



COMPARISON OF MATHEMATICAL MODELS OF REGRESSION ANALYSIS ON YOUTH CRIME AND DELINQUENCY

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ABSTRACT: This paper presents a comparative analysis of regression models applied to juvenile crime and minors' delinquency in the Slovak Republic. The aim of the research is to identify the most appropriate mathematical model for predicting the future development of juvenile crime and minors' delinquency, based on official statistical data from the Ministry of the Interior of the Slovak Republic for the period 2010–2024. The research analyses linear, exponential, logarithmic, polynomial, and power regression models, and evaluates their reliability using the coefficient of determination (R^2). The results show that the logarithmic model is the most suitable for the state and rate of minors' delinquency ($R^2 = 0.8526$; $R^2 = 0.8819$), while the polynomial model ($R^2 = 0.981$; $R^2 = 0.968$) proved to be the most reliable for the state and rate of juvenile crime. An analysis of demographic trends and the crime index reveal a downward trend in both groups, with the prediction models indicating a continuation of this trend. The research provides important information for the development of preventive strategies and policies aimed at reducing youth crime. The research also highlights the fact that, although crime and delinquency show a declining tendency, schools are increasingly facing the emergence of violent socio-pathological phenomena. The findings of this study can serve as a starting dataset for future research on direct criminogenic factors.

KEYWORDS: *Criminology. Crime analysis. Statistical Research. Minors. Juveniles.*

INTRODUCTION

Youth crime and delinquency represent one of the most significant socio-pathological phenomena of contemporary society, which requires systematic scientific research and effective preventive measures. In the context of the Slovak Republic, similarly to other European countries, it is possible to observe changing trends in youth crime, which require precise analysis and prediction of future development (Lantz, 2024), (Vaško, 2023). Regression analysis can be used as a basic tool for such research tasks. The use of statistical methods in criminology allows not only to analyse the current state, but also to create reliable prediction models that can serve as a basis for the creation of preventive strategies (Lacey, 2016), (Malik, 2015).

The specificity of youth crime lies in its different characteristics compared to adult crime. According to multiple research the most fundamental difference lies in the neurobiological development of the brain – significant endogenous criminogenic factor. Juvenile offenders aged 14-18 have an underdeveloped prefrontal cortex that matures approximately at the age of 25. This area of the brain is responsible for planning, self-control, impulse regulation, and assessing the consequences of actions. The immaturity of the prefrontal cortex explains why youth is significantly more impulsive, less able to control their emotions, and weaker at anticipating the long-term consequences of their actions (Steinberg, 2009; Icenogle, 2019). When it comes to exogenic criminogenic factors, youth can be more susceptible to peer pressure, fear of missing out and parent-child's relationships, when compared to adults (Gašpierik, 2010). Minors (persons under 14 years of age) and juveniles (persons aged 14-18 years) represent special categories that require a differentiated approach to crime analysis (Criminal code of the Slovak Republic, 2025). Research on crime in these age groups is particularly important in terms of early identification of risk factors and implementation of effective preventive measures (Olaoye, 2024), (Gašpierik, 2010).

The research uses official statistical data from the Ministry of the Interior of the Slovak Republic (2025) and the Statistical Office of the Slovak Republic (2025) for the period 2010-2024, which allows for a comprehensive longitudinal analysis. Demographic trends in the population of minors and juveniles in the monitored period show different characteristics - while the population of minors recorded an increase until 2022 with a subsequent decrease, the population of juveniles shows a gradual decrease throughout the monitored period.

The aim of this study is to compare the effectiveness (i.e., the ability to accurately describe historical data and provide reliable predictions) of different mathematical regression analysis models in predicting the development of crime and delinquency, evaluated through the coefficient of determination R^2 . Specifically, the analysis of linear, exponential, logarithmic, polynomial, and power models can be used to identify the most reliable approach based on the coefficient of determination R^2 (Hendl, 2004). The results of this comparative analysis can contribute to improving the methodology of youth crime and delinquency prediction and provide valuable information for law enforcement agencies and public policy makers. This research offers the review and comparison of different regression models which can be utilized. The contribution of this study is to provide professional and scientific public with demonstration of this method that can be also utilized for specific types of crime with combination of factors directly impacting the occurrence of socio-pathological phenomena.

1. CRIME ANALYSIS

Crime is a phenomenon that changes and develops over time. Crime statistics processed by the Ministry of the Interior of the Slovak Republic can be used as data sets for crime analysis. Crime analysis allows to create overviews of the development of registered crime over the monitored period. This information can be used for creation of crime prevention strategies. Criminology is a discipline that studies crime based on statistics, known perpetrators, victims. Criminology also studies possible prevention options, suitable response when crime emerges and consequences that can be the result of crime. The crime analysis is the study of quantitative and qualitative variables that can be clearly identified. Crime analysis studies:

- crime state,
- crime rate,
- structure,
- dynamics,
- clearance rate of crime (Gašpierik, 2010), (Dzurčanin, 2003).

For the purposes of this work, the state, rate and dynamics of crime will be further examined. The crime state is a quantitative indicator expressing the number of registered crimes in a certain territory at a certain time. It is expressed in absolute numbers. The crime state does not take into account the size of the population, which makes it an indicator with low informative value. The crime rate can be considered a more accurate quantitative indicator. This indicator takes into account the size of the population. As a generally accepted rule, it indicates the number of crimes per 100,000 inhabitants. It is calculated as the ratio of the number of registered crimes to the number of inhabitants and then multiplied by 100,000. The level of crime is expressed by the crime index I_k , and is calculated as (Dianiška, 2022), (Gašpierik, 2010):

$$I_k = \frac{\text{State of crime}}{\text{Population}} \cdot 100\,000$$

Where: I_k – Index of Crime.

The dynamics of the crime expresses changes in the state, rate or crime structure in a certain period. It is possible to distinguish the tendency of crime development as (Dianiška, 2022), (Gašpierik, 2010):

- growing development tendency (ascending),
- declining development tendency (descending),
- stagnant development tendency (steady).

Based on the above information, it can be stated that through statistical data processed by the Ministry of the Interior of the Slovak Republic, it is possible to study selected quantitative crime indicators. Using the regression analysis, it is possible to predict the future development of the number of crimes (crime state and crime rate) committed in the territory of the Slovak Republic. For the purposes of this paper, the possible future development according to the regression function of crime rate of juveniles and minors born in the Slovak Republic will be examined.

Minor is a person (child) who is younger than 14 years of age. A person (also a child) aged 14 to 18 years is a juvenile. This description is based on the Criminal Code of the Slovak Republic. There is also a term youth, which is often used in the context of crime and delinquency. Youth can be described as “young adults”, people who are under the age of 26 years. It is a specific group of people who are preparing to become a productive asset to the whole society and contribute to its development (Národný inštitút vzdelávania a mládeže, 2005).

According to the Statistical Office of the Slovak Republic it is possible to observe an increase in population of minors from year 2010 to 2022 (from 770732 to 817966 minors). The increase of population stopped in 2022, and since the 2022 a decrease of population can be observed up to the year 2024 with 803662 minors. Development of population of juveniles is a bit different. The development is steady – over the observed period from 2010 to 2022 it is possible to observe a slow decrease of population from 266014 to 219761 juveniles. This data is later used to calculate the crime rate. The development of population of minors and juveniles is shown in figure 1 and figure 2.

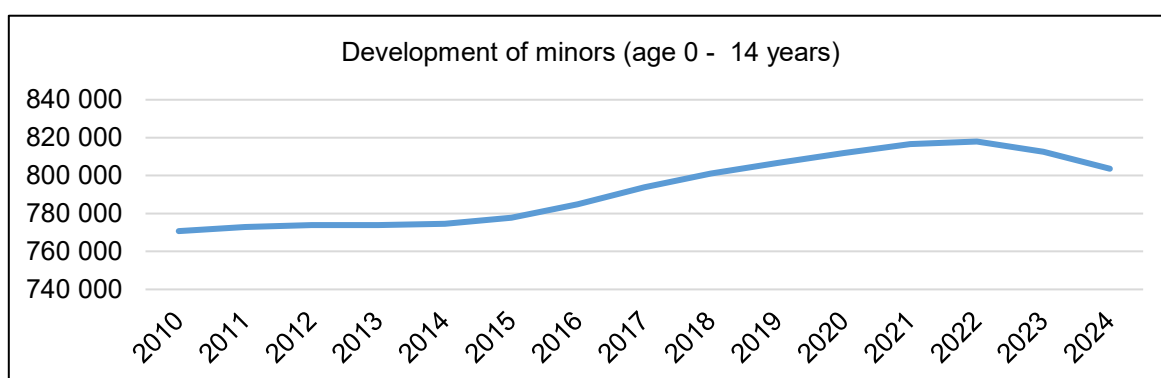


Figure 1 Development of minors (Statistical Office of the Slovak Republic)

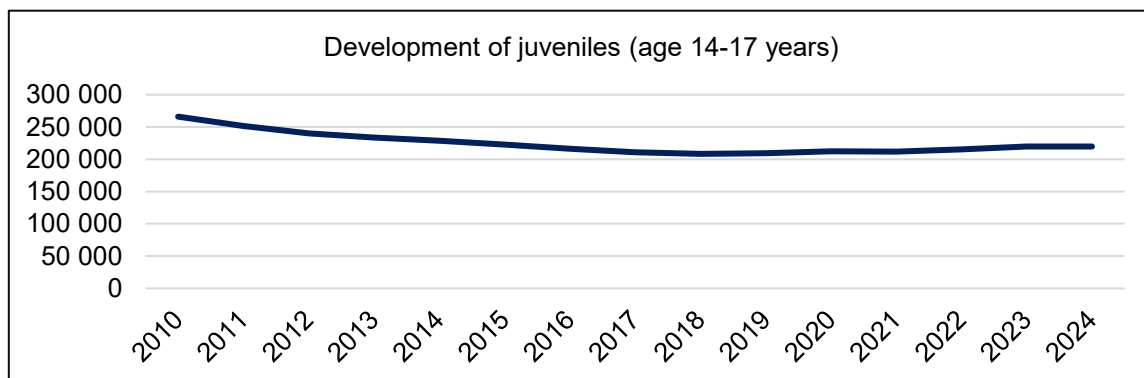


Figure 2 Development of juveniles (Statistical Office of the Slovak Republic)

According to this information it is possible to investigate possible future development of crime state and crime rate which can be used to determine possible need of new preventive measures.

2. METHODS

Within the framework of the analysis, data published by the Ministry of the Interior of the Slovak Republic and the Statistical Office of the Slovak Republic are processed. Based on the data, overviews of the crime state and rate from 2010 to 2024 are processed in the MS Excel program. Data on the number of

minors and juveniles in the territory of the Slovak Republic for the monitored time period are also processed.

The crime rate is calculated according to the formula given in Introduction (the population is considered only as population of minors or juveniles). A graph of the crime situation and crime rate for the monitored period is then created using MS Excel. Trend lines reflecting various mathematical models are gradually inserted in the above graphs. Trend lines for linear, exponential, logarithmic, polynomial and power models are processed. Mathematical models of equations are also generated by MS Excel for individual trend lines, to which the determination coefficient R^2 is subsequently assigned, defining the reliability of the model. A prediction of the future development of the status and level of juvenile and minor crime is then created for the most reliable model.

3. RESULTS

Official statistical data provided by Ministry of Interior of the Slovak Republic and Statistical Office of the Slovak Republic have been processed. In the table 1 it is possible to observe development of crime of juveniles and delinquency of minors and calculated crime rate for selected year.

Table 1 Development of minors and their crimes

Year	Minors			Juveniles			
	Number of Crimes	Number of Minors	Index of Crime Rate	Year	Number of Crimes	Number of Juveniles	Index of Crime Rate
2010	1105	770 732	143,37	2010	4282	266 014	1609,69
2011	1112	772 971	143,86	2011	4216	251 669	1675,22
2012	845	773 912	109,19	2012	3669	240 322	1526,70
2013	783	773 992	101,16	2013	3615	233 648	1547,20
2014	726	774 550	93,73	2014	3264	228 722	1427,06
2015	694	777 828	89,22	2015	2764	222 798	1240,59
2016	678	784 965	86,37	2016	2448	216 225	1132,15
2017	687	793 756	86,55	2017	2404	211 047	1139,08
2018	694	801 103	86,63	2018	2349	208 368	1127,33
2019	656	806 711	81,32	2019	2232	209 257	1066,63
2020	576	811 855	70,95	2020	1968	212 220	927,34
2021	696	816 652	85,23	2021	1735	212 079	818,09
2022	592	817 966	72,37	2022	1826	215 265	848,26
2023	393	812 652	48,36	2023	1741	219 748	792,27
2024	378	803 662	47,035	2024	1443	219 761	656,62

Presented data of crime state and crime rate can be graphically shown in figure 3 (for minors) and figure 4 (for juveniles).

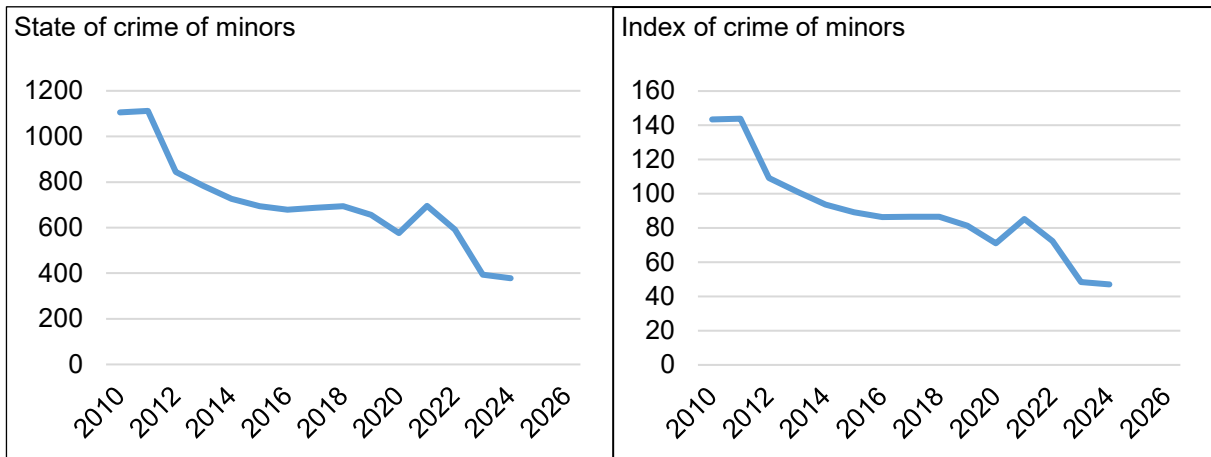


Figure 3 State and index of crime of minors

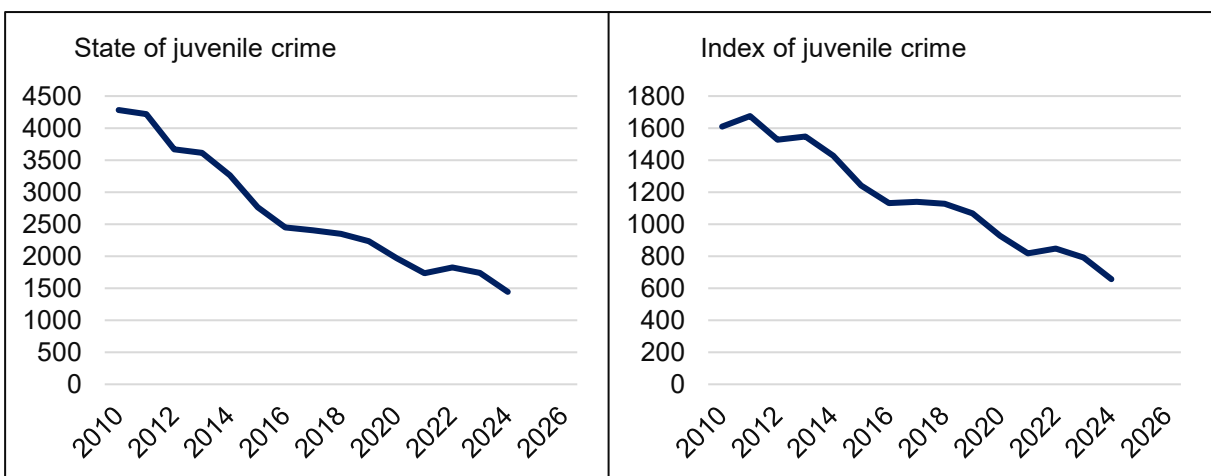


Figure 4 State and index of juvenile crime

For the presented graphical representation of analysed data, it is possible to analyse possible regression functions. The regression functions are presented in figure 5 (for minors) and figure 6 (for juveniles).

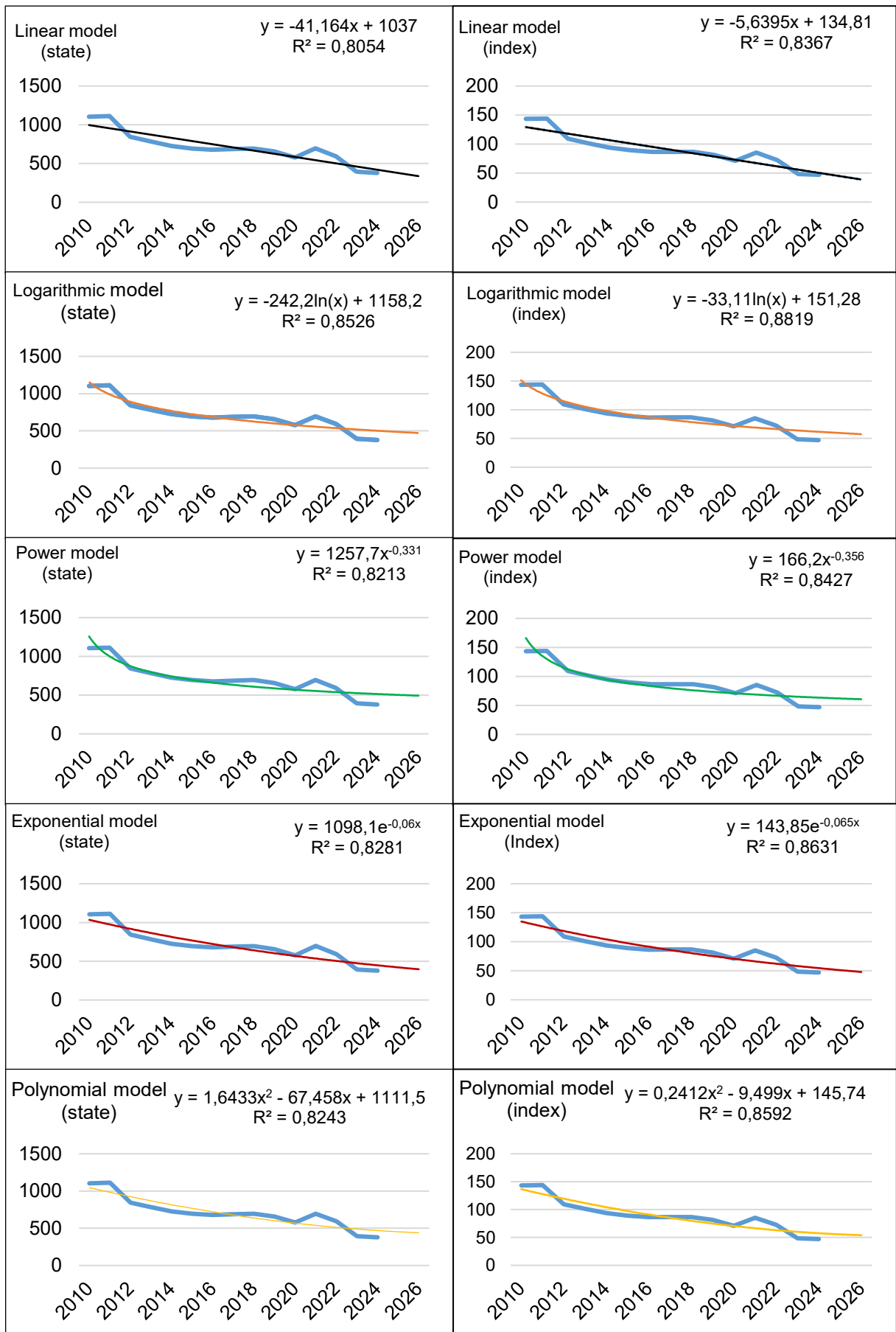


Figure 5 Examined regression models of crime state and rate of minors

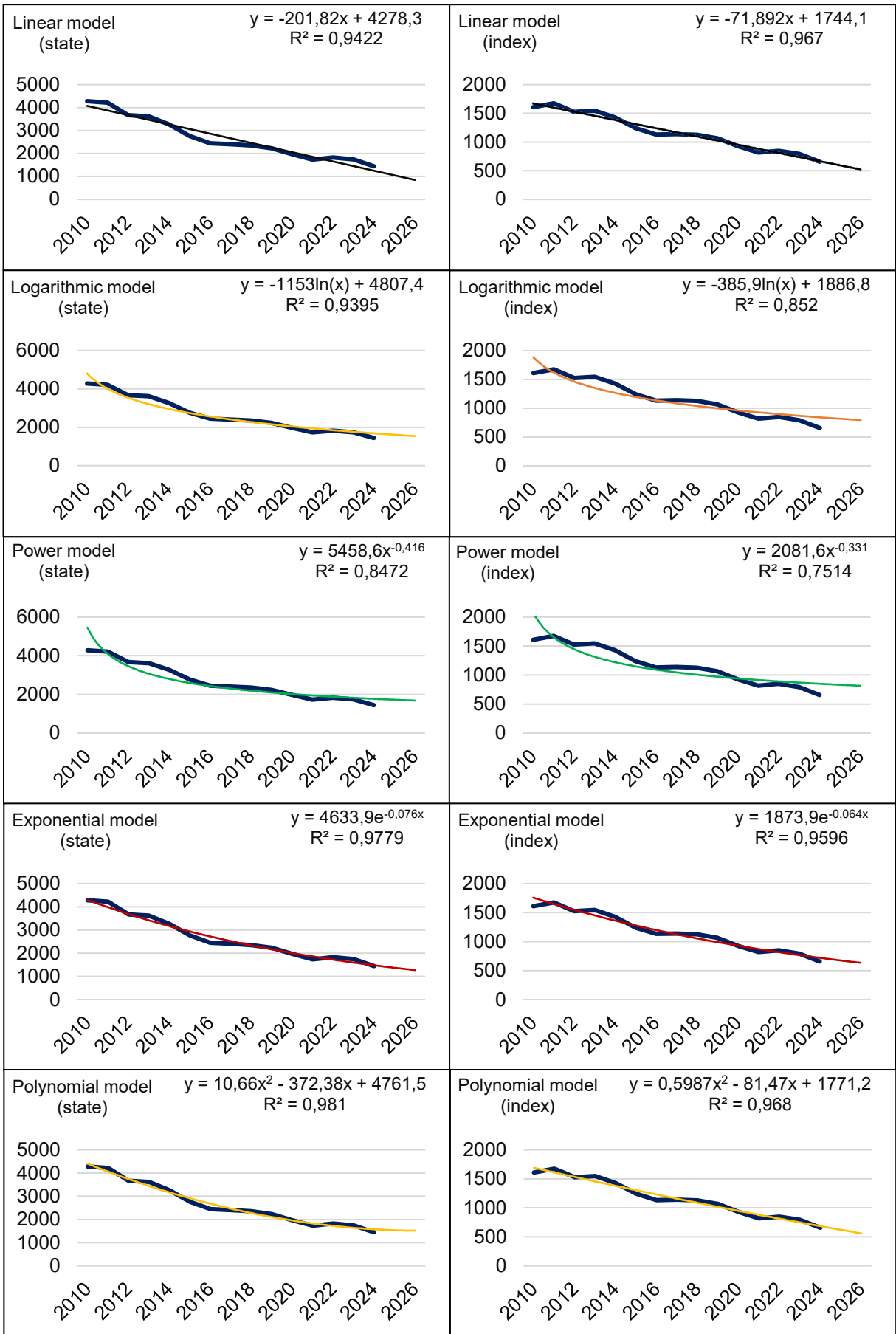


Figure 6 Examined regression models of crime state and rate of juveniles

4. CONCLUSION AND DISCUSSION

The real state and level cannot be clearly predicted, as several factors can directly influence the development of crime and delinquency. These factors can include external factors - those that objectively affect minors and juveniles and can influence their criminality (leisure activity options, financial situation of the environment, employment in the region, quality of education, etc.). The second group is internal factors (child upbringing, parental behaviour, peer behaviour, peer pressure, individual psychology and development, genetic predispositions, etc.) (Gašperik, 2010), (Dianiška, 2022).

In general, it can be stated, that the total crime state and the crime rate of juveniles are significantly higher than those of minors. Based on the analysis performed, it can be stated that in all cases the tendency of the future development of minor delinquency and juvenile crime appears to have a declining trend.

Interestingly, the linear regression model demonstrates strong coefficients of determination both for state and index of crime, particularly for juveniles ($R^2 = 0.81-0.84$ for minors and $0.94-0.97$ for juveniles as shown in Figure 6). This raises a critical methodological question regarding model selection criteria. While R^2 values are exceptionally high, the linear model possesses a fundamental logical limitation: it mathematically allows for negative crime values at future time points, which is conceptually impossible (a negative number of crimes or negative crime rate has no meaningful interpretation). From a practical standpoint, the logarithmic model for minors and polynomial model for juveniles better respect the logical constraints of the problem domain. However, it is acknowledged that for short-term predictions (1-3 years) the linear model could serve as a pragmatic tool for practitioners seeking simplicity over mathematical rigor, particularly for juveniles where the linear model maintains superior R^2 values.

The one reason, why the linear model is particularly high is not clear from the performed analysis. There might be multiple reasons, such as growing standard of living, low unemployment rate of adults/parents, changes in legislation or it can be an indication, that a continuous investment in prevention programs is effective crime prevention measure.

Based on the highest determination coefficient R^2 , it is possible to select and consider the models presented in Table 3 as the most accurate for the state and level of criminality (delinquency).

Table 2 Mathematical models of regression functions according to the highest coefficient of determination

Delinquency of Minors	
Crime state	Crime rate
Logarithmic model	Logarithmic model
$y = -242,2 \ln(x) + 1158,2$	$y = -33,11 \ln(x) + 151,28$
$R^2=0,8526$	$R^2=0,8819$
Crime of Juvenile	
Crime state	Crime rate
Polynomial model	Polynomial model
$y = 10,66x^2 - 372,38x + 4761,5$	$y = 0,5987x^2 - 81,47x + 1771,2$
$R^2 = 0,981$	$R^2 = 0,968$

Based on the above findings, it is possible to assume a stable decrease in the development of the state and level of crime and delinquency. From the selected mathematical functions, it is possible to predict the development of the state and level of crime and delinquency for the coming years. The values calculated based on the mathematical functions (from table 3) can be seen in Table 4.

Table 3 Prediction according to the mathematical model

Delinquency of Minors			
Crime state prediction		Crime rate prediction	
Year	State	Year	Crime Index
2025	502	2025	61,62
2026	486	2026	59,48
2027	471	2027	57,47
Crime of Juvenile			
Crime state prediction		Crime rate prediction	
Year	State	Year	Crime Index
2025	1574	2025	683,86
2026	1532	2026	620,95
2027	1511	2027	559,23

It can be stated that the mathematical functions describing the models represent a gradual downward trend in the state and level of juvenile crime and minor's delinquency. However, these models cannot be taken as binding. They represent only an informative prediction that can serve as a basis for crime prevention subjects in creating prevention programs. These findings also represent a possible basis for future research when specific factors influencing socio-pathological behaviour will be examined.

It is also important to point out, that even though the crime and delinquency have declining tendency, the schools are having issues with emergence of violent socio-pathological phenomena, such as radicalization or violent extremism. This fact can be the result of high latency of crime, or lack of coherent situational awareness of school management that does not report antisocial behaviour (possible law violations) to the police authorities possibly leading to tragical violent incidents in the future. Based on the above information, it is necessary to examine those factors that have an impact on the criminality and delinquency, identify them as criminogenic factors and act on them with appropriate preventive measures.

The practical significance of this research extends to law enforcement agencies, educational institutions and school administration, policy makers and academic research. Law enforcement agencies can utilize these prediction models to allocate resources efficiently and design preventive measures and intervention strategies. Specifically, the identified declining trends in both minors and juveniles' delinquency provide evidence-based justification for continued investment in prevention programs, while the distinction between age groups allows for age-tailored prevention strategies. School administrators and educators can use these forecasts to anticipate resource needs for socio-pathological prevention. Policy makers require reliable data for evidence-based decision-making regarding legislative changes and preventive policies. The research also serves as a foundational dataset for future interdisciplinary studies examining the direct criminogenic factors (socioeconomic, neurobiological, or environmental) that drive crime dynamics.

The comparative analysis of regression models contributes methodologically to criminology by demonstrating that logarithmic models (for minors) and polynomial models (for juveniles) provide superior logical validity compared to linear approaches for this problem domain, which has implications for crime prediction methodology in other research contexts.

5. LIMITATIONS OF THIS RESEARCH

Table 4 represents the practical output of this research. The predictions indicate a continuous decline in both juvenile crime and minors' delinquency through 2027. However, the accuracy of these forecasts can only be validated through subsequent empirical observation. These predictions should be interpreted as baseline scenarios representing the continuation of current trends under stable socioeconomic and legislative conditions. Table 4 projections can serve as a reference point for

detecting anomalies. If actual values significantly diverge from predictions, this will indicate a significant change in criminogenic factors.

A critical limitation of the current models pertains to their assumption of stable legislative and institutional contexts. The regression models presented are based on historical crime statistics from 2010-2024, a period with specific legal definitions. Recent and anticipated legislative changes in the Slovak Republic may significantly alter the predictive accuracy of these models. Changes in the legislation might reflect in next 1-2 years – especially changes in the misdemeanour amendment (small thefts). These changes in legislation will be studied separately in next research.

The crime statistics that were used to process the regression analysis. These open-source data may represent imperfections and depend on the accuracy of reporting by state administration entities. Information on the possible recidivism of offenders or information on the age and gender of minors and juveniles was also not considered.

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REFERENCES

- Criminal Code of the Slovak Republic 300/2005 Z. z.
- Dianiška, G., Strémy, T., Vrablová, M., (2022). *Kriminológia*. 4. Edition. Plzeň, Aleš Čeněk.
- Dzurčanin, Š. (2003) *Kriminológia pre bezpečnostný manažment*. Žilina, EDIS.
- Gašpírik, L. (2010). *Prevenia criminality a inej protispoločenskej činnosti*. Multiprint Košice.
- Hendl, J., (2004). *Přehled statistických metod spracování dat*. Praha: Portál, ISBN 80-7178-820-1
- Icenogle, G., Steinberg, L., Duell, N., Chein, J., Chang, L., Chaudhary, N., Di Giunta, L., Dodge, K. A., Fanti, K. A., Lansford, J. E., Oburu, P., Pastorelli, C., Skinner, A. T., Sorbring, E., Tapanya, S., Uribe Tirado, L. M., Alampay, L. P., Al-Hassan, S. M., Takash, H. M. S., & Bacchini, D. (2019). Adolescents' cognitive capacity reaches adult levels prior to their psychosocial maturity: Evidence for a “maturity gap” in a multinational, cross-sectional sample. *Law and Human Behavior*, 43(1), 69–85. <https://doi.org/10.1037/lhb0000315>
- Lantz, B., & Knapp, K. G. (2024). *Trends in juvenile offending: What you need to know*. Council on Criminal Justice. Retrieved from <https://counciloncj.org/trends-in-juvenile-offending-what-you-need-to-know/>
- Lacey, A. A. (2016). A mathematical model of serious and minor criminal activity. *Applied Mathematics Research*, 12(3), 123-145.
- Malik, T., Ali, S. A., Rasheed, A., & Siddiqui, A. A. (2015). Assessment of statistical approaches to model low count data: An empirical application to youth delinquency. *International Journal of Statistics in Medical Research*, 4(3), 282-286.
- Ministry of the Interior of the Slovak Republic (2025). Crime statistics. Retrieved from: <https://www.minv.sk/?statistika-kriminality-v-slovenskej-republike-xml>
- Národný inštitút vzdelávania a mládeže (2005). Review of Youth Policy – Slovak National Report. Retrieved from: <https://www.minedu.sk/data/att/d61/2289.869f85.pdf>
- Olaoye, F., Egon, A. (2024) Predictive policing and crime prevention. *Crime & Delinquency*. Retrieved from https://www.researchgate.net/publication/383565286_Predictive_Policing_and_Crime_Prevention
- Statistical Office of the Slovak Republic (2025). Demographic statistics. Retrieved from? <https://datacube.statistics.sk/#!/folder/sk/1001471>
- Steinberg, L., Cauffman, E., Woolard, J., Graham, S., & Banich, M. (2009). Are adolescents less mature than adults?: Minors' access to abortion, the juvenile death penalty, and the alleged APA “flip-flop.” *American Psychologist*, 64(7), 583–594. <https://doi.org/10.1037/a0014763>
- Vaško, A., Klátik, J., (2023) Criminal Law Protection of a Child by means of Slovak Criminal Law and European Union Law, *Access to Justice in Eastern Europe*, 3(20), 120-131. <https://doi.org/10.33327/AJEE-18-6.3-a000301>

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