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Is there a relationship between the use of motorcycles and the level of development of countries?

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Abstract. Our paper aims to analyse the hypothesis that locations with a higher Human Development Index (HDI) present lower rates of motorcycle use. For this we use an econometric model for 117 countries on five continents for the years 2013, 2015 and 2018. We assume that when a country reaches a higher level of development, its population is more likely to experience improvements in the quality of life, which also affects the quality of individual transportation, public transport and roads. Increases in income discourage the use of motorcycles, mainly due to their low safety and comfort features. Our results indicate that rates of motorcycle use in countries increase as HDI rises, before reaching a maximum point and then declining. Therefore, this evidence suggests that a certain degree of development discourages the use of this means of transport in favour of others.

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1. Introduction

Motorcycles are a means of transport with great uptake in the world. The estimated number of vehicles already exceeds three hundred million, with its largest concentration in Asia, which accounts for 77% of the global total. Europe and Latin America together comprise 16% of the total (Rogers, 2008). Fleet growth occurs in countries with different levels of income. In those with lower incomes, such as Colombia, motorcycle sales grew by 42.8% between 2010 and 2016 (Andi, 2017). In Brazil, the sale of all automobiles quadrupled between the years 1992 and 2007, as motorcycle numbers increased more than twelve-fold during the same period (Vasconcellos, 2008).

The fact that this growth had profound consequences in the spatio-temporal configurations, restructurings and practices of peoples' everyday lives is one of its appeals for geographical research and analysis. Some factors may explain the increasing use of this means of transport around the world, such as increases in fuel prices, facilitated transport, high congestion levels in large cities (Blackman et al., 2010) and the cost–benefit equation relative to others means of locomotion (Dargay et al., 2007). However, the factors that encourage its use vary between low- and high-income countries.

In low-income countries, drivers use the vehicle more frequently as a means of commuting to work or to transport passengers. In this case, less powerful models (single-cylinder) are more common (Haworth, 2012). This characteristic is justified by the fact that these countries have a deficiency in public transport infrastructure and problems related to traffic congestion (Da Silva et al., 2011). Concerning public transport, drivers consider the comfort that individual transport provides especially when considering the precariousness of public transport in developing countries (Hagen et al., 2016).

On two wheels, the time taken to travel to work decreases due to the ease with which this type of vehicle can travel on urban roads – mainly during periods of high car traffic. Another aspect is its ease of parking. Being smaller than four-wheeled automobiles, motorcycles can parked in smaller parking spaces or places with narrower streets. The low cost of maintenance and low insurance are also considered when purchasing motorcycles (Vasconcellos, 2008).

In contrast, higher-income countries link their use to purposes such as leisure (Rogers, 2008). In these regions, motorcycles are larger, tend to be more sophisticated and have a greater number of wheels. Additionally, drivers usually use the vehicle without passengers (Haworth, 2012), as in extreme sports (off-road), given its better performance on steeper roads and less accessible regions. In the United States, motorcycle sales for this purpose represented more than 22% of total motorcycle sales in 2007 (Morris, 2009). In Australia, it reached 35% of the total in 2016 (FCAI, 2016). It is still worth noting that motorcycles are not substitutes for public transport, since in these countries drivers usually use cars or other forms of transportation for work.

The transition process that changes the function of the motorcycle in countries is slow. Pongthanaisawan et al. (2010) point out that the relationship between the consumption of motorcycles and level of income is composed of two stages. In the first stage of development, the number of motorcycles exceeds the number of other automobiles. At this stage, countries are considered low-income and the use of motorcycles is more viable due to their low purchase price. As these countries reach a higher income stage, the number of motorcycles falls, while the number of other automobiles, mainly cars, increases. At a certain peak in the income level, individuals may prefer to consume cars rather than motorcycles, as this change is possible due to increased income. Some of the factors that influence this choice include the greater safety, convenience and comfort that four-wheeled cars provide in comparison to motorcycles.

The adoption of motorcycles in poorer countries also grows due to their use for the recreational purposes characteristic of societies with higher income levels, while the poorest population of this same region does not enjoy this means of transportation for leisure due to its lower income level. Thus, the concentration of income influences the rate of motorcycle use. Another relevant aspect is the educational level of the population of countries. Individuals with more years of study have greater opportunities in the labour market due to the increase in their skills, which reflects improvements in the population's liv-

ing conditions, such as increased income. Such an increase in the level of income can expand the offer of goods and services available, such as public transport, a factor that discourages the use of motorcycles as a means of transport, both because of their level of comfort and because they present a greater risk of accidents to passengers and riders.

In geographic terms, Nishitateno et al. (2014), using a panel method and data for 55 development countries for the period 1963–2010, verify a Kuznets curve that explains the relationship between motorcycle ownership and countries' incomes. The authors describe the increased dependence on the vehicle and then, as economies develop, the fall in that dependence.

Nagai (2003) analysed developing countries – with an emphasis on Thailand (Asia), and concluded that, as the rate of motorcycles increases in that region, the GDP *per capita* follows the same increase pattern. Kopits et al. (2008) and Dargay (2007) also find a positive relationship between the demand for motorcycles and a certain level of income of these countries.

Nkede Njie (2012), analysing the socio-cultural impact of the introduction of motor taxis in the rural community of Tombel, South West region, Cameroon, concluded that motor taxis are an instrument of development that sprang up in an environment where the disparity between population growth and demand for public transport is fast increasing. With the government's inability to provide public transport for all, individuals have begun to fill this gap as "a response from below".

Karema et al. (2017), examining the contribution of commercial motorcycles in poverty alleviation in Laikipia East Sub-County, Kenya, found that the commercial motorcycle contributes 10% towards poverty alleviation, and that key activities that arose as a result of commercial motorcycle ridership generated gainful employment.

Mbegu and Mjema (2019), in their analysis "Poverty Cycle with Motorcycle Taxis Business in Developing Countries: Evidence from Mbeya—Tanzania" concluded that, contrary to the reported growth and success of this business, the motorcycle taxi business has negatively impacted communities. In most cities and towns there is a serious increase in accidents involving motorcycle taxis. Urban insecurity, pollution and traffic are other problems associated with the motorcycle taxi business.

The difference in the use of motorcycles, as a hobby or recreational activity in developed countries, or as a means of transport or a way to increase individual or family income in developing countries, demonstrates that the level of development influences the use of this means of transportation.

Thus, this work aims to analyse the relationship between the Human Development Index (HDI) and the rate of motorcycle use per thousand inhabitants in countries from 2013 to 2018. The justification for using the HDI variable instead of the income level is that it can capture additional aspects of countries that can influence the use of motorcycles, going beyond a purely economic measure. Through an approach that considers the level of development of countries, the HDI is calculated from three main aspects: income, education and health. Thus, as these indicators improve, the country's HDI rises, reflecting the rising quality of life of the population. Therefore, the index is not restricted only to the economic aspect of the population, but also encompasses components such as life expectancy, the population's literacy index and the country's income.

Although the level of income in countries is usually related to motorcycle consumption, the distribution of that income is also a determining factor. Locations with high levels of income per resident do not necessarily reflect the reality of the entire population. Thus, it is important to consider the existing income inequality, a factor that more accurately highlights the living conditions of the population of a region. Meyer and Sullivan (2017) claim that income does not reflect issues of inequality, and consequently does not reflect a country's social well-being. According to Correia (2014), economic development involves a series of qualitative and quantitative variables, which lead to a radical change in the structure of the economy and society itself, including changes of a psychological, cultural, political and access nature. In this sense, the progress resulting from economic development provides structural changes, given that its structure undergoes substantial changes that lead to the new status. It is possible to identify some factors in a country's development process, such as breaking the

vicious circle of poverty (which is the initial challenge of any development policy), and technological progress.

Therefore, using the human development index to explain the rate of use of motorcycles would take into account the fact that both income and income distribution are closely linked to quality transport services such as individual cars and quality public transportation (subway, train, bus). The results show that the adoption of motorcycles by the population is highly related to the level of development of the country, where factors that stimulate an improvement in the quality of life, both in income and reduction of inequality within the country, can collaborate to reduce the use of this means of transportation. As in Pongthanaisawan et al. (2010), the evidence reinforces the two stages in which the countries' development index affects the rate of motorcycle use, showing that up to a certain level of income the rate of motorcycles increases and then tends to decline after a certain value – i.e. an inflection point is observed.

The article proceeds as follows. Besides this introduction, section 2 presents the research materials and methods of our study. Research results are presented in section 3. The discussion of our results is developed in section 4, and section 5 concludes the work.

2. Methods and research materials

Methods

To test the relationship between the level of development and the rate of motorcycle use in the countries, two geographic data analysis techniques were used in the statistical package of the Stata 15 software. The first, graphical analysis combined with map analysis, made it possible to identify the distribution of variables in space and offered quantitative information in relation to them – that is, from the maps, it sought to understand the relationship between HDI and motorcycle use rate for each country.

However, despite the fact that the language of maps presents relevant information, it only presents a descriptive examination of the data and that does not generally allow the data to provide more robust results, such as forecasts. The language of maps shows the relationship between two or more variables for a given period, though it does not allow us to understand how this relationship varies over time. Temporal variation needs to be included in the analysis, because the relationships within the data set can vary from year to year. Therefore, as a way of complementing the information obtained in the descriptive analyses, the econometric procedure was used, employing three techniques. The first refers to grouped data (Pooled Least Squares – POLS). Then, the panel data were estimated by adding Random Effects (RE) and Fixed Effects (FE). The main objective is to compare the three forms of estimation, verifying which one most adequately estimates the model presented. In general, the idea is to identify the relationship between development and rate of use of motorcycles from the evidence presented by the maps and then to check the robustness of this evidence via econometrics.

Research materials

For the empirical analysis of the relationship between the HDI and the use of motorcycles per thousand inhabitants, annual data from the years 2013, 2015 and 2018 were used. In total, 117 countries from five continents were analysed. The number of motorcycles in each country was collected from the World Health Organization's annual reports on road safety (World Health Organization, 2013; 2015; 2018). For the calculation of the motorcycle utilisation rate, we divided the estimated number of motorcycles in each country by the resident population in each year – the result was multiplied by one thousand. The HDI variable was extracted from the World Bank database; it ranges from zero to one, and the higher the index value, the better the country's quality of life. In general, the variable is a comparative measure that is used to classify countries by their degree of "human development". For its calculation, three dimensions are combined: life expectancy at birth, education and income.

Figure 1 shows the rate of motorcycles per thousand inhabitants in the selected countries in 2018. It can be seen that countries with high rates of mo-

torcycles are found in Asia. In India, for example, motorcycles reach a rate of 116 units per thousand inhabitants. Latin American countries also stand out, such as Uruguay, where the value reaches nearly 300 units per thousand inhabitants. In contrast, countries in Europe and North America show low motorcycle rates. In the United States and the United Kingdom, the vehicle does not exceed the rate of 50 units per 1000 inhabitants. In Australia, the pattern follows the same presented by most developed countries.

About the HDI, Fig. 2 presents the values for the countries in the year 2018. The regions marked in red have higher values, so the more intense the colour, the higher the index of the country. North America, Western Europe and Oceania include the countries with the highest HDI levels. Countries in Latin America mostly present values between 0.7 and 0.8. The continents of Africa and Asia contain a concentration of countries with the lowest values for the index, such as Togo and Afghanistan, with 0.5 and 0.48 points, respectively.

Figure 2 shows that countries with the highest HDI are concentrated in Europe and North America (United States and Canada). The common characteristics of these countries is that they have a high volume of public spending as a proportion of GDP (*several theoretical and empirical works, such as Ram (1986), Cashin (1995) and Ascahuer (1989) understand that public spending can increase human development, by increasing the productivity of the private sector. Infrastructure services (transport, telecommunications and energy) and the formation of a legal and security system, which preserve property rights and national defense, are some examples of activities that serve as inputs for the private sector*) and are very well evaluated when it comes to institutional performance in terms of governance, such as government integrity and judicial efficiency (*for more details on countries' spending as a proportion of GDP, see, https://tradingeconomics.com/country-list/government-spending-to-gdp. For institutional evaluation, see, https://www.heritage.org/index/heatmap*). In carrying out public spending under an efficient institutional apparatus, these countries do not develop what Evans (1995) calls the "Predator State", and therefore, allow the population to receive public transfers fully, in terms of welfare, thereby raising HDI.

When Figs 1 and 2 are compared, we observe an inverse relationship – in some countries – between the rate of motorcycle use and their respective HDI levels. It is worth noting that regions with higher levels of the index are more likely to have a

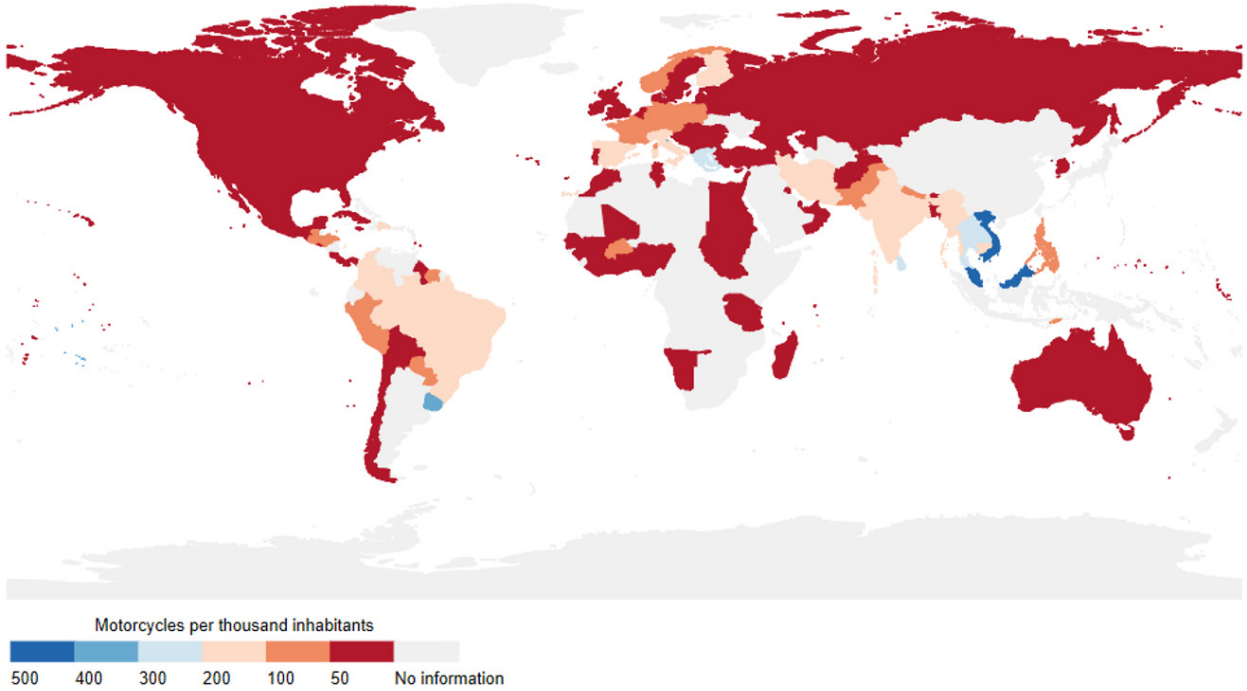

Fig. 1. Motorcycles per thousand inhabitants in selected countries (2018)
Source: Elaborated by the authors based on World Health Organization data

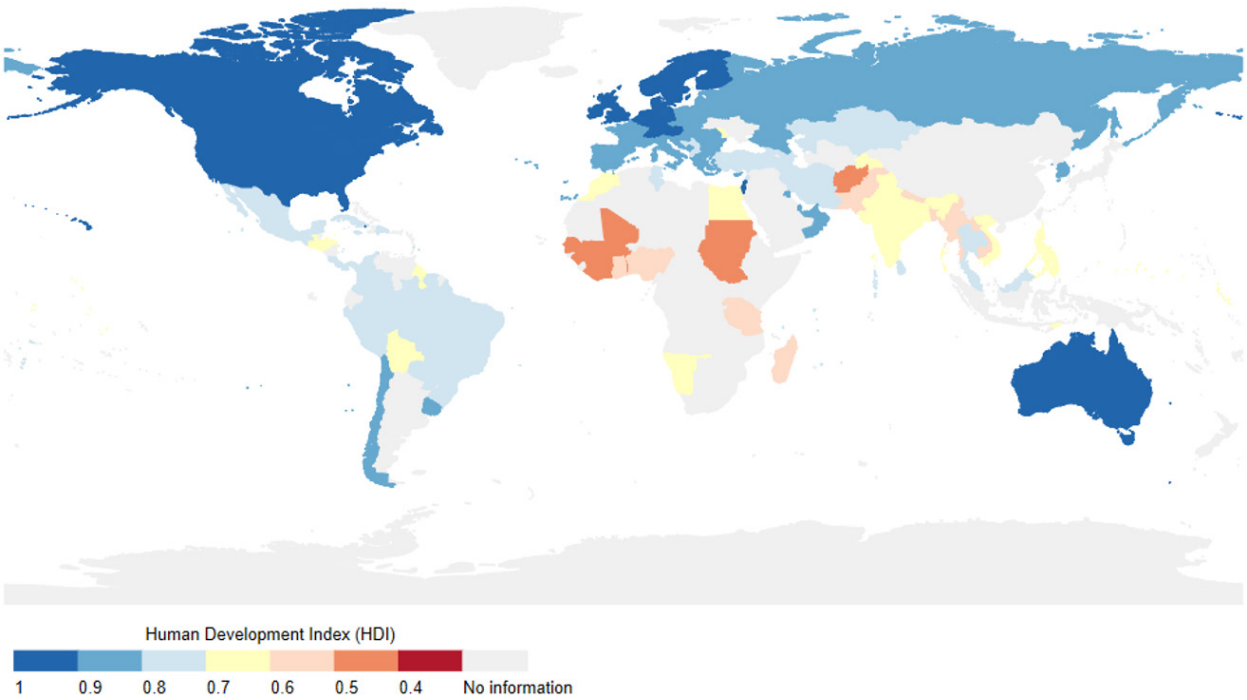

Fig. 2. HDI in selected countries (2018)
Source: Elaborated by the authors based on World Bank data

lower concentration of this type of vehicles, such as the United States and Australia. As the HDI decreases, the rate of motorcycles increases – as can be seen in countries in Asia and Africa and some in Latin America.

To make the inverse relationship between the motorcycle use rate and the HDI shown in Figs 1 and 2 robust, econometric analysis is applied, based on the empirical model represented in equation:

$$lnMot_{it} = \alpha + \beta_1 HDI_{it} + \beta_2 (HID_{it})^2 + \beta_3 X_{it} + \delta_t + \gamma_i + \varepsilon_{it}$$

where i represents a given country and t time.

In equation, the dependent variable denotes the natural logarithm of the motorcycle use rate per thousand inhabitants. describes the human development index level and its squared value. Other variables were selected as controls for influencing motorcycle rates in countries, such as unemployment, number of buses, population density and road infrastructure. They were obtained from data from Human Development Reports (2019) and the World Economic Forum.

The unemployment variable represents the percentage of the total workforce in a country that is not employed in a given year. Countries that have high unemployment rates, in addition to being poorer, possibly have reduced use of automobiles as transport due to the costs of fuel, maintenance and insurance among other things. According to Kuma (2011), in Lagos, Nigeria, commercial motorcycles provide employment for a large number of people, and in Uganda a government programme of using motorcycle taxis has been facilitated as a development tool to fight poverty and unemployment.

The number of buses in each country measures the supply of public transport in the countries, since it influences the demand for motorcycles in regions that have a low supply in the collective transport system (Hagen et al., 2016). Da Silva et al. (2011) and Vasconcellos (2013) showed that in peripheral regions or large communities in which the public system does not meet passenger demand, the adoption of motorcycles as an alternative form of private transport is evident. In empirical terms, Kuma (2011) states that the inability of large buses to meet demand caused the number of motorcycles to increase from 5,000 in 1995 to more than 40,000 in 2007 in the city of Kampala, Uganda.

The population density variable is obtained from the number of inhabitants of a given country divided by its territorial area. In countries with a large concentration of people, the use of motorcycles appears as an alternative to congestion, since they are

smaller, and thus easily manoeuvred between cars (Da Silva et al., 2011). Furthermore, Nishitateno and Burke (2014) find that a country's population density has a major effect on the adoption of motorcycles, where countries with a population density above the median have, on average, 3.5 times more motorcycles per 1000 inhabitants than countries with population densities below the median.

The variable that measures the quality of highways was extracted from the database of the World Economic Forum. Its value comes from a questionnaire prepared by the Executive Opinion Survey, in which interviewees answer questions about the quality of highways, applying scores that vary on a scale between 1 and 7. The closer to the maximum value, the better the quality of the roads in the country. For Mânica (2007) the geometric pattern and the environmental conditions of the roads are not always compatible with the use of two-wheeled vehicles, with many risks inherent to the operation.

The control variables are represented by the vector X_{it} and are in logarithmic format. Additionally, the factors δ_t and γ_i were inserted to capture the fixed effects of each cross-section and the specific and unobserved characteristics of each country, respectively. Finally, ε_{it} represents a random error term.

3. Research results

Table 1 shows the results obtained through the three tests. The first estimate considers only the relationship between the rate of motorcycle use, the HDI and its quadratic form. The other models add independent variables to the estimates separately, so that the fifth model covers the complete specification. The explanatory variables used in the estimates are the percentage of the total unemployed workforce (ln_{unemp}), number of buses (ln_{bus}), population density (ln_{dens}) and quality of roads (ln_{rod}), respectively.

The first step involves assessing the existence of unobserved effects, i.e., characteristics peculiar to the formation of each country that may influence the estimates. Many of these characteristics (heterogeneities) cannot be observed and can vary between units of the cross section. For this reason, the Breuch–Pagan test was performed after the model estimates with random effects. The results indicate that the null hypothesis (that there are no unobserved effects) can be rejected at a significance level of 1%. Therefore, POLS estimations are not enough, since they account for such heterogeneities. In the second step, it was compared whether modelling using random effects has a better fit than that estimated by fixed effects. For this, the Hausman test was used and the estimates rejected the null hypothesis that the random effects are consistent, pointing out that the best selection is the fixed effects (EF) models.

Among the models estimated by fixed effects, model five was chosen for the analysis of the parameters because it takes into account all the control variables presented in the empirical model, thereby allowing for more evidence on the determinants of motorcycle use in countries. The estimates point to the presence of a positive and statistically significant correlation between the rate of motorcycles and human development index for the countries analysed. Regarding its quadratic form, the estimates are also significant, though they point to an inverse relationship. Therefore, the positive HDI value and the negative HDI^2 value suggest that the relationship between the income proxy and the dependent variable follows an inverse U-shape function, indicating that the relationship between the level of human development and motorcycle use can be translated into a Kuznets Curve format. In other words, as human development increases in countries, so too does the number of motorcycles per 1000 inhabitants, but that this relationship has a maximum point, after which, ever higher levels of human development imply a lower number of motorcycles per person. It is also worth mentioning that, regardless of the structure and method to be considered in the estimation, the HDI and HDI^2 signs remain the same, reinforcing the evidence for the Kuznets curve shape.

It is worth highlighting that, although model five was adopted for the analysis of the parameters, the estimates of the models, 1, 2, 3 and 4 by fixed effects suggests that the HDI and motorcycle use rate are related in an inverse U-shape function. These estimations reinforce the results of model five, i.e. that an increase in HDI determines growth in the rate of motorcycle adoption at progressively decreasing rates.

Table 1. Adoption of motorcycles and level of human development

	1			2			3			4			5		
	POLS	**RE**	**FE**	**POLS**	**RE**	**FE**	**POLS**	**RE**	**FE**	**POLS**	**RE**	**FE**	**POLS**	**RE**	**FE**
HID	5.721	21.58***	53.67***	8.250	23.49***	61.22***	8.003	22.00***	63.01***	9.587	20.12**	62.15***	8.212	19.01**	61.51***
	(6.190)	(8.164)	(19.01)	(6.568)	(8.252)	(22.21)	(6.765)	(8.247)	(23.88)	(7.419)	(8.477)	(21.10)	(7.359)	(8.465)	(18.78)
HID^2	-0.959	-11.55*	-38.03**	-2.188	-12.79**	-43.64**	-2.150	-12.12**	-44.37**	-3.396	-10.65*	-42.71***	-2.312	-9.872	-42.22***
	(4.316)	(5.894)	(15.26)	(4.501)	(5.941)	(16.85)	(4.582)	(5.928)	(18.17)	(5.150)	(6.080)	(16.13)	(5.109)	(6.071)	(14.20)
$year_{2015}$			0.201*			0.198*			0.213**			0.198***			0.193***
			(0.103)			(0.109)			(0.0956)			(0.0708)			(0.0655)
$year_{2018}$			0.414**			0.412**			0.378**			0.381**			0.371***
			(0.162)			(0.166)			(0.159)			(0.149)			(0.120)
ln_{unemp}				-0.556***	-0.429***	-0.201	-0.599***	-0.391***	-0.168	-0.599***	-0.361***	-0.124	-0.564***	-0.338***	-0.125
				(0.132)	(0.127)	(0.124)	(0.125)	(0.126)	(0.104)	(0.148)	(0.124)	(0.0951)	(0.151)	(0.125)	(0.0938)
ln_{bus}							0.179***	0.235***	0.283**	0.173***	0.147**	0.0549	0.173***	0.142**	0.0545
							(0.0467)	(0.0544)	(0.142)	(0.0452)	(0.0619)	(0.175)	(0.0455)	(0.0618)	(0.178)
ln_{rod}										0.0764	-0.0255	0.0610	-0.107	-0.0849	0.0656
										(0.400)	(0.401)	(0.289)	(0.393)	(0.401)	(0.303)
ln_{dens}													0.178***	0.206*	0.126
													(0.0608)	(0.124)	(0.900)
Constant	-0.867	-6.581**	-15.57**	-1.043	-6.492**	-17.58**	-2.547	-8.170***	-21.30***	-3.018	-6.735**	-19.40***	-3.203	-7.159**	-19.75***
	(2.133)	(2.754)	(6.023)	(2.264)	(2.775)	(7.386)	(2.315)	(2.798)	(7.331)	(2.690)	(2.925)	(5.678)	(2.637)	(2.925)	(7.161)
Observations	342	342	342	316	316	316	305	305	305	267	267	267	267	267	267
R-squared	0.127		0.173	0.193		0.182	0.253		0.235	0.242		0.217	0.258		0.217
Countries		114	114		111	111		111	111		101	101		101	101
BreuschPagan	254.73			217.65			195.16			159.77			158.17		
Prob> chibar2	0.00			0.00			0.00			0.00			0.00		
Hausman	16.88			16.89			17.83			18.36			18.37		
Prob>chi2	0.00			0.00			0.00			0.00			0.00		

Source: Elaborated by the authors. Estimates using Pooled Least Squares (POLS), Random Effects (RE) and Fixed Effects (FE). Dependent variable: number of motorcycles per 1000 inhabitants. Standard error in parentheses. *** p <0.01, ** p <0.05, * p <0.1

Finally, regarding the control variables, none was statistically significant in model 5 when estimated by fixed effects, although some were significant in at least one of the other estimates. Additionally, only the quality of the highways (ln_{rod}) was not significant in any of the estimated variations. This suggests that socio-economic (unemployment rate), demographic (demographic density) and infrastructure and transport (number of buses and road infrastructure) factors are relevant for determining the rate of motorcycle use in these countries. Regarding time dummies, all were significant at a minimum of 90% confidence, indicating that specific factors in a given year – e.g. natural events, income shocks, among others – are relevant to explain the rate of motorcycle use.

4. Discussion

Estimates show that the adoption of motorcycles by the population is highly related to the level of development in countries, where factors that stimulate an improvement in quality of life (those related to both income and reduced inequality within the country) can collaborate to reduce the use of this means of transportation. In general, these results converge with those presented by Nkede Njie (2012); Karema et al. (2017) and Mbegu and Mjema (2019) indicating a positive relationship between motorcycle use and social well-being. However, this relationship follows a function in the form of an inverse U, similar to the function estimated by Nishitateno et al. (2014) when portraying the relationship between motorcycle use rate and countries' GDP. Thus, the relationship between the level of human development and the use of motorcycles can be represented on a Kuznets curve. As in Pongthanaisawan et al. (2010), our results show two stages in which the countries' development index affects the rate of motorcycle use. The positive HDI estimate suggests that the use of motorcycles is a fundamental factor for the population of less developed countries as it reduces the time spent in traffic, as well as constituting a complementary means of transport to the absent / reduced public transport. However, as the country becomes more developed, the motorcycle is no longer seen as a factor of primary need. This phenomenon can be explained through the improvement in life quality of the population allowing other means of transport to be adopted to replace motorcycles, such as four-wheeled vehicles, which are safer and more comfortable. At the same time, the increase in the quality and quantity of public transport, given that a more developed country is more likely to present a more accessible, efficient and cheap public transport system, can also encourage the population to use public transport at the expense of motorcycles.

5. Conclusions

Although level of income is relevant for understanding the rate of motorcycle use among countries, additional aspects influence the use of the vehicle, such as the level of development of the regions as measured by the levels of inequality, education and life expectancy of the population. In this regard, the adoption of the human development index (HDI) provides a more comprehensive and enlightening view by adding economic and social factors from the countries under analysis. Therefore, to broaden the discussion produced by the literature on the adoption of motorcycles, the present study empirically investigated the correlations between level of human development and motorcycle use.

Estimates indicate that as HDI increases, the rate of motorcycle use also increases. However, after reaching a certain level of development, an inflection point can be spotted, at which the use of the vehicle begins to decrease. This result is reasonable, since countries with a low level of development have few resources to obtain any type of vehicle. However, as countries reach an intermediate level of development, motorcycles start to play an important role in the private mode of transport, since the slight increase in consumers' purchasing power opens space for them to purchase private vehicles. Finally, when the level of development reaches higher stages, consumers change their preference – possibly considering factors such as comfort and safety – replacing motorcycles with cars or other forms of mobility.

Finally, given that other factors that may influence the use of motorcycles by the population were

not addressed by the present study, as a research agenda, a more in-depth analysis is suggested to assess the specific socio-economic characteristics of each country – such as income, education and mobility – that reflect a higher rate of motorcycle use.

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