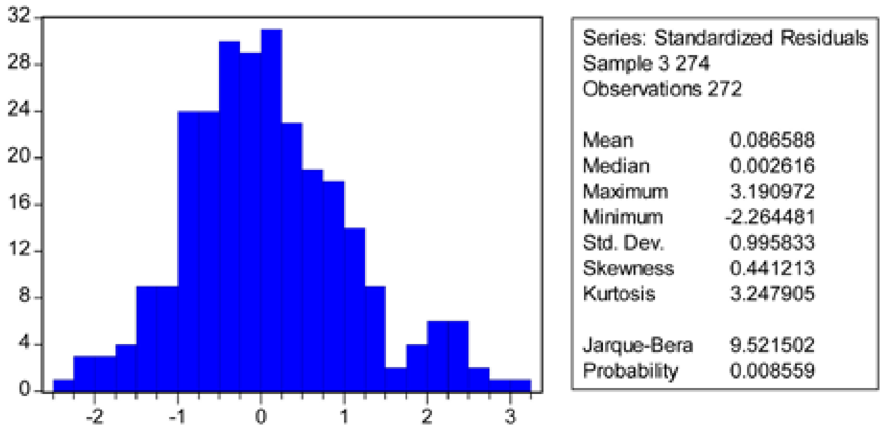

Fig. 2.
Standardized Residuals for TGARCH

5. Conclusions

This study has provided a useful modeling approach to speed limit offenders for a small developing country, Mauritius. Results show that the offences committed are particularly higher during the weekends. The very success of GARCH model in modeling speed limit offenders show that violation of speed limits does move in bunches or clusters. Above all, the leverage parameter used is found to be negative and statistically significant corroborating the fact that volatility in the number of speed limit offenders tend to be higher whenever there is a positive shock. The above study confers many benefits. First, the GARCH models can be used for forecasting purposes in case the government would like to know its forthcoming revenues generated by these offences. Second, despite the very fact that the study was conducted in Mauritius, it is very likely that its findings are also relevant to other countries like US and Europe, where comparable findings are expected to be obtained. Hence, future research in the developed countries will undeniably provide added boost to the application of GARCH models. The last but not the least, the study adds beauty to GARCH applications, stretching its use beyond finance towards other spheres of life problems and applications, in particular, for traffic modeling.

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MODELIRANJE PREKRŠIOCA OGRANIČENJA BRZINE NA MAURICIJUSU UZ PRIMENU SIMETRIČNIH I ASIMETRIČNIH MODELA GARCH: OD FINANSIJSKOG DO SAOBRAĆAJNOG MODELIRANJA

Indranarain Ramlall

Sažetak: Mnoge zemlje su usvojile važnu politiku koja ima za cilj da ograniči broj povreda/saobraćajnih nezgoda sa fatalnim ishodom, a kao najvažnija izdvaja se primena zakona o ograničenju brzine. Na Mauricijusu je u tom smislu nedavno počela da se primenjuje strategija korišćenja kamera s ciljem uočavanja prekoračenja brzine. Empirijska literatura o prekršiocima ograničenja brzine je veoma skromna kada je reč o modeliranju. U suštini, ovaj rad predstavlja prvu studiju koja pruža pouzdano ekonometrijsko modeliranje za prekršioce ograničenja brzine. Rezultati pokazuju da GARCH model može da posluži za modeliranje broja prekršilaca ograničenja brzine. Zabeležili smo različite uticaje, jasno prikazujući važnost tipa saobraćajnog toka prekršilaca ograničenja brzine koji leži u osnovi nepoštovanja propisa, odnosno prekoračenja brzine. Rezultati pokazuju jasan uticaj vikenda, što potvrđuje veštačka varijabla. Očekujemo da će naše istraživanje dati prednost primeni modela GARCH za modeliranje saobraćaja ne samo u slučaju Mauricijusa već i u slućaju drugih zemalja u svetu.

Ključne reči: primena ograničenja brzine, modeli GARCH, ekonometrijsko modeliranje, Mauricijus.