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DROPOUT INTENTION IN MATHEMATICS: AN APPLICATION OF CUMULATIVE LINK MIXED ODELS IN A UNIVERSITY CONTEXT

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ABSTRACT

University dropout is a global, complex, and multifactorial phenomenon that encompasses academic, social, economic, and institutional dimensions. This study analyzes the factors influencing the intention to drop out among students enrolled in the Bachelor's programs in Mathematics and Mathematics Teaching at the University of Panama, within the framework of its institutional conditions. A robust statistical approach is employed through Cumulative Link Mixed Models, which are suitable for ordinal variables and capable of incorporating random effects. The results reveal that economic dependence and native origin are significantly associated with higher levels of dropout intention, whereas variables such as gender, availability of financial resources, and family environment show no significant effects. The model thresholds indicate a cumulative progression in dropout probability. The random component explains a limited proportion of the variability (ICC ≈ 2.4%), suggesting that group differences are minor compared to individual effects. Furthermore, differentiated patterns are identified in the perception of factors according to socioeconomic conditions, highlighting self-sufficient native students as a vulnerable group. These findings provide empirical evidence to inform targeted institutional strategies for improving student retention.

KEYWORDS: University Dropout, Higher Education, Social Factors, Socioeconomic and Cultural Conditions, Student, Student Retention.

1. INTRODUCTION

University dropout has been widely studied since the mid-20th century (Bean and Metzner, 1985; Spady, 1971; Tinto, 1975). However, it remains a subject of debate due to the lack of consensus both in its definition and in the factors that explain it. In general terms, it is understood as the voluntary or involuntary withdrawal from an academic program prior to obtaining a degree (Himmel, 2002). Beyond conceptual discussions, dropout generates significant impacts at different levels: on students, by affecting their self-esteem, quality of life, and social mobility; on higher education institutions, by negatively influencing their retention and academic efficiency indicators; and on governments, by causing economic losses derived from investments in students who do not complete their studies (González-Campos et al., 2020; Sandoval-Palis et al., 2020).

University dropout is a global and persistent phenomenon, whose impact is particularly intense in certain regions of the world, especially in Latin America. In this region, more than 50% of higher education students do not complete their academic programs (Ferreyra et al., 2017), while in Panama dropout rates are estimated to range between 10% and 40%, among the highest in the region (Aguirre et al., 2023; Brunner et al., 2024). Various studies have identified associated factors that span individual, academic, economic, social, and institutional dimensions (Casanova et al., 2023; Gallego et al., 2021; Heredia and Carcausto-Calla, 2024; Melo et al., 2022; Ortiz-Lozano et al., 2020). These factors should be considered when designing preventive measures, strengthening educational policies, and promoting the development of social programs aimed at reducing dropout in Latin American universities (Heredia et al., 2024).

Studies conducted in Panama and other countries in the region consistently point out that economic factors and the lack of vocational guidance are among the most recurrent determinants. Concrete examples illustrate this situation: for instance, Torres (2015) reported a dropout rate of 46% in the Financial Administration and International Business program at the University of Panama, attributing the main causes to economic constraints and the absence of vocational support. Similarly, in Chile, Smulders Chaparro (2018) found that dropout in Business Engineering was explained by psychological factors in 55% of the cases, while economic aspects accounted for 40%. In Colombia, Chalela-Naffah et al. (2020) reported that 84.5% of students considered family support essential for their persistence, although 68% stated they did not feel identified with the university environment. These findings highlight that dropout responds to multiple interrelated factors, which vary depending on institutional and national contexts.

In this sense, dropout should be understood as a multifactorial phenomenon, shaped by motivation, prior academic weaknesses, teaching methodology, institutional perception, economic and social circumstances, and the student's capacity to adapt to the university environment. At the University of Panama, the low enrolment in the Mathematics program—only 58 students in 2019, of whom an estimated 12% dropped out—raises questions about the effectiveness of retention strategies and the need for empirical evidence to inform academic and institutional policy decisions.

Within this institutional framework, it is relevant to review the origin and development of the Bachelor's Degree in Mathematics Teaching at the University of Panama, created as part of an institutional process initiated in 1994, aimed at developing specialized programs to train educators in Biology, Chemistry, and Mathematics for lower and upper secondary education. After multiple meetings and curricular revisions, the study plans were approved in August 2001, and the program was formally launched in 2002 (Vejerano and Trujillo-González, 2019). This academic achievement, however, brought new challenges: the need to keep curricula up to date and, especially, to address the persistent problem of student dropout, a phenomenon that directly affects the efficiency of the Panamanian educational system and the training of professionals in strategic areas such as Mathematics.

Based on this institutional context, the present study focuses on analyzing the factors that influence dropout intention among students in the Mathematics and Mathematics Teaching programs at the University of Panama. To this end, a robust statistical approach is applied through Cumulative Link Mixed Models (CLMM), a technique that allows modeling ordinal response variables and incorporating random effects, providing a comprehensive understanding of how individual, academic, economic, and institutional conditions affect the probability of student dropout.

Since cumulative link models and other related approaches have been scarcely applied in the study of university dropout, their use could provide new insights into the factors influencing students' intention to withdraw.

2. MATERIAL AND METHODS

2.1. Data Description

The data were obtained through the administration of an instrument specifically designed to identify and analyze the factors influencing dropout intention in the Mathematics Bachelor's programs at the University of Panama. The instrument, structured into ten thematic blocks, integrates theoretical and empirical dimensions previously validated in studies on university dropout, covering demographic, academic, economic, institutional, social integration, and self-directed learning aspects (Bean and Metzner, 1985; Donoso and Schiefelbein, 2007; Spady, 1971; Tinto, 1975, 1989). Additionally, methodological references such as the College Persistence Questionnaire (CPQ) (Davidson et al., 2009), CADES (Díaz and Tejedor De León, 2017) and the EUDIQ (Bernardo et al., 2022), were incorporated, instruments that have proven effective in evaluating factors associated with student retention and dropout in university contexts.

The questionnaire was administered during 2025 to active students at the School of Mathematics, affiliated with the Faculty of Natural, Exact, and Technological Sciences at the University of Panama. The selection of this population is based on three main criteria. First, it is a strategic academic group for national scientific training, whose dropout represents a critical challenge for the continuity of professionals in the field of Mathematics. Second, the Mathematics programs have historically recorded high dropout rates, making this context particularly relevant for analysis. Third, a validated instrument was available, assessed by expert judgment and supported by appropriate Aiken's V indices (Lynn, 1986; Penfield and Giacobbi, 2004) ensuring the methodological quality and relevance of the data collected.

The results of the content validation analysis, conducted by three experts for each of the questionnaire criteria, are presented in Table 1.

Table 1: Expert Validation Using Aiken's V.

Expert judges	Sufficiency		Coherence		Relevance		Clarity	
	V	95% CI	V	95% CI	V	IC9% CI	V	95% CI
1	0.73	0.70-0.75	0.74	0.72-0.76	0.73	0.70-0.75	0.69	0.66-0.72
2	0.67	0.64-0.70	0.67	0.64-0.70	0.67	0.64-0.70	0.68	0.65-0.71
3	0.75	0.73-0.77	0.75	0.73-0.77	0.70	0.67-0.73	0.72	0.69-0.71

Table 1 shows that all items are sufficient, coherent, relevant, and clear, both at the sample level ($V \geq 0.67$) and at the population level (lower limit of the 95% confidence interval ≥ 0.64).

During data processing, questionnaires with incomplete or inconsistent responses were removed, resulting in a cleaned and reliable dataset for statistical analysis. In this final dataset, consisting of 99 students, the general distribution patterns were preserved, ensuring that no bias was introduced in the estimation of the influential factors.

The response variable, called *Effect Level*, was measured on an ordinal scale with categories ranging from *None* to *High*.

In this study, the variables were grouped into the conceptual blocks mentioned above, representing factors associated with dropout intention in the Mathematics Bachelor's programs at the University of Panama.

To ensure the objectivity of the statistical analysis, highly subjective variables were excluded, favoring observable and measurable factors. Specifically, the model included students' individual profiles (demographic data and prior academic performance), economic factors, current circumstances, course interest, institutional perceptions, social and academic integration, and self-directed learning. These blocks allowed for the analysis of both structural and motivational conditions influencing the decision to persist in or withdraw from studies.

2.2. Methodology

This study employed the Cumulative Link Mixed Model (CLMM), an extension of the Cumulative Link Model (CLM) proposed by Agresti (2002). In the specialized literature, the CLM is also referred to as the **Ordered Logit Model (OL)** or the Proportional Odds Model (PPO) (Greene and Hensher, 2010).

The main advantage of using a CLMM lies in its ability to incorporate **random effects** to model heterogeneities among groups. In this study, it is assumed that students with similar characteristics—such as the same sex, age, or academic conditions—tend to exhibit similar behaviors regarding their dropout intention. This allows for capturing **intraclass correlation** and improving the estimation of individual effects. The general CLMM model is defined as follows:

$$P(Y_i \leq j) = y_{ij} = F\left(\theta_j - x_i^T \beta\right) \text{ con } i = \overline{1,n} \;\; j = \overline{1,J}$$

where the intercept parameters

$$-\infty \equiv \theta_0 \leq \theta_1 \leq \cdots \leq \theta_{J-1} \leq \theta_J \equiv \infty$$

are ordered, F is called the inverse link function, and x_i^T is a p-dimensional vector of regression variables for the parameters β. The linear model x_i^T is assumed to be the same across all response categories, as it does not depend on j.

A typical choice of link function is the probit $F^{-1} = \Phi^{-1}$, where Φ is the standard normal cumulative distribution function (Agresti, 2002; Christensen et al., 2011). The CLMM was estimated using the R package **ordinal** (Christensen, 2019; R Core Team, 2022).

3. RESULTS AND DATA ANALYSIS

3.1. Descriptive Analysis

Of the 99 students surveyed, 30.0% were enrolled in the Bachelor's in Mathematics Teaching and 70.0% in the Bachelor's in Mathematics. Regarding gender, 46.0% were female and 54.0% male. Age distribution indicated that 26.3% were under 20, 40.4% between 20 and 24, 10.1% between 25 and 29, 9.0% between 30 and 34, 8.1% between 35 and 39, and 6.1% were 40 or older. Most students were single (78.8%), while 12.1% were married, 8.1% in a domestic partnership, and 1.0% divorced.

Regarding residence, 61.6% lived with their parents, 16.2% with a spouse or partner, 14.1% with other relatives, 5.1% alone, 2.0% with friends, and 1.0% in student housing. Most students (78.8%) had no children, while 9.1% had one, 7.1% two, and 4.0% three or more.

In terms of economic factors, 58.6% depended financially on their parents, 32.3% on themselves, 5.1% on a spouse or partner, and 4.0% on other relatives. A total of 65.7% reported sufficient resources for living expenses, while 34.3% did not. Only 15.2% received scholarships or grants, 5.1% loans, and 79.8% had no support. Monthly income was below $500 for 60.6% of students, $500–1,000 for 25.3%, $1,000–1,500 for 7.1%, and over $1,500 for another 7.1%.

Regarding prior academic factors, 79.8% entered with a high school diploma, 16.2% with a university degree, and 4.0% with technical or other qualifications. Most students came from public schools (79.8%), and 90.9% had not interrupted their secondary education before university. Time elapsed between high school graduation and university entry was less than one year for 42.4%, one year for 13.1%, two years for 9.1%, three years for 5.1%, and more than three years for 30.3%.

Concerning institutional integration, 41.4% rated their relationships with professors as good, 27.3% very good, 30.3% fair, and 1.0% poor. Regarding peers, 41.4% considered relationships good, 38.4% very good, 19.2% fair, and 1.0% poor. Most students (70.7%) attended classes regularly. The campus environment at the University of Panama was rated as good by 38.4%, fair by 39.4%, very good by 20.2%, and poor by 2.0%.

3.2. Inferential Analysis

The CLMM was used to examine the relationships between explanatory factors and dropout intention among students in the Mathematics Bachelor's programs. The model results are presented in Table 2. In this study, the fixed effects included program of enrollment, reason for choosing the program, availability of financial resources, economic dependence, family environment, origin, and gender. Additionally, a random intercept was incorporated to account for group heterogeneities and to consider intraclass correlations.

The model thresholds were significant for the transitions between Some and Considerable, and between Considerable and High, indicating that the probability of moving to higher levels of dropout intention follows a consistent cumulative pattern.

Among the fixed effects, economic dependence and native origin showed positive and significant associations with higher levels of dropout intention. In contrast, variables such as gender, availability of financial resources, and family environment did not have significant effects. The random component accounted for a small proportion of the total variation (ICC ≈ 2.4%), indicating that differences between student groups were limited compared to individual effects.

Table 2: Results of the Cumulative Link Mixed Model.

Threshold Coefficients				
Category	Estimate	S. D.	z-value	p-value
None/Low	-0.907	0.297	-3.05	0.002**
Low/Some	-0.028	0.294	-0.10	0.923
Some/Considerable	1.120	0.297	3.77	**<0.001*** **
Considerable/High	2.142	0.305	7.02	**<0.0001*** **
Category				
Fixed Effects				
Program of Study: Bachelor's in mathematics	0.201	0.167	1.20	0.221

Reason for Choosing Program: Career Guidance	0.281	0.226	1.27	0.213
Reason for Choosing Program: Other	-0.071	0.207	-0.38	0.702
Reason for Choosing Program: Vocation	0.257	0.177	1.45	0.145
Availability of Financial Resources: Yes	-0.122	0.141	-0.81	0.415
Economic Dependence: Yes	0.366	0.152	2.41	**0.016***
Family Environment Supports Studies: Yes	-0.023	0.169	-0.14	0.891
Origin: Native	0.322	0.141	2.29	**0.022***
Gender: Male	-0.091	0.151	-0.60	0.546
Random Effects				
Group (random intercept)	Variance	S.D.	Intra-class Correlation	
Factor	0.082	0.287	0.024	
Overall Sample: n=710	Log-likelihood = 1120.00	AIC=2268.00		

These results are presented in Figure 1, which shows the percentage distribution of dropout intention levels (None, Low, Some, Considerable, High) according to two dimensions: origin (immigrant or native) and economic status. On the vertical axis, students are distinguished as financially self-sufficient (No, i.e., not dependent on others for their sustenance) and financially dependent (Yes, receiving support from parents, partner, or other relatives).

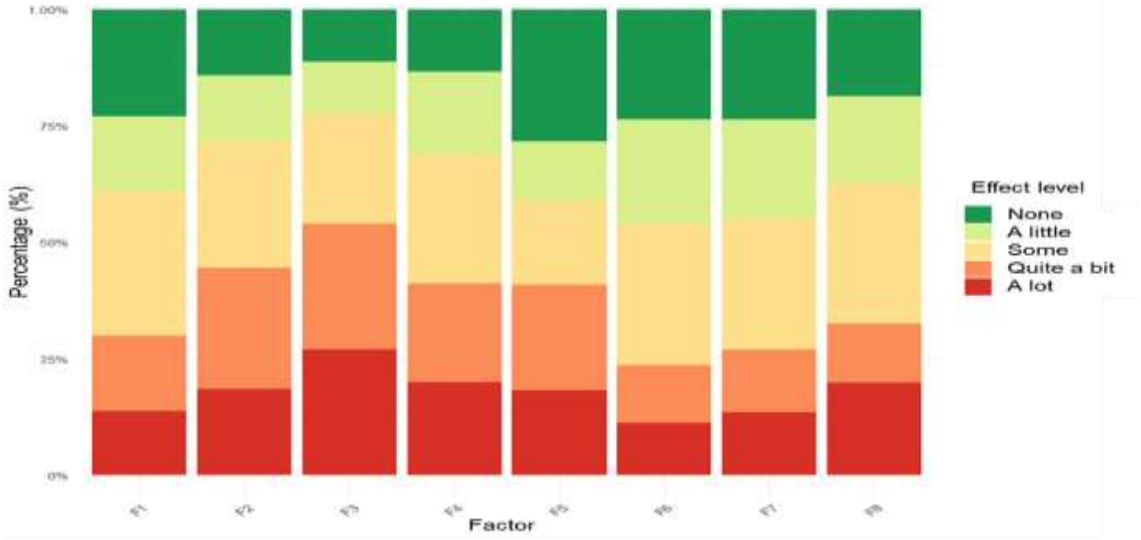

Figure 1: Levels of Dropout Intention in Students According To Explanatory Factors.

The patterns observed in Figure 1 highlight how the perceived impact of different factors varies across these groups. Specifically, the Prior Knowledge and Economic Situation factors concentrate a higher proportion of responses in the upper levels (Considerable and High), particularly among financially dependent students and native students. In contrast, the Institution and Social and Academic Integration factors show distributions dominated by the lower levels (None or Low), suggesting that students' perceptions of the effects of certain factors are strongly influenced by their origin and socioeconomic status.

Figure 2 presents the percentage distribution of dropout intention levels (None, Low, Some, Considerable, High) according to two dimensions: origin (immigrant or native) and economic status. On the vertical axis, students are distinguished as financially self-sufficient (No, i.e., not dependent on others for their sustenance) and financially dependent (Yes, receiving support from parents, partner, or other relatives).

The results shown in Figure 2 reveal an additional finding: within the population of native students reporting no economic dependence —i.e., those who are likely to work or support themselves — the Economic Situation factor stands out, with a high proportion of responses at the Considerable and High levels. This pattern suggests that financially self-sufficient students perceive the negative effects of this factor more intensely, which could increase their risk of dropout. This evidence supports the

hypothesis that, despite their financial independence, these students face additional pressures that influence their academic persistence, making them a priority group for preventive institutional interventions.

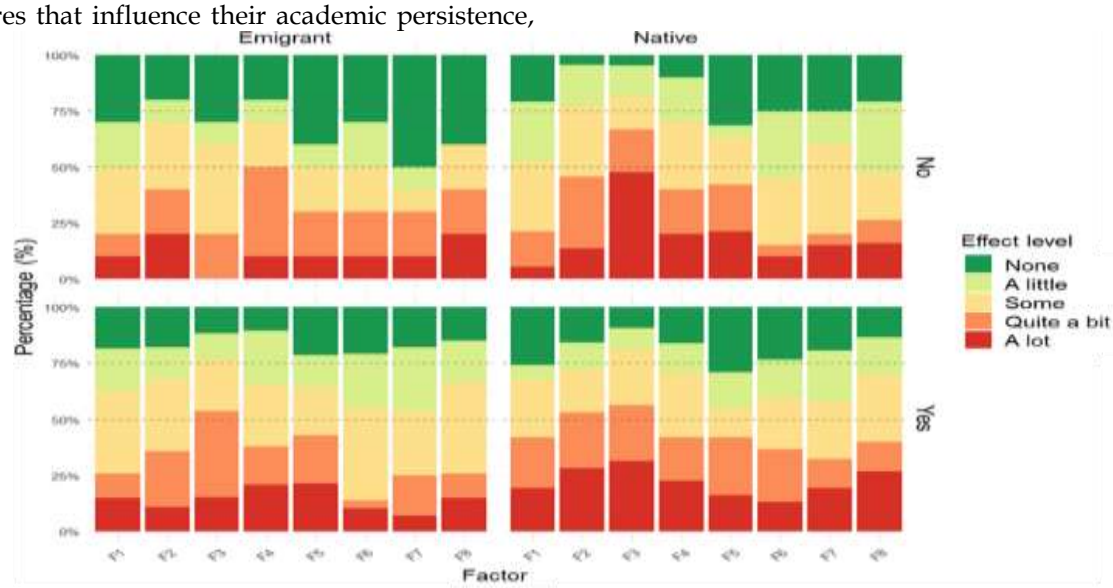

Figure 2: Niveles De Intención De Abandono En Estudiantes Nativos Autosuficientes Económicamente.

4. DISCUSSION

The results indicate that dropout intention in the Mathematics Bachelor's programs at the University of Panama is strongly associated with structural factors, particularly economic dependence and native origin. Students who are financially dependent on others showed a higher likelihood of reporting elevated levels of dropout intention, confirming the importance of financial conditions as a central determinant of university persistence. Similarly, students from native communities exhibited greater vulnerability, suggesting that socioeconomic and cultural inequalities directly influence the risk of dropout.

These findings align with research highlighting the influence of economic and social factors on higher education dropout (Casanova et al., 2023; Gallego et al., 2021; R. C. R. Heredia & Carcausto-Calla, 2024; Melo et al., 2022). Financial difficulties have been identified as one of the main reasons for dropout in the regionn (Smulders Chaparro, 2018; Torres, 2015), while belonging to historically vulnerable populations underscores the need for targeted support policies (Chalela-Naffah et al., 2020).

The Prior Knowledge and Economic Situation factors concentrate a higher proportion of responses in the upper levels (Considerable and High), especially among financially dependent students and those of native origin, whereas the Institution and Social and Academic Integration factors are predominantly reported at lower levels (None or Low). This distribution demonstrates that the perceived impact of factors varies according to socioeconomic and cultural conditions, reinforcing the hypothesis that dropout intention is shaped by a combination of individual and contextual elements.

At the regional level, studies in Chile, Colombia, and the European Union reveal similar patterns: economic limitations and social factors are consistent predictors of dropout (Chalela-Naffah et al., 2020; Espinoza et al., 2025; Guerrero et al., 2024). This suggests that, although specific figures may differ, the structural causes of university dropout transcend national contexts and require comprehensive strategies.

Finally, the results highlight the need to strengthen financial, academic, and psychosocial support mechanisms, with a particular focus on students from native communities and those with high economic dependence. Institutional interventions should prioritize equity, providing flexible and sustained guidance that reduces structural gaps and contributes to the successful completion of studies in Mathematics.

5. CONCLUSIONS

The analysis of dropout intention in the Mathematics and Mathematics Teaching Bachelor's programs at the University of Panama reveals that students who are economically dependent and those of native origin have a higher likelihood of reporting elevated levels of dropout intention. These results confirm that socioeconomic conditions and cultural background play a decisive role in university persistence. Although most of the demographic and

academic variables considered did not show significant effects, the evidence highlights the need to address structural inequalities affecting specific groups of the student population.

The model showed that the distribution of dropout intention is heterogeneous, concentrating at higher levels among economically dependent students and those from native communities, while other groups, such as those associated with Institution and Social and Academic Integration factors, cluster at lower levels. This suggests that dropout is not solely driven by academic performance but is influenced by a complex interplay of social and economic factors that condition continuity in higher education.

To strengthen student retention and improve academic trajectories in Mathematics programs, it is recommended to implement financial support programs, academic and psychosocial guidance strategies from the first semesters, as well as vocational counseling and personalized monitoring mechanisms to identify at-risk students early. Additionally, specific policies should be designed to address the needs of students of native origin and those with high economic dependence, aiming to reduce gaps in opportunities for successful program completion.

The findings of this study contribute to the academic discussion on university dropout in the field of mathematics education and provide valuable input for institutional decision-making at the University of Panama. They also reinforce the importance of continuing to investigate this phenomenon from a comprehensive perspective that considers both individual and structural factors in the pursuit of effective solutions.

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