Correlation Between Unemployment Rates and Socioeconomic Factors in the Municipalities of Puerto Rico

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Graduate Project EXPO, May 2026

Abstract *— This study examines the relationship between municipal unemployment and three socioeconomic indicators, poverty rate, educational attainment, and broadband subscription, across Puerto Rico's 78 municipalities from 2019 through 2024. A custom .NET data pipeline ingests data from the Bureau of Labor Statistics Local Area Unemployment Statistics and the Census American Community Survey 5-Year Estimates, constructs a balanced municipality-year panel of 468 observations, and applies Pearson correlation, Spearman rank correlation, and Ordinary Least Squares multiple regression. The poverty rate emerges as the dominant correlate of municipal unemployment, with positive and highly significant coefficients in every annual cross-section and in the pooled model. Educational attainment shows a substantial bivariate correlation but loses joint significance when collinear with poverty. The broadband coefficient increases monotonically over the study window and becomes significant in the pooled specification. Findings support geographically targeted policy investments in the southern and southwestern municipalities with the weakest socioeconomic profiles and the highest unemployment rates.*

Keywords *— Broadband Adoption, Multiple Linear Regression, Municipal-Level Analysis, Panel Data, Puerto Rico, Unemployment.*

INTRODUCTION

Unemployment is one of the most consequential problems a community can face. Beyond lost income, it narrows social participation and pushes households toward poverty, with effects that deepen over time [1]. Labor economists have long studied how unemployment relates to structural factors such as schooling, poverty, and access to infrastructure. In the United States, education significantly improves an unemployed worker's odds of re-employment, with the largest gains at high school and bachelor's thresholds [2], and broadband Internet access raises local employment and labor-market activity at the county level [3]. What remains less clear is whether these relationships hold at the sub-national level in economies shaped by fiscal, institutional, and geographic constraints.

Puerto Rico is a compelling setting for this question. The territory has been in economic contraction since 2006, when the Section 936 tax incentive phase-out began unraveling its manufacturing base. A prolonged debt crisis followed, leading to PROMESA in 2016 and a federal fiscal control board [4], and then to Hurricanes Irma and María (2017), earthquakes (2020), and the COVID-19 pandemic, each straining infrastructure and labor markets. Today, roughly 40% of Puerto Ricans live below the poverty line, more than three times the national rate, and labor force participation sits near 43%, far below the U.S. average of about 63% [5]. Territory-level numbers, however, hide a great deal: the real story plays out municipality by municipality.

Three factors stand out as likely correlates of municipal unemployment: education improves re-employment after job loss [2]; poverty is tied to weak labor-market attachment, with unemployment raising poverty in the long run [1]; and broadband shapes access to job information, remote work, and training, with expansion raising employment in U.S. counties and reducing poverty in rural Latin America [3] [6]. These vary widely within Puerto Rico: broadband adoption exceeds 80% in the San Juan metro area but falls to 18% in some central mountain

municipalities [7], weekly wages are far higher in the metro area [4], and although all 78 municipalities are areas of persistent poverty, the depth of disadvantage is far from uniform [5]. Yet few studies examine how these factors co-vary across municipalities over time; most island work treats aggregate indicators or the fiscal crisis rather than municipal labor-market outcomes.

This study fills that gap. It examines how municipal unemployment relates to education, poverty, and broadband access across Puerto Rico's 78 municipalities, using public BLS Local Area Unemployment Statistics and U.S. Census American Community Survey data. It builds a municipality-year panel and applies correlation and regression methods to identify which factors track most closely with unemployment and whether the pattern holds year to year, producing evidence to inform geographically targeted policy and the broader question of how socioeconomic conditions and digital infrastructure shape labor markets in small, constrained economies [6].

LITERATURE REVIEW

This section reviews the empirical literature on the links between unemployment, education, poverty, and broadband, and identifies the research gap this study addresses.

Education and Unemployment

Education and unemployment have one of the most reliably documented relationships in labor economics. Human capital theory holds that schooling raises productivity and adaptability and lowers exposure to joblessness. Riddell and Song [2] tested this causally with U.S. data, using an instrumental-variable strategy based on compulsory schooling laws, child labor laws, and Vietnam-era conscription risk. More schooling significantly raised re-employment rates for displaced workers, with the largest jumps at 12 and 16 years of schooling, indicating credentials, not just years in a classroom, matter. The work also supported a broader view that education helps workers adjust when the economy shifts, which speaks directly to Puerto Rico, where repeated shocks have made adaptability an ongoing requirement.

Education's role extends beyond direct employment: more schooling is associated with better access to the online tools now central to job search, training, and remote work. In Puerto Rico, attainment is only slightly below the U.S. mainland, yet labor force participation is far lower and unemployment far higher [4], suggesting that something else impedes the translation of educational capital into employment. Examining how attainment relates to unemployment at the municipal level is a first step toward identifying that factor.

Poverty and Unemployment

Poverty and unemployment reinforce each other bidirectionally. Job loss drains household income and pushes families toward poverty; poverty in turn limits the resources needed to search for work, travel to interviews, retrain, or relocate. Ngubane et al. [1] examined this with quarterly South African data from 2000 to 2021, fitting linear and non-linear autoregressive distributed lag (ARDL) models. Unemployment significantly raised poverty in the long run, and economic growth reduced it; the non-linear results showed that both positive and negative unemployment shocks increased poverty, suggesting the damage to living standards is not easily reversed. South Africa is not Puerto Rico, but the reinforcing cycle between joblessness and poverty in economies with high poverty and constrained labor demand carries over.

In Puerto Rico, the poverty-unemployment link runs especially deep: about 40% of residents live below the federal poverty line (roughly 12% on the mainland), and the territory's Gini coefficient exceeds that of any U.S. state [5]. CentroPR [5] traces this to the economy's limited capacity to generate well-paid jobs, the collapse of export-oriented manufacturing after the Section 936 phase-out, outmigration of working-age residents, and PROMESA austerity, all of which reduced labor demand and public investment. Poverty is also

unevenly distributed, shaped by local economic base, geographic access, and disaster exposure, so any municipal-level analysis of unemployment in Puerto Rico must put poverty at the center.

Internet/Broadband Access, Digital Divide, and Labor-Market Outcomes

The evidence linking broadband Internet to labor-market outcomes has grown over the past decade. Atasoy [3] studied U.S. county broadband rollout from 1999 to 2007 with a county- and year-fixed-effects panel: gaining broadband access raised the county employment rate by roughly 1.8 percentage points, with larger effects in rural and isolated areas, concentrated among college-educated workers, consistent with broadband complementing human capital. García-Mora and Mora-Rivera [6] extended this to a Latin American context, finding, with quasi-experimental rural-Mexico data, that Internet access lowered poverty and improved living standards, with the strongest effects in the least developed regions, settings whose constraints resemble Puerto Rico's.

Puerto Rico's digital divide is substantial and geographically structured. Nearly 30% of residents report no home Internet (about 10% nationally), and adoption varies sharply: San Juan and its metro area sit near the top, while central mountain municipalities fall as low as 18%, among the lowest of any U.S. county-equivalent jurisdiction [7]. Also, 99% of residents qualify under at least one federal "covered population" designation due to digital-access barriers, and infrastructure was severely damaged by the 2017 hurricanes and the 2020 earthquakes. The Puerto Rico Broadband Program (2022) has since received over $1.2 billion in federal funding (including roughly $329 million through BEAD). Municipal broadband differences are therefore plausibly linked to unemployment through job search, information access, and remote work, though this study is correlational and cannot settle causation.

Synthesis and Research Gap

Education, poverty, and broadband access each have well-documented connections to labor-market outcomes, and sub-national analyses reveal disparities that aggregate statistics conceal. Causal U.S. evidence shows education improves re-employment [2] and broadband expansion raises employment [3]; poverty and unemployment reinforce each other in high-poverty, labor-constrained settings [1]; and Latin American evidence shows Internet access reduces poverty in less developed regions like parts of Puerto Rico [6]. Panel data addresses this by following units over time and accounting for fixed municipal characteristics. Atasoy [3] used county- and year-fixed effects this way, a direct precedent. What is missing is a study that pulls these threads together for Puerto Rico, where inter-municipal variation is substantial, and policy must be targeted. This study fills that gap by using a municipality-year panel for the 78 municipalities (2019–2024) and BLS LAUS and Census ACS data.

METHODOLOGY

This section presents the research design, data sources, panel construction, statistical methods, and the software system implemented for reproducibility.

Research Design

This study uses a combined cross-sectional and longitudinal design built around a municipality-year panel: each row corresponds to one of Puerto Rico's 78 municipalities, with data from 2019 to 2024. With six years and 78 units, the panel holds 468 socioeconomic-indicator observations (78 × 6) and 5,460 monthly unemployment observations (78 × 70 months). March and April 2020 are missing because BLS suppressed subnational LAUS estimates during the early COVID-19 disruption, so the 2020 averages use the remaining 10 months. The structure

supports within-year cross-municipal comparison and tracking whether predictor-unemployment relationships hold over time. The work is observational (no manipulation or treatment), so results are associations, not causal effects.

Data Sources

The study draws on two publicly available federal data sources. Unemployment data come from the Bureau of Labor Statistics (BLS) Local Area Unemployment Statistics (LAUS) program, which publishes monthly unemployment estimates for every U.S. county and county equivalent, including Puerto Rico's 78 municipalities. The BLS data are pulled directly from the agency's flat-file archive. Three files matter for this work: *la.data.46.PuertoRico* for time-series values, *la.series* for mapping series identifiers to areas and measures, and *la.area* for matching area codes to municipality names. Records are filtered to Puerto Rico county equivalents (state FIPS code 72) and to measure code 03, which is the unemployment rate [8]. The Puerto Rico state FIPS code (72) follows the U.S. Census Bureau ANSI/FIPS state code standard [9].

Socioeconomic indicators come from the U.S. Census Bureau's American Community Survey (ACS) 5-Year Estimates, accessed through the Census API. The 5-Year estimates aggregate data collected over a 5-Year window to produce reliable values for small geographic units, such as municipalities. Every query uses the geographic filter for Puerto Rico's county equivalents under state FIPS code 72, returning data for all 78 municipalities. Three separate queries are issued per year, one each for the variables behind the poverty rate, the broadband access rate, and the educational attainment rate.

Variables

Dependent variable. The outcome of interest is the annual municipal unemployment rate. BLS LAUS reports unemployment monthly, so the twelve-monthly values for each municipality in each year are averaged into a single annual rate. Averaging smooths out seasonal swings and aligns the BLS data with the Census indicators on an annual basis.

Independent variables. Three independent variables are computed from ACS data, each expressed as a percentage on the 0–100 scale to match the units of the BLS unemployment rate:

Poverty rate. The number of people below the federal poverty level (variable B17001_002E) divided by the total population (B01001_001E). This captures the share of a municipality's residents experiencing income poverty, a factor the literature treats as both a predictor and a consequence of unemployment [1].

Broadband access rate. The number of households with an Internet subscription (B28002_004E) divided by the total number of households (B28002_001E). This captures the share of households with home connectivity, which research has linked to job search, labor-market matching, and employment outcomes [3].

Educational attainment rate (bachelor's or higher). The sum of bachelor's degrees (B15003_022E), master's degrees (B15003_023E), professional degrees (B15003_024E), and doctorates (B15003_025E), divided by the population aged 25 and older (B15003_001E). The Census restricts table B15003 to adults 25 and older because younger people may still be in school. Using this denominator is the standard convention in labor economics and Census-based research, and it prevents the rate from being artificially deflated in municipalities with younger populations. The measure captures the share of adults with higher education credentials; a factor linked to better re-employment outcomes [2].

Panel Construction

The final dataset is a municipality-year panel. Each row carries one municipality, one year, and the four variables: annual unemployment rate, poverty rate, broadband access rate, and educational attainment rate. Construction is straightforward. BLS unemployment data and Census ACS data are joined on two keys: the five-digit FIPS code (state

code 72 plus the three-digit county-equivalent code) and the year. Only municipality-year pairs with data from both sources are kept. With 78 municipalities and six years, the panel can hold up to 468 rows, though the actual count may be slightly lower if values are missing or suppressed.

One temporal-alignment detail is worth noting. BLS LAUS values are monthly and rolled up to annual averages. In contrast, ACS 5-Year estimates represent data collected over a rolling five-year window ending in the labeled year (the 2024 estimates reflect 2020 through 2024). ACS values, therefore, shift gradually rather than capturing a single year, a known Census trade-off for reliable municipal-level estimation. ACS values for a given year are matched to the BLS annual average for the same year, the standard approach in research using ACS municipality data.

Statistical Methods

Two complementary approaches are used to examine the relationship between unemployment and the three socioeconomic indicators: correlation analysis and multiple linear regression. All computations are done programmatically using *MathNet.Numerics*, an open-source numerical library for the .NET platform.

Correlation analysis. For each year and for the pooled dataset, two coefficients are computed between unemployment and each independent variable. The Pearson coefficient (r) measures the strength and direction of a linear relationship and runs from −1 to +1. The Spearman rank coefficient (ρ) measures a monotonic relationship using ranks, making it robust to outliers and non-normal distributions. Reporting both captures strictly linear associations as well as monotonic patterns that need not be linear. Each analysis produces six correlation values (three variables × two methods).

Multiple linear regression. A multiple linear regression model is fit using Ordinary Least Squares (OLS) to look at how the three indicators jointly relate to unemployment, with each predictor controlling for the others. The model specification follows the standard multiple linear regression framework [10]. The model is:

$$unemployment\_rate = \beta_0 + \beta_1(poverty\_rate) + \beta_2(bachelors\_plus\_rate) + \beta_3(broadband\_rate) + \varepsilon \quad (1)$$

Where β_0 is the intercept, β_1 through β_3 are the predictor coefficients, and ε is the error term. The model is estimated for each year and for the pooled panel. Each fit reports the coefficients with standard errors, t-statistics, and p-values (null: coefficient equals zero), R^2, adjusted R^2, and the number of observations. P-values come from the t-distribution with $n - k - 1$ degrees of freedom, where n is the number of observations and $k = 3$.

All four variables in the model, the dependent unemployment rate and the three independent indicators, are expressed as percentages on the 0–100 scale. Coefficients, therefore, have a direct percentage-point interpretation: a one-unit change in any predictor represents a one-percentage-point shift in that indicator. In the discussion of results, effects are reported in 10-percentage-point increments to match the practical magnitudes observed across municipalities.

Rankings. Municipalities are also ranked by unemployment rate each year, with their socioeconomic indicators displayed alongside, allowing identification of persistently high-unemployment municipalities and a brief look at whether the distribution's extremes share common socioeconomic features.

Limitations

Several limitations apply. First, the study is correlational, so relationships cannot be read as causal; unobserved characteristics (industry composition, urban proximity, public-service quality, historical investment) may confound estimates. Second, ACS 5-Year estimates are smoothed over a five-year window and miss rapid year-to-year change, a Census trade-off for reliable small-area estimates. Third, the model lacks spatial controls or fixed effects for clustering or time-invariant characteristics, which future work could

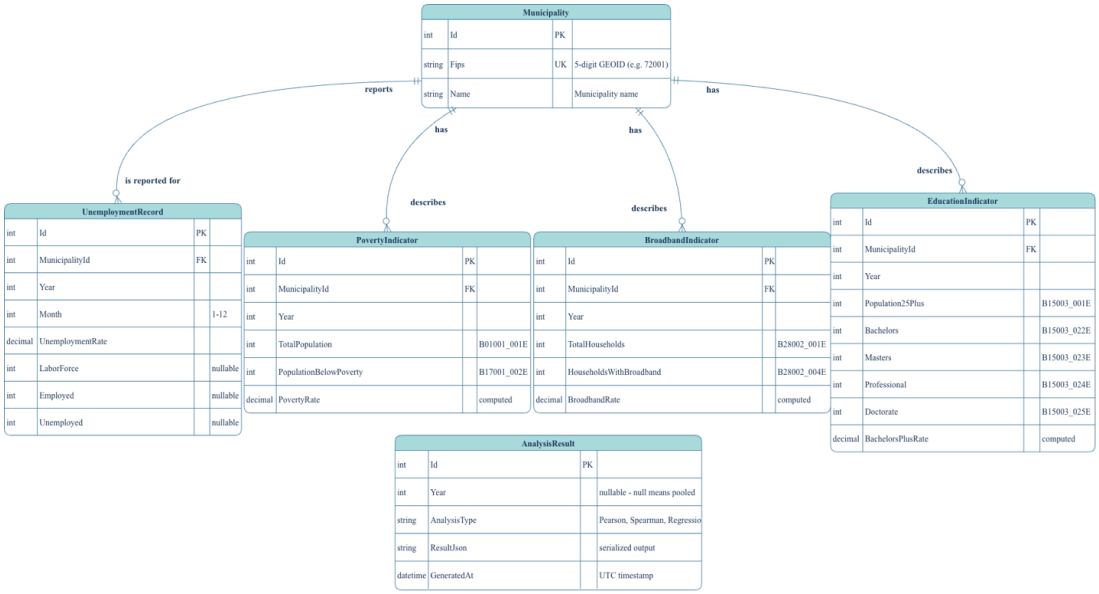

Figure 1

Third Normal Form Entity-Relationship Diagram: Municipality as the Central Table Linked to the Unemployment Record and the Poverty, Broadband, and Education Indicators (each from one Census ACS source table), plus the Persisted Analysis Result Table

address. Fourth, the five-year panel limits long-term inference. Finally, the BLS LAUS series is missing for March and April 2020 due to COVID-19 suppression; the 2020 averages use the remaining ten months. This gap is a source-data feature, not a study choice, and does not affect the structural correlations reported.

System Design and Implementation

The analytical pipeline was implemented as a reproducible system: a RESTful Web API in .NET 10 and ASP.NET Core (C#) following a Clean Architecture pattern with separate Core, Infrastructure, and API layers. Data are persisted in PostgreSQL through Entity Framework Core (Npgsql) using code-first migrations, with a Third Normal Form schema (Figure 1) linking the unemployment record to three socioeconomic indicators (each from one Census ACS source table: B17001, B28002, B15003) and a central Municipality table keyed by FIPS code. A three-stage process ingests BLS LAUS and Census ACS data, parses them into entities and derived rates, and persists them; correlation and OLS regression run through *MathNet.Numerics*. A batch endpoint persists all analyses as a dated snapshot, and a CSV export supports external reproduction.

Results

This section reports the sample composition, descriptive statistics, bivariate correlations, and the results of multiple linear regression.

Sample and Data Completeness

The realized panel includes 468 municipality-year observations covering all 78 municipalities from 2019 through 2024, formed by joining BLS LAUS unemployment with Census ACS 5-Year indicators on FIPS codes and year. All 468 cells are populated for all four variables, with no missing values or imputation. The unemployment data derive from 5,460 monthly BLS LAUS observations (78×70 months); the 156-month shortfall relative to the 5,616 maximum corresponds to the documented BLS suppression of March and April 2020, so 2020 rates are averaged over 10 months. The Census ACS 5-Year tables for poverty, broadband, and education are complete across all 1,404 municipality-year-indicator records.

Descriptive Statistics

Across the 468 observations, the descriptive picture matches widely reported features of Puerto Rico's economy. Mean municipal unemployment is 8.13% (SD 2.64, range 1.65 to 19.32), well above the U.S. mainland average. Mean municipal poverty is 45.33% (SD 8.27, range 20.84 to 66.88), more than three times the mainland figure [5]. Broadband subscription rates average 67.82% but vary widely (SD 14.10, range 22.17 to 91.35), reflecting the digital divide between the San Juan metropolitan area and the island's mountainous interior [7]. Bachelor's-or-higher attainment averages 23.49% (SD 6.23), ranging from 7.99% in the least-educated municipality to 50.49% in the most-educated, indicating substantial human-capital variation across geography.

Annual cross-section means show meaningful trends across the six-year window. Mean unemployment fell 3.05 percentage points (from 9.79% in 2019 to 6.74% in 2024). Broadband adoption rose 20.74 points (from 57.70% to 78.44%), the largest absolute movement of any variable in the panel. Bachelor's-or-higher attainment rose 3.57 points, and the poverty rate fell 3.72 points. The COVID-19 disruption is visible in the 2020 unemployment value, but does not interrupt the overall downward trend in unemployment or the steady upward trend in broadband adoption.

Bivariate Correlations

Table 1 reports the Pearson and Spearman correlations between each predictor and the unemployment rate, calculated separately for each year and for the pooled panel.

Table 1
Pearson and Spearman Correlations with Unemployment, by Year

Year	r Pov	r Bach+	r BB	ρ Pov	ρ Bach+	ρ BB
2019	0.663	−0.467	−0.322	0.617	−0.363	−0.300
2020	0.667	−0.551	−0.374	0.623	−0.499	−0.313
2021	0.654	−0.556	−0.427	0.723	−0.526	−0.336
2022	0.646	−0.455	−0.422	0.720	−0.390	−0.346
2023	0.680	−0.443	−0.433	0.703	−0.340	−0.363
2024	0.674	−0.476	−0.450	0.711	−0.403	−0.301
Pooled	0.629	−0.497	−0.523	0.623	−0.447	−0.517

The stability of the poverty correlation across all six years, including the COVID-disrupted 2020 cross-section, is the most notable feature. The structural relationship between poverty and unemployment in Puerto Rico's municipalities appears robust to short-term economic shocks.

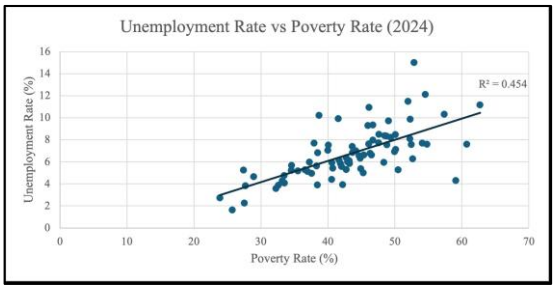

Figure 2
Municipal Unemployment Rate Against Poverty Rate, 2024 (n = 78), with OLS Trend Line and R^2 Annotated; Education and Broadband Relationships are reported in Tables 1 and 2

Multiple Linear Regression

Ordinary Least Squares fitted a multiple linear regression model for each year and for the pooled panel, with unemployment rate as the dependent variable and the three socioeconomic indicators entered jointly as predictors:

$$unemployment\_rate = \beta_0 + \beta_1(poverty\_rate) + \beta_2(bachelors\_plus\_rate) + \beta_3(broadband\_rate) + \varepsilon \quad (2)$$

Coefficients are interpreted as the change in the unemployment rate (in percentage points) associated with a one-percentage-point increase in the predictor, holding the other two predictors constant. P-values are computed from a two-sided t-test against the null hypothesis that the true coefficient equals zero.

Table 2
OLS regression results, by year and pooled (n = 78/year; pooled n = 468). Bold indicates p < .05.

Year	R^2	adj R^2	Intercept	β Pov (p)	β Edu (p)	β BB (p)
2019	0.440	0.417	−3.093	**0.263 (<.001)**	0.003 (.967)	0.008 (.774)
2020	0.468	0.446	6.537	**0.098 (<.001)**	−0.046 (.135)	−0.009 (.434)
2021	0.486	0.465	7.054	**0.117 (<.001)**	−0.074 (.067)	−0.028 (.059)
2022	0.452	0.430	3.131	**0.144 (<.001)**	−0.014 (.719)	**−0.033 (.044)**
2023	0.489	0.469	1.717	**0.170 (<.001)**	0.013 (.747)	−0.036 (.054)
2024	0.482	0.461	1.533	**0.182 (<.001)**	0.024 (.580)	−0.042 (.052)
Pooled	0.471	0.468	6.044	**0.144 (<.001)**	−0.029 (.140)	**−0.055 (<.001)**

Across the annual cross-sections, R^2 ranges from 0.440 to 0.489 (adjusted R^2 0.417 to 0.469); the

pooled model achieves $R^2 = 0.471$ and adjusted $R^2 = 0.468$. The poverty coefficient is positive and highly significant ($p < 0.001$) in every year and in the pooled sample, ranging from $\beta = 0.098$ (2020) to $\beta = 0.263$ (2019), typically about 0.15. The education coefficient is not significant in any year or in the pooled analysis (p between 0.135 and 0.967 annually; $p = 0.140$ pooled). The broadband coefficient is significant in the pooled model ($\beta = -0.055$, $p < 0.001$) and at the 5% level in 2022 ($\beta = -0.033$, $p = 0.044$), with borderline values ($0.05 < p < 0.06$) in 2021, 2023, and 2024.

Three findings stand out. First, the model explains a stable, substantive share of cross-municipal variation, roughly half the differences across municipalities in every specification. Second, poverty is the only consistently significant predictor: a 10-percentage-point rise in poverty is associated with about 1.0 to 2.6 additional percentage points of unemployment (typically ≈ 1.5), holding education and broadband constant. Third, the bachelor's-or-higher coefficient loses significance in the joint model despite its strong bivariate correlation, a characteristic of multicollinearity: the poverty-education correlation across the panel is ≈ −0.69, large enough that, once poverty is in the model, education adds little independent explanatory power.

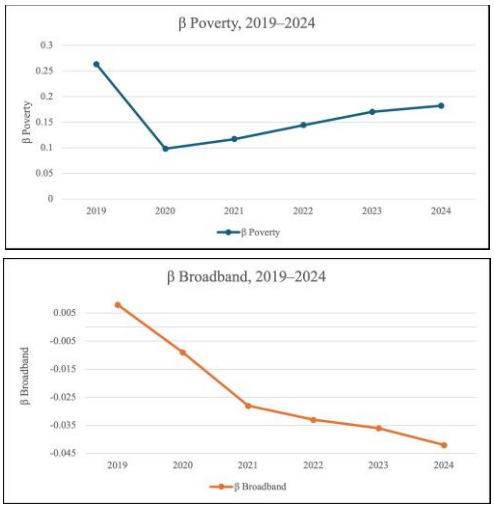

Figure 3
Year-by-Year Coefficient Estimates for Poverty and Broadband from the Multiple Regression Model, Showing the Stability of the Poverty Effect and the Gradual Emergence of the Broadband Effect across the Panel

The broadband coefficient also displays a notable pattern across the window. In 2019, the broadband coefficient was effectively zero ($\beta = 0.008$, $p = 0.774$). By 2024, it had grown to $\beta = -0.042$ with a p-value of 0.052, and in the pooled specification, it reached $\beta = -0.055$ with $p < 0.001$. The coefficient strengthens monotonically in magnitude after 2020, suggesting that broadband infrastructure has become an increasingly meaningful correlate of municipal unemployment over the study window.

Geographic Patterns

The municipalities at the extremes of the unemployment distribution exhibit a sharply bimodal geographic structure. The five municipalities with the highest unemployment rates in 2024 are concentrated along the southern and southwestern coasts and in the western interior. Maricao reports the highest unemployment rate at 15.02%, paired with low broadband adoption (39.04%), high poverty (52.89%), and low educational attainment (13.38%), the weakest socioeconomic profile among the five high-unemployment municipalities. Maunabo, Arroyo, Guánica, and Guayanilla complete the top five, all with unemployment rates above 10% and elevated poverty levels. These municipalities lie within the same southwestern region affected by the 2019–2020 earthquake sequence, which caused substantial damage to homes, schools, and economic infrastructure.

The San Juan metropolitan core encompasses the five municipalities with the lowest unemployment rates. Guaynabo (2.73%), Trujillo Alto (2.25%), Toa Baja (3.58%), and Carolina (3.83%) all combine low poverty (below 33%), high educational attainment (above 28%), and broadband adoption above 85%. Culebra, a small offshore municipality, reports the panel's lowest rate (1.65%), an outlier whose tourism-driven economy and small population produce idiosyncratic dynamics. The contrast matches the regression: Maricao combines the worst values across all three predictors with the highest unemployment, while

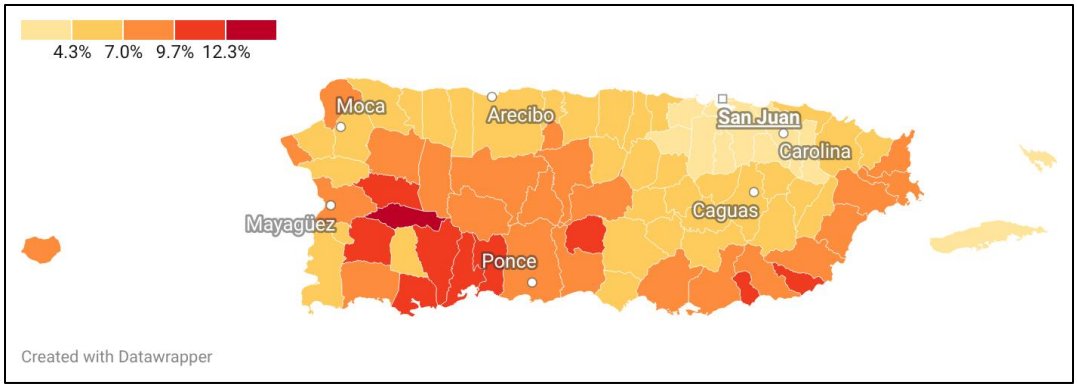

Figure 4

Unemployment Rate by Municipality, Puerto Rico, 2024

The geographic concentration of high unemployment along the southern and southwestern coasts contrasts with the labor-market advantage of the San Juan metropolitan area.

Guaynabo combines the best predictor values with one of the lowest.

Counterexamples exist that confirm no single predictor determines outcomes. Arroyo combines high broadband adoption (85.71%) with the third-highest unemployment (11.50%), and Culebra combines low educational attainment (18.14%) with the lowest unemployment in the panel. These cases are consistent with the model, which explains 47% of the variance rather than a deterministic share, leaving room for unobserved factors such as local industry composition, geographic isolation, and post-disaster recovery effects.

DISCUSSION

This section interprets the findings on poverty, education, broadband, and the geographic structure of municipal unemployment, considering prior literature.

Poverty as the Dominant Correlate of Municipal Unemployment

The most consistent finding is the strength and stability of the association between poverty and unemployment. Poverty is positively and significantly correlated with unemployment in every year and survives adjustment for education and broadband in every regression specification ($p < 0.001$ throughout). The coefficients indicate that a 10-percentage-point rise in a municipality's poverty rate is associated with roughly 1.5 additional percentage points of unemployment on average, holding the other predictors constant. This aligns with the South African evidence in Ngubane et al. [1], where unemployment shocks raised poverty in the long run, and extends it by demonstrating the relationship in cross-section across small geographic units within a structurally constrained U.S. territorial economy.

The mutually reinforcing dynamic Ngubane et al. identify, joblessness depleting the resources needed to find and accept work, operates clearly at the municipal level in Puerto Rico, where a mean poverty rate near 45% leaves limited capacity to absorb labor-market disengagement. The southwest's concentration of high poverty alongside high unemployment fits this mechanism: the deepest-poverty municipalities are the same ones where workers have the fewest resources to weather job loss or retrain. CentroPR [5] documents that all 78 municipalities qualify as areas of persistent poverty but with highly uneven depth, heaviest in the southwestern and central mountain municipalities.

Education as a Bivariate but Not Joint Predictor

The bivariate correlations between bachelor's-or-higher attainment and unemployment ($r = -0.44$ to -0.56 across years) are consistent with the human capital literature, anchored by Riddell and Song [2]: more educated municipalities have lower

unemployment rates. However, with poverty included in the model, the education coefficient is statistically insignificant in every year and in the pooled sample.

Two interpretations are possible. The first is methodological: education and poverty are highly correlated across municipalities (bivariate $r \approx -0.69$), so the lowest-attainment municipalities are largely the highest-poverty ones, and this multicollinearity absorbs the bivariate education signal into the poverty coefficient when both are jointly entered. The second is substantive: at the municipal cross-sectional level, the apparent education-unemployment association may operate primarily through household income rather than as an independent mechanism. Riddell and Song identified causal effects at the individual-worker level using exogenous variation in schooling laws and conscription risk; the present observational municipal design cannot replicate that strategy, so these results do not contradict theirs but rather show that, at the municipal scale, education and poverty are too entangled to separate cleanly.

The Strengthening Broadband-Unemployment Relationship

The broadband-unemployment correlation strengthens across the panel from $r = -0.32$ in 2019 to $r = -0.45$ in 2024. The broadband coefficient in the multiple regression model becomes statistically significant in the pooled specification ($\beta = -0.055$, $p < 0.001$). It reaches or approaches significance in the most recent three years (p between 0.044 and 0.059). This pattern is consistent with the U.S. county-level evidence reported by Atasoy [3], in which broadband access raised employment rates with the largest effects in rural and isolated areas, and with the rural Mexico evidence in García-Mora and Mora-Rivera [6], who found that Internet access reduced poverty most strongly in the least developed regions.

Two factors plausibly explain the strengthening. First, broadband adoption rose by more than 20 percentage points over the window, increasing predictor variance and the power to detect its effect. Second, the period from 2020 coincides with the COVID-19 era, when remote work, online job search and training, and digital public services became substantially more important to labor-market participation. The mechanism Atasoy and García-Mora describe would register more strongly as digital channels became central to employment, as the data show.

García-Mora and Mora-Rivera's finding that Internet access matters most in less developed regions has direct implications for Puerto Rico. Maricao, the municipality with the highest unemployment in 2024, also reports one of the lowest broadband adoption rates (39.04%), and the southwestern and mountain municipalities with the worst labor-market outcomes are systematically those with the weakest broadband infrastructure. The Puerto Rico Broadband Program [7] digital equity plan acknowledges this structure, noting that adoption closely tracks municipal income. The strengthening broadband effect suggests that ongoing federal infrastructure investment under the Bipartisan Infrastructure Law has meaningful potential to affect labor-market outcomes in the most disadvantaged municipalities. However, the cross-sectional design cannot establish this causally.

Geographic Structure and Persistence

The five municipalities at the top of the 2024 unemployment distribution (Maricao, Maunabo, Arroyo, Guánica, Guayanilla) show similar patterns across the panel, indicating slow-moving structural disadvantage rather than year-specific artifacts. COVID-19 is evident in the 2020 cross-section but did not substantially alter the rank ordering, and recovery has not closed the geographic gap. This supports the Federal Reserve Bank of New York [4] and CentroPR [5] argument that aggregate territorial statistics obscure sub-territorial heterogeneity, making municipal-level analysis necessary for evidence-based policy targeting.

CONCLUSION

Across a 468-observation municipality-year panel for Puerto Rico's 78 municipalities (2019–2024), poverty is the dominant correlate of municipal unemployment, with a stable, strongly positive association in every year and pooled (a 10-percentage-point rise in poverty corresponds to roughly 1.5 additional points of unemployment); educational attainment correlates bivariately but loses joint significance, operating principally through poverty, while broadband shows a moderate negative correlation strengthening to pooled significance. These results extend prior work [1] [2] [3] [6] into a small, fiscally constrained U.S. territory, are robust to shocks, including COVID-19, and support geographically targeted investment, particularly in poverty alleviation and broadband expansion, in municipalities that combine the weakest broadband adoption with the highest unemployment. Methodologically, the study contributes a fully reproducible analytical pipeline that future work can extend without rebuilding the data infrastructure.

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