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Land artificialization, economic growth, and road insecurity: Theoretical improvements and empirical validation for the case of Algeria

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Abstract. This paper applies the Kuznets (1955) curve approach to road traffic crashes in Algeria based on active population, motorization rate, income per capita, and land artificialization. It aims to establish a link between economic development and road safety by estimating the terms of quadratic equations related to the occurrence of traffic collisions. The results reveal that a link between economic development and road safety can be validated by two econometric specifications for the Kuznets curve (KC). Indeed, because economic conditions remained favorable, the Algerian economy reached its inflection point in 2011 and then entered the second phase of the KC. The increase in the level of economic development then in turn led to an improved road-safety situation in terms of lower mortality rates on the roads.

Keywords. economic development; Kuznets curve; road traffic collisions, road injuries

1. Introduction

The artificialization of land initially referred to the loss of agricultural and forest areas due to changes in land use. These days, this concept refers to the overall loss in the amount of agricultural, wooded, and other natural lands due to changes in land use (Da Selva et al., 2020; Sokołowska et al., 2020). In several countries, the artificialization rate is used as one of the wealth indicators that have been developed for monitoring public policies (Madhavan et al., 2001; Phinn et al., 2002; Lu and Weng, 2006; Beasi et al., 2019).

Several recent studies have attempted to better understand the economic and social determinants of land artificialization and its impacts on environmental quality and agriculture, with the aim being to promote interventions that limit its negative effects on society and the environment (European Commission, 2012; Li, 2015). To this end, researchers have developed geographic, economic, and social tools to analyze the effects of land artificialization.

The Kuznets curve (KC) was initially developed to examine the relationship between social development and income (Kuznets, 1955). A few years later, Grossman and Krueger (1995) adapted this concept to develop the environmental Kuznets curve (EKC) with the aim of testing the relationships between atmospheric pollution, development, and the quality of the environment (Newman and Kenworthy, 1988; Stern, 2004; M’raihi et al., 2014). They revealed an inverted-U-shape relationship between environmental degradation and per capita income, indicating that in the early stages of economic growth, pollution and its effects on the environment increase. Once the level of per capita income reaches a certain threshold, however, further economic growth results in more public spending to improve the environmental quality (Stern, 2004; M'raihi et al., 2014; Gill et al., 2018).

Initially, production stimulates economic growth, but it requires the intensive use of natural resources and obsolete production technologies, both of which deteriorate the quality of the environment. However, the quality of the environment can improve later as the growth in the national income allows the use of cleaner technologies and renewable resources (Stern, 2004; M'raihi et al., 2014).

In a recent study, Madani et al. (2020) identified and quantified several dysfunctions that characterized road traffic collisions in Algeria during the 2010–2017 period by describing the road-safety situation through various indicators, such as the ratio of traffic collisions or damage and levels of road use, to help public decision-makers in establishing suitable policies. Bougueroua and Carnis (2016), meanwhile, estimated the impact of economic conditions and mobility on traffic collisions in Algeria and showed that the number of traffic collisions is positively influenced by the GDP per capita in both the short and long term. Several other authors have also demonstrated a link between economic development and road safety in the long term (Garcia-Ferrer et al., 2007; Harizi, 2008; Gaudry and Himouri, 2013; Harizi et al., 2016). However, while road accidents are socially structured from a sociological viewpoint, their socioeconomic effects are still understudied in terms of the other social problems they cause (Matthewman, 2012). This relationship builds on developments for the KC that have established a relationship between the level of economic development and social inequalities. The KC approach has also been applied to evaluate the quality of the environment, thus linking the level of economic development with pollution (Grossman and Krueger, 1995). In addition, the EKC suggests that during the early stages of economic development, agents pay little attention to the environment, but when income levels improve beyond a certain threshold, called the turning point, concern for the environment increases (Bergel-Hayat et al., 2013; Brüde and Elvik, 2015). Economic growth is then accompanied by improvements in environmental conditions, particularly a reduction in pollution. Thus, an inverted-U-shaped relationship is observed.

Since land artificialization is an explanatory variable for economic growth and development, and because this phenomenon relates to urban renewal policies and their objectives in the social mix (Baumont and Guillain, 2016), there is possibly a relationship between land artificialization and other variables linked to the development of infrastructure networks, such as a safe road network. On the other hand, if the increase in the level of economic development leads to improvements in road safety, in terms of the number of fatalities, it is theoretically possible that from a certain turning point, an increase in land artificialization will lead to a drop in the number of traffic collisions and therefore the number of fatalities, so road safety is improved regardless of interventions made by the authorities (Bergel-Hayat et al., 2013).

Consequently, this paper focuses on the relationship between economic development and road safety in Algeria by applying the KC with the integration of two key variables: income per capita and land artificialization per capita.

The remainder of this paper is structured as follows: First, we examine the theoretical background for the use of KC in studies related to environmental conditions and development, the land artificialization process, and road safety. We then introduce our empirical study by presenting our proposed model, the study context, and data sources. Next, we present our methodology, data analysis, and results. We then discuss these results by detailing all the key findings and the theoretical and practical implications of this work, as well as describing its limitations and making some suggestions for further research. Finally, we conclude this paper.

2. Theoretical background

2.1. Kuznets Curve and environmental externalities

The dynamics of the EKC result from the simultaneous action of three structural effects (i.e., scale, composition, and technological) on the production of pollutants (M'raihi et al., 2014). In this sense, several empirical studies have applied the EKC in an urban context to understand the relationships between the economic externalities of production and environmental degradation (Newman and Kenworthy, 1988; M'raihi et al. 2014; Fujii et al., 2018; Mosconi et al., 2020). In this context, several consequences of urban sprawl are not considered. While certain variables represent development indicators (e.g., growth in motorization, the building of road networks, accessibility, mobility), others represent the negative effects of increased transport, such as noise pollution and road crashes (Matthewman, 2012; M'raihi et al., 2014; Harizi et al., 2016).

In urban areas, several determinants for the quantity of pollutants resulting from personal transportation have been considered in empirical studies, such as modal choice (e.g., a preference for private vehicles over public transport), travel distances, speeds, and the state of the vehicle fleet (e.g., average age, maintenance, and the technical characteristics of vehicles, such as engine size and fuel type). However, urban sprawl and land artificialization necessitate the building of new road infrastructure to access these new areas. What is more, despite the benefits of transport networks, they also generate negative effects, such as noise pollution and traffic collisions.

The effects of income on pollution can be observed on several levels. At the behavioral level, the increase in per capita income has a direct influence on vehicle ownership and consequently urban mobility. Generally, the growth in income per capita largely explains the urban-motorization rate but not necessarily the urban travel rate, because the cost of using individual cars results in an arbitration between individual and collective movements, causing road insecurity. An increase in per capita income therefore exerts an indirect effect on mobility, especially when individuals have access to several alternatives other than owning a car. In the same context, higher incomes provide access to cleaner vehicles based on newer technologies. At this level, the price effect exerted by the high prices for these vehicles may outweigh the income effect. At the political level, an increase in income may encourage governments to provide public subsidies in order to encourage a modal shift, investment in cleaner technologies, and the purchase of cleaner vehicles. They may also seek to build safer transport networks.

2.2. Land artificialization process on road safety

Researchers consider land artificialization as a phenomenon where land use changes over time from agricultural or natural use to urban environments and artificial green spaces, such as parks and golf courses. The interest in collecting such information ranges from quantifying the effects of urban sprawl to calibrating forecast models for the artificialization of land (Mulder et al., 2016). Consequently, the measured land segments or lots are associated with several spatial scales that focus on several elements, ranging from individual buildings to city blocks and on to neighborhoods, districts, agglomerations, and even suburbs (Zeng et al., 2015). This variety of scales leads to different levels of granularity, ranging from fine details to generalizations for a set of these segments, such as lots, neighborhoods, and so on (Kaspersen et al., 2015; Dijkstra et al., 2020).

In Algeria, like in several other countries, artificialized land is often used for built-up areas with coated or stabilized soil, such as roads, railways, car parks, and paths (Bendjelid, 2004; Hebbar et al., 2020), as well as for several other artificial purposes, such as for mines, quarries, landfills, construction sites, vacant lots, and artificial green spaces like urban parks and leisure facilities (Bousmaha and Boulkaibet, 2019). Artificialization corresponds to a change in use, one that is not necessarily irreversible, but the process generally works to the detriment of agricultural activities (Bendjelid, 2004; Bousmaha and Boulkaibet, 2019; Hebbar et al., 2020).

The approaches to identify urbanization and the land-artificialization process therefore take various forms depending on the scale of the observation and the desired information. However, the measuring process appears to be limited in fitting time sequences to the real rates of expansion, because in reality they correspond to the dates of information collection (Li, 2015; Banzhaf et al., 2009; Aguejdad and Hubert-Moy, 2016).

Urban fringes may be included depending on the adopted definition and the approaches developed. These may correspond to the collection of municipalities included within the urban areas or transitional areas that are more associated with the sub-urbanization process, because the establishment of residences, services, and commercial businesses outside the urban boundary often transforms the landscape in inconsistent ways. These may be partly rural areas, but many residents and workers will not have originated from those areas (Banzhaf et al., 2009; Li, 2015; Aguejdad and Hubert-Moy, 2016).

Urban planners and economists have widely considered land artificialization as both a cause and result of development (Cerema, 2014). The effects of land artificialization are enormous, because this phenomenon generates exogenous capital for investment that specifically targets medium or small urban centers by favoring the establishment of activities that cause urbanization. However, the phenomenon of exogenous urbanization has direct implications for converted land, such as in terms of biodiversity, infrastructure density, noise pollution caused by increased motorization, and the loss of agricultural land. In addition, this phenomenon increases the demand for housing, leading to peri-urban issues such as the fight against a diffuse and discontinuous urban sprawl, the need to distinguish individual housing, and the use of collective housing in the housing-production process. Finally, the land is effectively transformed into a housing service (Fujita and Mori, 1997; Baumont and Guillain, 2016). This land-use transformation requires in-depth studies of the new social organizations in the city, especially when households have different socioeconomic characteristics in terms of income level, social class, nationality, culture, race, and so on (Baumont and Guillain, 2016). The architecture of social interactions within, and between, each social group determines the possible urban balances, particularly in terms of segregation or socioeconomic diversity (Galster, 2007; Baumont and Guillain, 2016). In addition, rural depopulation also presents a social problem with several implications for the sustainability of socioeconomic development (Xingan, 2015).

Economic models have proven the relationship between economic growth and development and urban sprawl. Out of necessity, urban sprawl is needed to meet the needs of businesses and households for their economic and social activities, so they can continue to contribute to the process of economic growth and social development. At a specific level of development, social conditions, and quality of life, economic growth starts to show positive spillover effects for development in the form of improved transport infrastructure quality, which likely in turn improves road safety.

2. Empirical study

Several studies have shown that economic development is a determining factor in explaining the level of road safety in a country (Joksch, 1984; Wagenaar, 1984; Kopits and Cropper, 2005; Iwata, 2010; Law et al., 2011). However, no study has yet verified whether land artificialization leads to more road injuries or not, as well as whether there is a turning point at which land artificialization starts to improve the level of road safety. We therefore seek to establish if there is a theoretical relationship between the level of income per capita, land artificialization per capita, and the number of fatalities in an evolving region. Thus, we propose the following quadratic equations to reflect the relation of the KC:

$$TD_t = \alpha_0 + \alpha_1 GDPC_t + \alpha_2 GDPC_t^2 + \alpha_3 AP_t + \alpha_4 MR_t + \mu_t \quad \textbf{(1)}$$

$$TD_t = \alpha_0 + \alpha_1 ALPC_t + \alpha_2 ALPC_t^2 + \alpha_3 AP_t + \alpha_4 MR_t + \mu_t \quad \textbf{(2)}$$

Where *GDP* represents the income per capita, *TD* is the total number of fatalities due to road crashes, *AP* designates the active population, *MOTOR* is the motorization rate, and *LAPCT* is the rate of land artificialization. In addition, the α_i series represents the parameters to be estimated, while μ_t is the error term for the model.

From the perspective of the *KC*, we seek to test two relationships: (*i*) the relationship between the number of fatalities and economic development and (*ii*) the relationship between the number of fatalities and land artificialization. To this end, we are interested in the respective variations of $\delta(TD)/\delta(GDPPC)$ and $\delta(TD)/\delta(ALPC)$, where α_1 must take a positive sign and α_2 a negative sign in each case. In other words, the second derivative of *TD* with respect to *GDPC*, as well as *TD* with respect to *ALPC*, must be negative. In each case, however, the second derivative must be equal to $2\alpha_2$, so their respective expressions will be:

$$\delta(TD)/\delta(GDPPC) = \alpha_1 + 2\alpha_2 GDPC \quad \textbf{(3)}$$

$$\delta(TD)/\delta(ALPC) = \alpha_1 + 2\alpha_2 LAPC \quad \textbf{(4)}$$

At the inflection point of each curve, the number of fatalities will peak, so we will obtain:

$$\alpha_1 + 2\alpha_2 GDPC = 0 \quad \textbf{(5)}$$

$$\alpha_1 + 2\alpha_2 ALPC = 0 \quad \textbf{(6)}$$

At this inflection point, the income level and the land artificialization level will therefore be, respectively:

$$GDPC = (-\alpha_1/2\alpha_2) \quad \textbf{(7)}$$

$$ALPC = (-\alpha_1/2\alpha_2) \quad \textbf{(8)}$$

As *GDPC* and *ALPC* will take positive values, the two parameters α_1 and α_2 must take opposite signs in both cases. In addition, to verify that this really is a peak, the second derivative must be negative.

3.1. Study context

Algeria has a land area of 2,381,741 km², with it hosting 43,820,839 inhabitants in 2020. This population is growing at an average annual rate of 1.9%. The country recorded a total of 3,049 fatalities and 30,121 injuries as of result of 18,379 traffic collisions up to October 2020 (CNPSR, 2020). Improvements in living standards and an increase in the motorization rate have contributed to increases in the movement of people and the flow of goods. Despite this, there has been an average decrease of about 12.88% in the number of road crashes since 2015, with the exact number varying from one city to another. For example, Oran in the northwest of the

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country is considered the third most important city in Algeria. It is characterized by significant commercial activity and dynamic demographic and economic factors. Its road network comprises 186 km of national roads and 580 local roads (**Figure 1**). This port city is a relay point for several other Algerian regions due to its access to the Mediterranean and the number of major roads connecting with the city, but it has long faced problems due to its geography and its road network. From a topographical viewpoint, Oran has a bay to the north, and directly to the west, there is the mountain known as *Aïdour* or *Murdjajo*, with a height of 580 meters and the plateau of *Moulay Abd al Qadir al-Jilani*. The agglomeration extends on both sides of the *Wadi Rhi* ravine. The city has experienced significant urban sprawl due to an increase in land artificialization (**Figure 2**).

3.2. Data sources

Data for road crashes in Algeria came from several sources, such as Bougueroua and Carnis (2016), CNPSR (2020), Hebbar et al. (2020), and Madani et al. (2020). Data for GDP and population came from the World Bank (2020). The variables relating to the active population and motorization were calculated from data from the National Statistics Office (NOS), with the motorization rate being calculated as follows:

$$(CN/POP) \times 1000 \quad \textbf{(9)}$$

Where, CN is the number of cars and POP is the population size.

Figure 1 - Location of the study area

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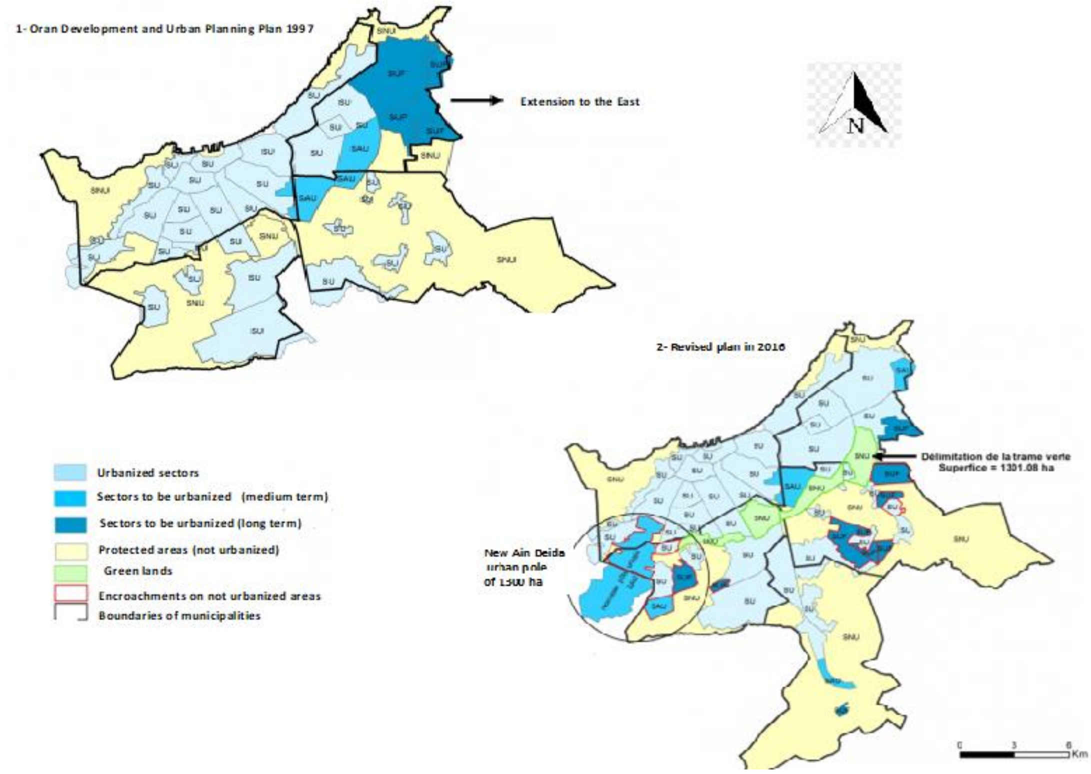

Figure 2 - Evolution of the four urbanization sectors defined by the Travel and Urban Development Plan of Oran

4. Methodology

Eq. 1 was estimated over a 49-year period from 1970 to 2019, while Eq. 2 was estimated using semi-annual data for a 30-year period from 1989 to 2019. However, we also used several data sources for the Oran agglomeration based on previous results of remote-sensing studies applied to a series of satellite images (Bendjelid, 2004; Bousmaha and Boulkaibet, 2019). Oran is the second-largest city in Algeria, and it has seen a sustained rate of urbanization in recent decades (**Figure 1**) due to the massive need to build housing and other buildings on the outskirts of the city (Messahel, 2010; Maachou and Otmane, 2016; Missoumi et al., 2019; National Cadastre Agency [NCA], 2020).

To check whether the specified models meet the requirements for the KC, we needed to estimate the econometric specifications (1) and (2) and ensure that in each case the parameter α_1 has a positive sign and α_2 has a negative sign. Second, to choose the model that best explained the studied phenomenon, we compared the two models. However, the comparison revealed that the two models had the same number of explanatory variables based on a comparison of their Adjusted R-squared values and the use of Akaike information criterion (AIC), the Schwarz criterion (SC), and the Bayesian information criterion (BIC).

5. Data analysis and results

Table 1 gives the estimation results for the two econometric specification models (1) and (2). Model 2 explains more than 88% of the variation in the number of fatalities in Algeria (Adjusted R-squared = 0.88336), while model 1 explains 80% of this variation (Adjusted R-squared = 0.80139). All the coefficients of equations (1) and (2) are significant because the calculated Student *t* value for each variable is greater than the critical value for the 5% significance level, while the F-statistics probability also indicates that the models are globally

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significant. The error uncorrelation hypothesis is also verified by the Durbin Watson (DW) test (DW_model 1 = 1.8612; DW_model 2 = 1.9273≈2). Finally, as shown in **Figures 3 and 4**, both models are robust.

Consistent with the hypothesis supported by the KC, the α_1 terms of both models are positive, while the α_2 terms of both models are negative. As expected, an inverted-U-shape relationship exists (*i*) between the number of fatalities and income per capita and (*ii*) between the number of fatalities and land artificialization per capita. The presence of a Kuznets curve is therefore verified by the two models.

Finally, although both models are significant, model 2 has more explanatory power than model 1. Indeed, model 2 has a higher Adjusted R-squared value, and it minimizes the AIC and SC criteria (**Table 1**). Therefore, the variable we introduced for the first time (land artificialization) is more convincing than income per capita for justifying the presence of a KC related to development and road safety.

Table 1. Estimation results for models (1) and (2)

Model (1)				Model (2)			
Variable	Coef.	Stand. Error	t-Statistic	Variable	Coef.	Stand. Error	t-Statistic
C	-6132.18	2051.71	-4.88	C	-7017.62	1962.12	-4.09
GDP	4.99***	1.31	4.41	LAPC	5.81***	1.21	4.01
GDP2	-0.002***	0.0001	-4.11	LAPC2	-0.003***	0.0002	-4.79
POPACT	27.12**	10.81	2.34	POPACT	26.76**	10.81	2.34
MOTOR	103.55***	24.34	4.12	MOTOR	129.85***	29.73	4.94
R-squared	0.8112				0.863177		
Adjusted R-squared	0.80139				0.88336		
F-statistic	80.4111				82.4111		
Prob(F-statistic)	0.0001				0.0002		
Mean Dependent var	30702.4				30702.4		
S.D. dependent var	847.20				12420.43		
Durbin-Watson stat	1.8612				1.9273		
Akaike info criterion	-1.20978				-1.90087		
Schwarz criterion	-1.13809				-1.3371		
Bayesian information criterion	-1.11192				-1.3109		

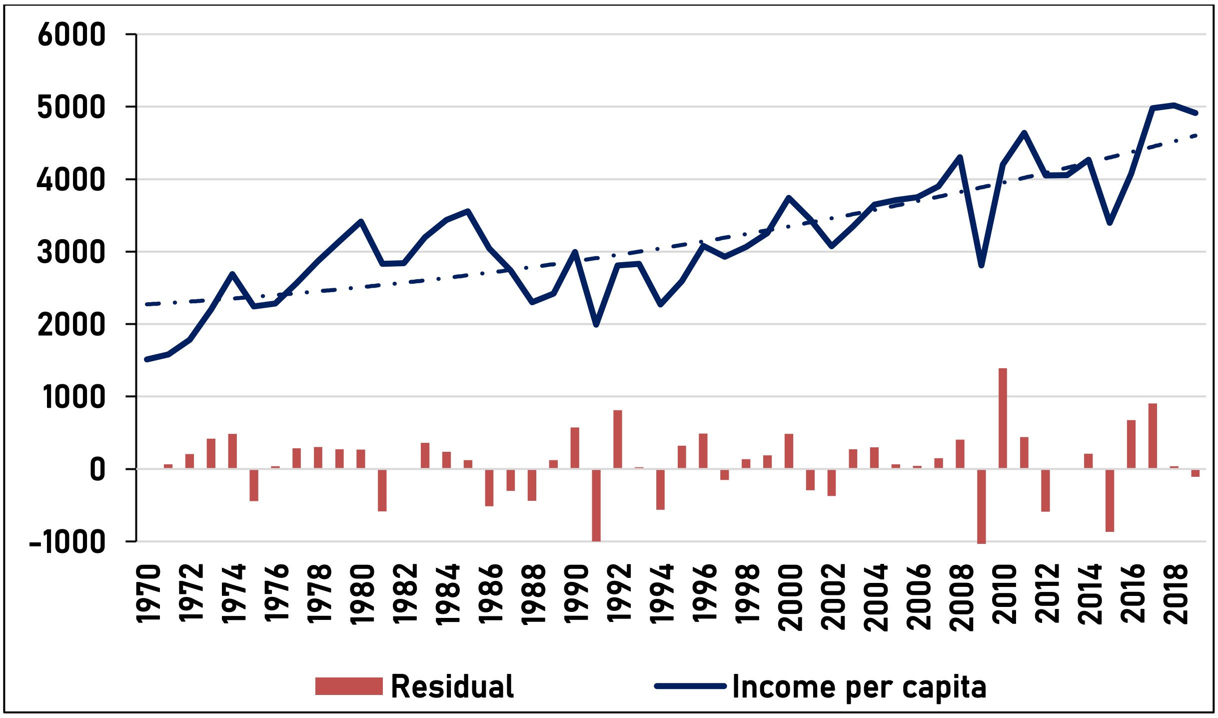

Figure 3 - Residuals and predictive power of model (1)

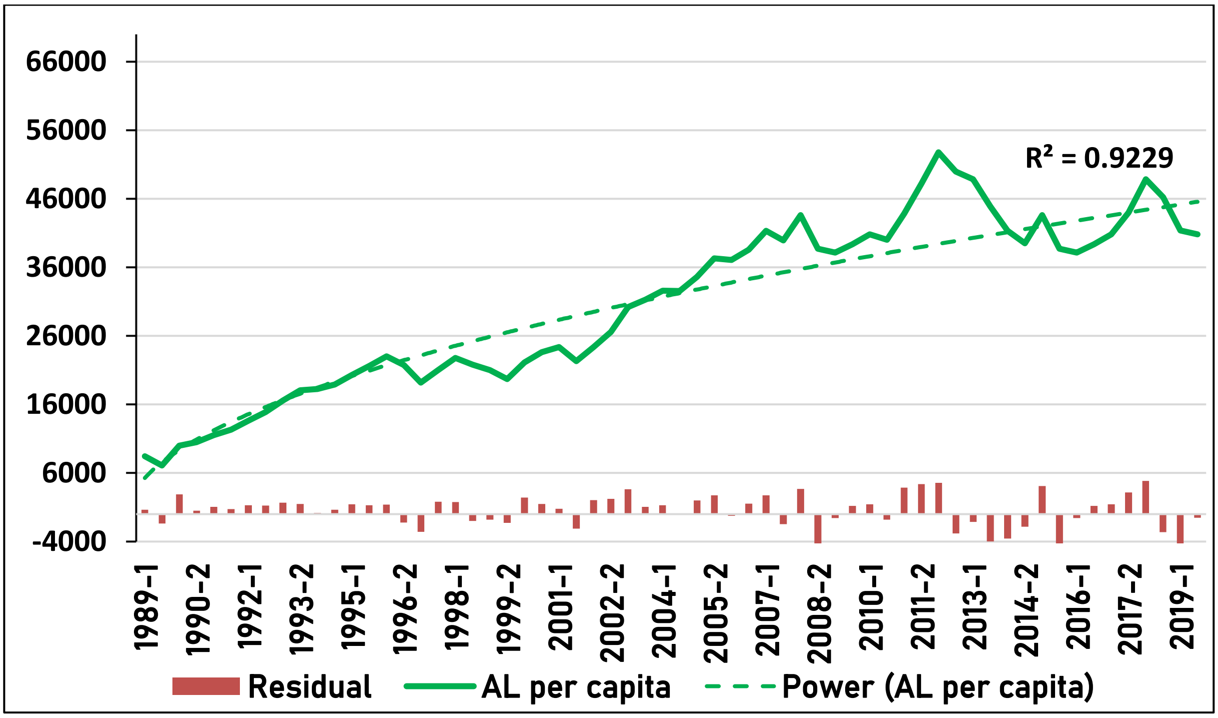

Figure 4 - Residuals and predictive power of model (2)

5. Discussion

5.1. Key findings

In 2015, the GDP per capita grew by 2.1%, which was significantly higher than in previous years. Thus, with economic conditions remaining favorable, the inflection point is estimated by our model at $3,399 USD (constant for 2010), and this has already been reached according to the latest available estimates for income per capita. Indeed, Algeria is in the second phase of the Kuznets curve, so an increase in economic development should lead to improvements in road safety in terms of a lower mortality rate on the roads. Economic development should therefore help improve road safety, independent of any additional interventions taken by the authorities.

In 2011, the land artificialization per capita recorded a growth rate that was markedly higher than in previous years. This is important from a public decision-making viewpoint. Urban sprawl occurs to meet the demands of households and businesses, so the economic conditions for land use change and investment in new plots of land remain favorable. The inflection point estimated by our model was 43,863 square meters per capita, and this had been already reached in 2011. Furthermore, Oran is in the second phase of the Kuznets curve, so an increase in the level of land artificialization will lead to improvements in the road safety situation in terms of lower mortality on the roads due to better quality road infrastructure thanks to the economic benefits of development.

5.2. Theoretical implications

We present three theoretical implications for these results: First, like in several previous studies, economic development determines the level of road safety in a country (Joksch, 1984; Wagenaar, 1984; Kopits and Cropper, 2005; Iwata, 2010; Law et al., 2011), and this is a long-term relationship (Garcia-Ferrer et al., 2007; Harizi, 2008; Gaudry and Himouri, 2013; Harizi et al., 2016; Hebbar et al., 2020). This relationship is based on a KC that links GDP with the number of fatalities on the roads (Gaudry and Himouri, 2013; Bougueroua and Carnis 2016; Madani et al., 2020). We confirmed these findings by including a new variable that has been rarely considered in the economic and social literature. We therefore showed that using land artificialization could confirm the link between development and road safety and that this long-term relationship takes the form of a KC. Furthermore, to the best of our knowledge, this is the first study that has investigated how alternative variables like land artificialization can help explain the relationship between development and transport externalities through the Kuznets curve.

Second, by using this variable, this study better explains the phenomenon and complements the results of several previous studies that have applied the KC to environmental factors (Newman and Kenworthy, 1988; M'raihi and al. 2014; Fujii et al., 2018; Mosconi et al., 2020) in order to confirm a turning point for the impact of development on the environment (Bergel-Hayat et al., 2013). Indeed, land is artificialized in response to economic needs, such as the need for more housing and locations for industrial activities. In the mature phase, the vision of public authorities embraces other considerations, and this subsequently translates into improvements in the quality of transport infrastructure.

Third, our research extends the existing research for urban planning and geographic economics (Baumont and Guillain, 2016) that has introduced special factors into economic reasoning by showing that land artificialization can be used as a proxy for economic growth and development. Indeed, urban sprawl is a process that responds to urban expansion policies and induces social diversity. This work also joins previous studies that have stipulated that land is transformed to provide several services, such as housing, when cities require expansion (Fujita and Mori, 1997; Baumont and Guillain, 2016). In addition, urban expansion generates new social organizations within a city due to the varying socioeconomic characteristics of the population demanding a new framework for social interactions within new social groups, thus ensuring a sustainable quality of life and a balanced urban environment in terms of socioeconomic diversity (Galster, 2007; Xingan, 2015; Baumont and Guillain, 2016). In these circumstances, the quality of new infrastructure plays a role in the midst of these transformations.

Whatever ambiguities are involved in the concept of urban sprawl and land artificialization, new artificialized lands are the result of development and a location for human activities. With larger spaces for cities, housing, economic activities, and exchange networks improve, which tends to lead to improvements in the level of road safety.

5.3. Practical implications

Artificialized land has become a major issue for public debate and political concerns because it leads to an overall decrease in the proportion of land available for agricultural and forestry activities, as well as for natural spaces, so areas other than agriculture should be taken into account (European Commission, 2012; Li, 2015; Madani et al., 2020). Indeed, several researchers consider land artificialization to be one of the main factors reducing biodiversity (Hooper et al., 2005; Allison and Martiny, 2008). However, it also responds to the need for housing and locations for business and other social, cultural, and sporting activities (Fujita and Mori, 1997; Baumont and Guillain, 2016).

The artificialization of land is often approached from the perspective of cities, but transport networks also play a role that should not be neglected when studying the process. Indeed, their effects are clearly direct, because transport infrastructure needs to permanently occupy the converted land. Public authorities must therefore rationalize the process by taking into account the accessibility of areas and the mobility of people and goods while maintaining sustainable road safety on transport networks.

5.4. Limitations and future research

The literature reveals existing uncertainties about the measurement of spatial change, regardless of the model used (Verburg et al., 2013; Houet et al., 2015). In this work, we calculated urban sprawl by omitting certain uncertainties linked to calculating land artificialization, particularly those linked to the quality of the measurement of change and classification or associated pre-treatments. Modelling the artificialization of land raises issues such as multi-scale modelling and taking into account a more detailed nomenclature in order to be able to refine any evaluation of its impact on bio-geochemical processes. However, our investigation paves the way for this, and we encourage future research to explore more land-related variables that may be useful when studying the size of cities and its relationship with road safety.

Transport networks also have an indirect effect on the artificialization of land, because they contribute to the creation of new activity zones, thus supporting the urban-expansion process. This interdependent relationship between transport networks and land artificialization has been the subject of many studies without really addressing the consumption of space head-on. We may therefore wonder about the way in which land artificialization is understood in terms of transport infrastructure projects and how it impacts the evolution of land use in terms of deforestation and the loss of agricultural lands.

6. Conclusions

We have examined the relationship between two variables, namely the level of economic development and land artificialization, and road safety in Algeria through a Kuznets curve. We showed that an inverted-U-shaped relationship exists between development and the number of fatalities. During the initial phase of economic growth, development tends to degrade road safety. Algeria has currently passed its inflection points for the level of economic development and land artificialization, and this should help reverse the trend in the increasing number of road fatalities.

In previous work, researchers showed that the inflection point of the Kuznets curve for France and Italy was observed before 1973, while for Portugal, Spain, and Greece, the peak was observed in 1986, 1989, and 1996, respectively (Bergel-Hayat et al., 2013). It therefore seems that Algeria has had about a 15-year delay in arriving at this turning point.

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