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Article

Implication of education levels on gender wage gap across states in the United States and Puerto Rico

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SUMMARY

The Gender Wage Gap (GWG) refers to the disparity in earnings between women and men, with women typically earning less than men for the same work. Recognizing the persistent challenge posed by this gap and the need for deeper investigation into its causes, we examined the relationship between education levels and the GWG among men, women and all adults in the United States (US) and Puerto Rico. We hypothesized that higher levels of education are likely associated with a lower GWG, whereas lower levels of education are more likely linked to a higher GWG. Utilizing data from 2010 to 2022, we analyzed trends in Annual Median Income and GWG dynamics across varying education levels. Based on data from all states, District of Columbia, and Puerto Rico, we uncovered significant disparities in GWG, highlighting an inverse correlation between education levels and GWG, where higher education is associated with reduced disparities. This underscores a potential relationship between education and wage disparities. By acknowledging the impact of education on GWG, policymakers can implement targeted strategies to close the gender gap in higher education, thereby promoting educational achievement and advancing socioeconomic standing. The results of our study highlight important implications for advancing gender equality, informing policy decisions and fostering a more equitable society through targeted interventions.

INTRODUCTION

Gender discrimination involves unfair treatment based on gender or gender identity, seen in workplaces, education, healthcare, and legal systems (1–4). Gender discrimination perpetuates inequalities such as pay gaps, limited opportunities based on gender, and biased access to services such as healthcare and educational services (5). Gender discrimination has deep historical roots, with examples across various cultures and time periods (5). While it is challenging to pinpoint an exact starting point, historical records indicate that gender-based inequalities have existed for centuries (6). Ancient societies often upheld patriarchal structures that assigned women to subordinate roles, limiting their rights, opportunities, and freedoms compared to men (1). Examples of patriarchal structures include restrictions on women's participation in politics, education, and the workforce, as well as practices such as forced marriage and gender-based violence (7).

Pay discrimination, particularly the Gender Wage Gap (GWG), is a pernicious form of gender discrimination. GWG denotes the unequal compensation between men and women despite them having similar or identical job roles (2). GWG persists even among individuals with similar qualifications and educational attainments (8). Factors such as occupational segregation, discriminatory hiring practices, and societal gender role expectations contribute to this disparity (9). The ramifications of this inequality include diminished lifetime earnings for women and thus heightened vulnerability to poverty which persists even after retirement (10). The GWG further translates into reduced social security and pension benefits for women, with their average benefits amounting to only 80% of those received by men (10). Despite existing legal protections, inconsistencies in enforcement perpetuate these disparities, especially for marginalized groups facing multiple challenges.

Research examining the relationship between the GWG and educational level has generally found that while education reduces the GWG, it does not eliminate it (9, 11–13). Most studies support a correlation between the GWG and educational level and often emphasize that higher levels of education tend to be associated with narrower GWG. For instance, one study revealed that while a GWG existed across all education levels, it tended to be narrower among individuals with higher educational attainment (9). Another study indicated that while higher education levels are linked to increased earnings for both men and women, women still earn less than men at every level of education (13). However, the extent to which education mitigates the GWG remains debated. Some studies suggest that education plays a significant role in reducing GWG, while others argue that factors such as occupational segregation plays a role thereby creating GWG in all education levels (14).

Building on this existing research, we explored the relationship between GWG and educational attainment. We hypothesized that there would be a negative correlation between higher levels of education and GWG. Despite educational progress and varying economic contexts among states, we hypothesized that there would be a persistent GWG across all education levels in the United States (US) and Puerto Rico, although this may vary by state. Our investigation suggested that there was a correlation between education levels and the GWG in the US and Puerto Rico. Annual Median Income (AMI) has consistently risen from 2010 to 2022, indicating overall economic growth, yet GWG persists, with men consistently out-earning women. Despite income increases for both genders, men experienced a faster rate of growth, widening the income gap over time. Analysis of GWG across education levels showed notable differences since 2014. Individuals with less than a high school education have consistently faced the highest disparities. State-

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specific analysis highlighted an inverse relationship between education levels and GWG.

RESULTS

We examined data from the American Community Survey (ACS), focusing on the estimated AMI for individuals aged 25 and above from 2010 to 2022 except for 2020, as there was no survey conducted because of the COVID pandemic. Our analysis revealed a consistent upward trajectory in AMI over this timeframe (**Figure 1**). GWG persisted with men consistently out-earning women. The AMI for all adults increased from approximately $33,300 in 2010 to approximately $50,000 in 2022. Meanwhile, the AMI for men rose from approximately $40,000 in 2010 to approximately $56,500 in 2022, whereas for women, it increased from approximately $28,500 in 2010 to approximately $42,000 in 2022. Specifically, the AMI for men increased by approximately $16,500, while for women, it rose by approximately $13,500 during the period from 2010 to 2022.

The equations for the trendlines representing AMI for all adults, men, and women are as follows:

For all adults:

$$y = 1249.8x + 30672 \; (R^2 = 0.92,\ p\text{-value} = 8.5 \times 10^{-7}) \quad (1)$$

For all men:

$$y = 1298.9x + 36680 \; (R^2 = 0.92,\ p\text{-value} = 9.6 \times 10^{-7}) \quad (2)$$

For all women:

$$y = 1095.5x + 25802 \; (R^2 = 0.86,\ p\text{-value} = 2.3 \times 10^{-6}) \quad (3)$$

These equations had high R^2 values (>0.85) and low p-values (<0.05), which indicated strong and statistically significant relationships between AMI (y-axis) and year (x-axis) and suggested that the linear models provided good fits to the data. These equations suggested that the rate of AMI growth among men as indicated in the slope values of the trendlines surpassed that among women over the period analyzed. Hence, both the AMI and the rate of increase in AMI were higher for men compared to women during the period from 2010 to 2022 (**Figure 1**).

We proceeded to examine the GWG between men and women across different education levels for the period from 2010 to 2022 to ascertain any correlation between education levels and the GWG (**Figure 2**). Observing a distinct difference in the relationship between education levels and GWG across two periods (2010 to 2013 and 2014 to 2022), we categorized 2010 to 2013 as Zone 1 and 2014 to 2022 as Zone 2 to better analyze these trends. Throughout this period, the GWG ranged from about 29% to about 37%. Notably, from 2010 to 2013, the GWG for all education levels remained relatively consistent, suggesting a minimal association between education levels and the GWG (depicted as Zone 1 in **Figure 2**). However, since 2014, the GWG for adults with less than a high school education level was consistently the highest among all education levels, followed by the GWG for adults with a high school education level (depicted as Zone 2 in **Figure 2**). The GWG exhibited a wider distribution in Zone 2, ranging from about 29% to about 37%. Among people with more than a high school education, there appeared to be little correlation between education level and the GWG in Zone 2. Overall, there was a discernible widening of the GWG in Zone 2 compared to Zone 1, suggesting a shift in the dynamics of gender wage disparities over time.

We analyzed the GWG across 50 states, District of Columbia, and Puerto Rico, and education levels for 2022. GWG among all adults varied from 14% to 40% by geography, with Utah having the highest and District of Columbia the lowest (**Figure 3**). Across education levels, GWG ranged

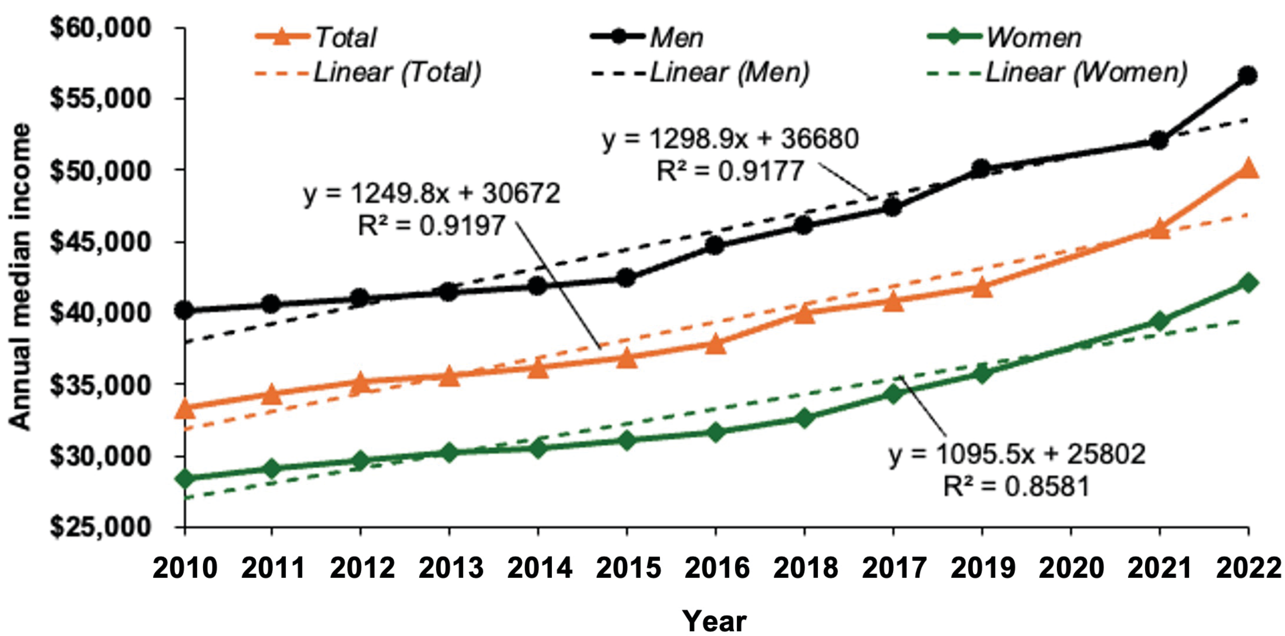

Figure 1: Trends in annual median income (AMI) of adults above the age of 25 in the US and Puerto Rico, 2010-2022. AMI rose consistently throughout this time period. All adult AMI ranged from about $33,300 (2010) to about $50,000 (2022), men AMI from about $40,000 to about $56,500, and women AMI from about $28,500 to about $42,000. Men AMI growth outpaced that of women. Dashed lines indicate linear fits.

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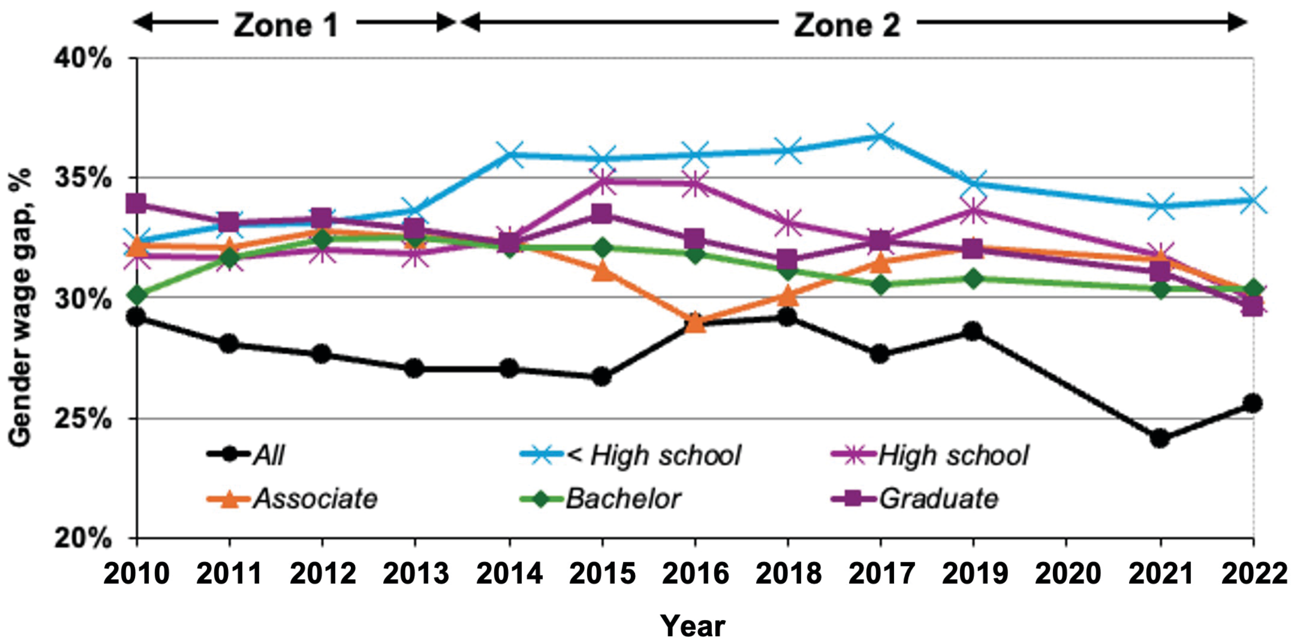

Figure 2: Gender wage gap (GWG) in the US and Puerto Rico for different education levels, 2010-2022. GWG ranged from 29% to 37%. Zone 1 (2010-2013) showed minimal association between education levels and GWG. Since 2014 (Zone 2), adults with less than a high school education consistently exhibited the highest GWG. High school graduates showed a high GWG compared to other education levels within Zone 2, indicating a shift in gender wage disparity dynamics.

from 12% to 48%, with the highest disparities observed among individuals with less than a high school education and lowest among those with a graduate degree. For example, GWG was highest in Rhode Island for individuals with less than a high school education, and lowest in Alaska for those with a graduate degree. State-specific GWG varied from 4% to 31% across education levels, with the District of Columbia having the highest variation across different education levels and Washington, Vermont, and Florida the lowest. In some states, including Washington, Vermont, Florida, Idaho, Wisconsin, Maryland, and Connecticut, the GWG across different education levels varied by approximately 5%. For example, in Washington, the GWG was 33% for individuals with less than a high school diploma, 30% for those with a high school education, 31% for an associate degree, 34% for a bachelor's degree, and 33% for a graduate degree, resulting in a range of 4% (34% - 30%). In contrast, several states, such as Alabama, Connecticut, Idaho, South Carolina, Texas, Utah, Virginia, and Washington, had GWGs exceeding 30% across all education levels.

The relationship between education levels and GWG was initially unclear. To improve clarity, we ranked the data by each state's GWG from highest to lowest, assigning a value of 1 to the highest GWG and 5 to the lowest (**Figure 4**). We plotted normalized data for five years (2017, 2018, 2019, 2021, and 2022) across all educational levels (**Figures 4a–e**). We believe that analyzing data from these five years provides a sufficient basis to determine the frequency of GWG rankings across all education levels in all. On average, 53% of states had the highest GWG among individuals with less than a high school education, while only 8% had the lowest GWG among this group (**Figure 4a**). Conversely, on average, 41% of all states had the lowest GWG among individuals with a graduate education, while only 9% had the highest GWG among this group (**Figure 4e**). This transition was evident in the 2nd polynomial trendline on average GWG values across all education levels (**Figure 4f**). The inverse relationship between education levels and GWG is evident, supported by data spanning five years.

The polynomial trendline equations for each education level are as follows:

For less than high school:

$y = 0.0537x^2 - 0.4244x + 0.8825$ ($R^2 = 0.97$, p-value = 0.03) (4)

For high school:

$y = -0.0118x^2 + 0.0259x + 0.2518$ ($R^2 = 0.67$, p-value = 0.33) (5)

For associate's degree:

$y = -0.0485x^2 + 0.3006x + 0.1686$ ($R^2 = 0.86$, p-value = 0.14) (6)

For bachelor's degree

$y = -0.0215x^2 + 0.1739x - 0.085$ ($R^2 = 0.55$, p-value= 0.45) (7)

For graduate degree:

$y = 0.0226x^2 - 0.0611x + 0.1349$ ($R^2 = 0.98$, p-value = 0.02) (8)

The polynomial trendlines indicate how the frequency of state GWG rankings for the years 2017, 2018, 2019, 2021, and 2022 varies with education levels. The goodness of fit, measured by the R^2 values and p-values, suggests that a second-order polynomial accurately models these variations for education levels of less than high school ($R^2 = 0.97$ and p-value = 0.03) and graduate degree ($R^2 = 0.98$ and p-value = .02) since both have strong fits and are statistically significant (p-value < 0.05). In these cases, the high R^2 values indicate that changes in education levels correspond closely with shifts in state GWG rankings. However, for

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States	All	< High school	High school	Associate degree	Bachelor degree	Graduate degree
Alabama	32%	31%	37%	38%	34%	35%
Alaska	22%	27%	28%	26%	28%	12%
Arizona	21%	30%	23%	23%	29%	31%
Arkansas	27%	33%	32%	32%	30%	22%
California	22%	32%	25%	28%	25%	28%
Colorado	26%	33%	31%	28%	33%	31%
Connecticut	24%	32%	34%	30%	30%	31%
Delaware	21%	16%	22%	21%	33%	27%
District of Columbia	14%	44%	NSS	NSS	14%	21%
Florida	23%	27%	28%	27%	27%	31%
Georgia	24%	33%	25%	31%	31%	31%
Hawaii	26%	24%	25%	32%	29%	21%
Idaho	32%	37%	37%	35%	38%	33%
Illinois	27%	33%	32%	32%	29%	27%
Indiana	28%	31%	33%	35%	31%	26%
Iowa	25%	32%	38%	32%	28%	21%
Kansas	27%	36%	34%	33%	31%	28%
Kentucky	27%	29%	35%	32%	31%	28%
Louisiana	32%	38%	42%	39%	29%	29%
Maine	22%	NSS	24%	33%	23%	23%
Maryland	21%	31%	30%	31%	26%	26%
Massachusetts	25%	29%	34%	28%	29%	29%
Michigan	28%	38%	32%	34%	33%	29%
Minnesota	25%	35%	32%	31%	26%	18%
Mississippi	27%	37%	36%	34%	32%	25%
Missouri	25%	36%	31%	31%	27%	29%
Montana	28%	44%	42%	32%	27%	21%
Nebraska	26%	36%	29%	37%	26%	24%
Nevada	19%	19%	21%	24%	24%	20%
New Hampshire	28%	17%	28%	36%	32%	28%
New Jersey	26%	30%	35%	29%	29%	32%
New Mexico	19%	34%	26%	26%	22%	28%
New York	20%	33%	30%	27%	24%	22%
North Carolina	22%	32%	28%	27%	29%	35%
North Dakota	28%	46%	32%	35%	27%	25%
Ohio	26%	38%	33%	31%	29%	26%
Oklahoma	27%	40%	33%	33%	30%	29%
Oregon	24%	31%	26%	30%	28%	22%
Pennsylvania	27%	40%	32%	30%	30%	27%
Puerto Rico	NSS	NSS	22%	23%	14%	29%
Rhode Island	23%	48%	32%	26%	25%	24%
South Carolina	28%	40%	34%	33%	34%	40%
South Dakota	22%	31%	26%	30%	24%	21%
Tennessee	25%	25%	29%	30%	34%	31%
Texas	27%	38%	36%	31%	30%	34%
Utah	40%	36%	35%	39%	40%	41%
Vermont	14%	24%	27%	28%	NSS	23%
Virginia	27%	41%	34%	30%	31%	34%
Washington	28%	33%	30%	31%	34%	33%
West Virginia	28%	30%	37%	35%	25%	30%
Wisconsin	26%	30%	34%	30%	29%	29%
Wyoming	32%	NSS	42%	35%	31%	23%

NSS: Not statistically significant

Increase in GWG →

>10% to ≦20%	>20% to ≦30%	>30% to ≦40%	>40% to ≦50%

Figure 3: Gender wage gap (GWG) across states, District of Columbia, Puerto Rico, and education levels, 2022. GWG ranged from 14% to 40% among all adults, highest in Utah and lowest in the District of Columbia. Across education levels, GWG varied from 12% to 48%, with Rhode Island's less than high school graduates and Alaska's graduate degree holders at extremes. Some states, including Washington and Vermont, showed narrow GWG ranges. Several states, including Alabama, Connecticut and Idaho, exhibited GWG exceeding 30% across all education levels.

high school (R^2 = 0.67 and p-value = 0.33) and bachelor's degree (R^2 = 0.55 and p-value = 0.45), the lower R^2 values and higher p-values suggest that a second-order polynomial does not explain the variations as well, implying weaker correlations between these education levels and state GWG rankings. The associate degree (R^2 = 0.86, p-value = 0.14) shows a strong model fit because of high R^2 value but its high p-value (p-value > 0.05) suggests that this relationship is not statistically significant.

DISCUSSION

This study explored the relationship between GWG and educational levels across the US and Puerto Rico, focusing on trends from 2010 to 2022. Using data from the ACS, we analyzed AMI trends for men and women and examined how the GWG varied across different education levels and states. Our findings revealed a persistent GWG across all education levels, with men consistently out-earning women, and identified an inverse relationship between education levels and GWG. These results highlight the importance of addressing educational disparities and systemic biases to reduce GWG and promote gender pay equity nationwide.

The findings from our investigation into the AMI trends among individuals aged 25 and above from 2010 to 2022 revealed clear trends. Firstly, we identified a consistent upward trajectory in AMI over the study period, indicating overall economic growth within the US and Puerto Rico. This upward trend is consistent with broader economic indicators such as Gross Domestic Product (GDP) and unemployment rate and reflects positive advancements in the nation's financial well-being (15). However, amidst this growth, a gender gap in AMI persisted, with men consistently outearning women. Despite the overall increase in AMI for both genders, we found that the rate of income growth among men surpassed that of women over the analyzed period. The equations derived from the trendlines further support the observations, indicating a higher rate of AMI growth among men compared to women.

The examination of the GWG across different education levels from 2010 to 2022 revealed patterns in the dynamics of GWG in the US and Puerto Rico. From 2010 to 2013 (Zone 1), the GWG across all education levels remained relatively stable, indicating minimal association between education and the wage gap. However, since 2014 (Zone 2), individuals with less than a high school education consistently experienced the highest GWG, followed closely by high school graduates. This widening gap, ranging from 29% to 37%, highlights increasing GWG, particularly among those with lower educational attainment. Beyond these groups, little correlation between education and GWG was observed in Zone 2, signaling a divergence in earnings trajectories tied to education levels.

The analysis of the GWG across all states, District of Columbia, and Puerto Rico, and education levels for the year 2022 provides valuable insights into the variations and determinants of gender wage disparities in the US and Puerto Rico. Across all states, District of Columbia and Puerto Rico, the GWG exhibited a wide range, with disparities ranging from 14% to 40%. These differences could be influenced by factors such as the proportion of individuals with higher education levels, which tends to correlate with higher wages and narrower GWGs. For instance, the District of Columbia has a higher concentration of individuals with advanced degrees and professional jobs, which may offer more equitable pay structures. According to the US Census Bureau, 65.9% of District of Columbia residents aged 25 and over had a bachelor's degree or higher (16). Conversely, Utah's larger GWG could reflect a workforce concentrated in industries or roles with significant wage disparities and traditional gender norms that may limit women's workforce participation in higher-paying positions (17). Additionally, variations in state-level labor laws, childcare support, and cultural attitudes toward gender

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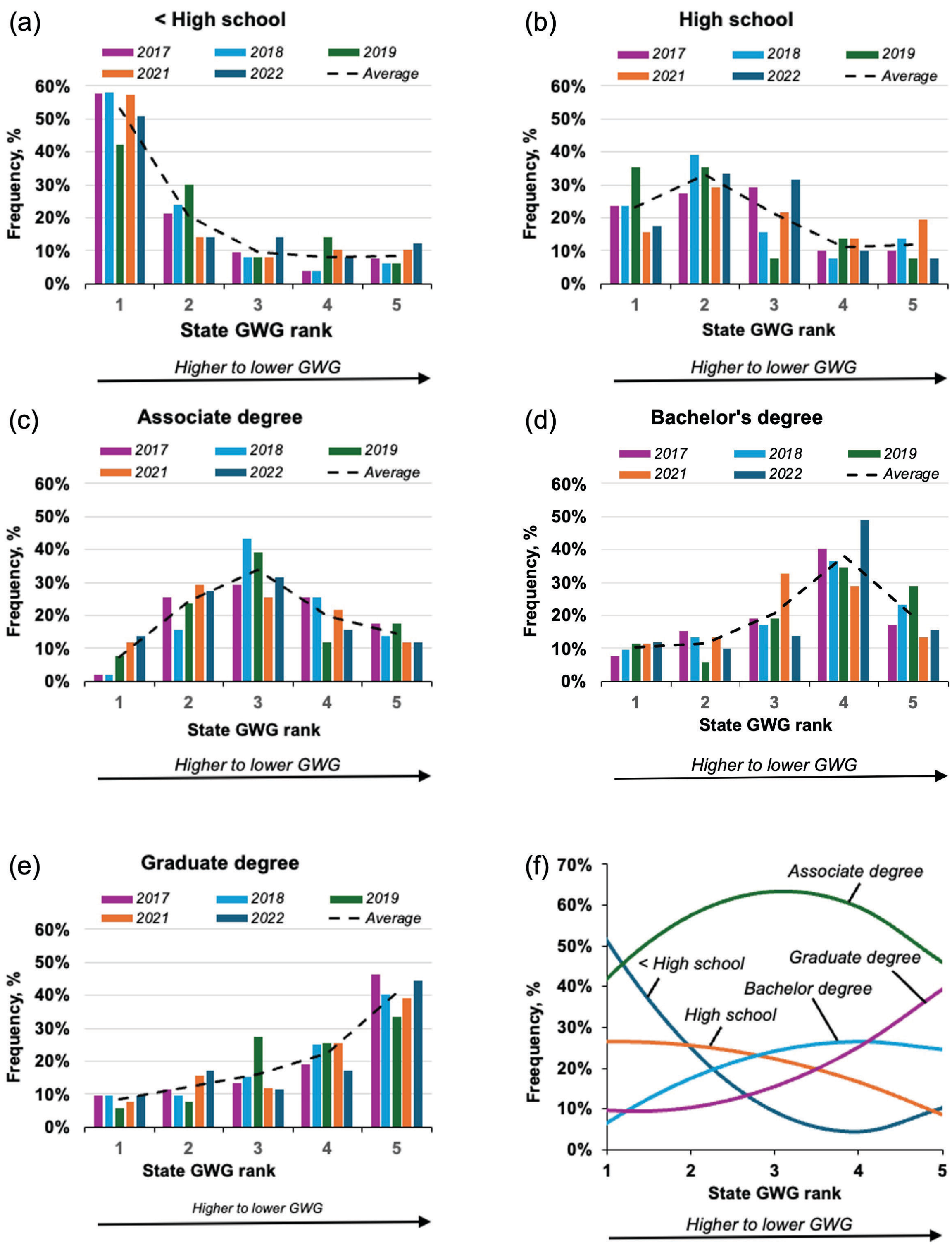

Figure 4: Frequency of gender wage gap (GWG) rank across education levels in all states, District of Columbia and Puerto Rico. Plots of GWG in 2017, 2018, 2019, 2021, 2022, and the average of this five-year period for the following education levels: **(a)** Less than high school, **(b)** High school, **(c)** Associate degree, **(d)** Bachelor's degree, and **(e)** Graduate degree. **(f)** Trendlines depicted average frequencies for each education level. The state GWG rank for various educational levels within each state was initially assessed on a scale from 1 to 5, where 5 indicated the smallest GWG disparity and 1 indicated the largest. The frequency percentage was subsequently calculated by tallying the occurrences of ranks 1 through 5 across all states for each educational level, multiplying by 100, and then dividing by the total number of states with statistically significant data. GWG was highest for less than high school education and lowest for graduate degree holders. Polynomial trendlines (f) and averages, as shown by the dashed lines in (a-e) depicted an inverse relationship between education levels and GWG, supported by five-year data.

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roles could also play a role in shaping these disparities. When examining GWG across education levels, further disparities emerge, with ranges varying from 12% to 48%. Particularly striking was the finding that individuals with less than a high school education in Rhode Island faced the highest GWG, while graduate degree holders in Alaska experienced the lowest, underscoring the influence of educational attainment on gender wage disparities. State-specific analysis revealed considerable variability in GWG, with disparities ranging from 4% to 31% across education levels. Some states, such as Washington, Vermont, Florida, Idaho, Wisconsin, Maryland, and Connecticut, demonstrated narrow GWG ranges of about 5% across education levels, suggesting a more equitable distribution of wages between genders within these states. This may be attributed to factors such as stronger labor laws promoting wage transparency, higher union representation, or industries that employ a more balanced gender distribution in higher-paying roles. Conversely, several states, including Alabama, Connecticut, Idaho, South Carolina, Texas, Utah, Virginia, and Washington, exhibited GWG exceeding 30% across all education levels, indicating significant challenges in achieving gender wage equality. These disparities could stem from industry composition, with men-dominated, high-paying industries being more prevalent, or cultural and policy differences, such as weaker protections against wage discrimination or limited access to affordable childcare, which disproportionately impact women's participation in high-wage jobs.

The normalization of GWG data and its subsequent plotting across different educational levels and years provided a clearer understanding of the relationship between education levels and GWG dynamics in the US and Puerto Rico. Comparing data of education levels of less than high school and graduate degree, representing two extreme education levels, it's clear that GWG is inversely related to these educational categories. The second-order polynomial trendlines show a strong relationship between education levels and GWG, as demonstrated with high R^2 values and low p-values for less than high school (R^2 = 0.97 and p-value = 0.03), and graduate degree (R^2 = 0.98 and p-value = 0.02). These results indicate that lower and higher education levels are more strongly correlated with state GWG rankings. However, the lower R^2 values and higher p-values for high school (R^2 = 0.67 and p-value = 0.33) and bachelor's degree (R^2 = 0.55 and p-value = 0.45) suggest a weaker relationship, suggesting that other factors such as occupation segregation may be influencing GWG rankings at these education levels. While the associate degree (R^2 = 0.86, p-value = 0.14) shows a strong model fit, its lack of statistical significance (p >0.05) indicates that the observed relationship may be due to random chance rather than a consistent trend.

Select other studies found little to no correlation between educational attainment and the GWG. One study reported that gender differences in educational attainment played a negligible role in explaining the earnings gap in 1985 and 1990 (18). Another study suggested that gender disparities in wages were primarily due to variations in labor market characteristics, which refer to factors such as occupational segregation (the tendency for men and women to work in different industries or job types) and geographic differences in employment opportunities and wage levels. These factors may influence GWG because women are often overrepresented in lower-paying occupations or regions with fewer high-paying job opportunities, while men are more likely to occupy roles or locations with higher earning potential (19). The authors emphasized that these differences in market dynamics, particularly among executives, played a significant role in shaping wage gaps (19). Conversely, data from the Pew Research Center suggested that while the GWG varied across educational levels, it remained persistent even among highly educated individuals (11). Additionally, a study highlighted that while women's educational advancements historically contributed to narrowing the gender income gap, differences in chosen fields of study, occupational segregation, and factors such as industry type, work hours, and career interruptions now play a greater role in contemporary income inequality among young workers (14). Overall, while some research suggests that higher levels of education are associated with a narrower GWG, other studies indicate that education alone may not be sufficient to eliminate gender-based wage disparities. Factors such as occupational segregation, discrimination, and societal norms may also significantly contribute to the persistence of the GWG across different educational levels (13).

Understanding the factors contributing to GWG is essential for advancing economic equity and social justice. Beyond its moral imperative, closing the wage gap carries significant economic benefits, such as boosting productivity, alleviating poverty, and fostering inclusive economic growth. According to a Moody's Analytics analysis, Organization for Economic Cooperation and Development (OECD) countries could increase global economic activity by approximately 7%, or about $7 trillion, by closing GWG (20). Most OECD countries are classified as developed, characterized by high-income economies and advanced infrastructure. Examples include the US, Germany, and Japan, though the OECD also includes some upper-middle-income countries, such as Mexico and Turkey. In 2022 alone, the GWG led to a collective loss of over $1.6 trillion for working women in the US, equivalent to 6.3% of the US GDP for that year (21). From 1967 to 2021, women endured a cumulative wage loss of $61 trillion due to this gap, nearly doubling the US government debt in 2023 (21). Women's wages are vital for family well-being and US economic prosperity. However, the existence of the GWG reflects societal factors that contribute to disparities in workforce participation. These disparities may pressure women into making caregiving sacrifices, such as reducing their work hours or leaving the labor force altogether (3). Furthermore, addressing GWG aligns with broader initiatives aimed at advancing gender equality and cultivating inclusive workplaces, benefiting individuals, families, and society at large. Addressing these disparities requires multifaceted approaches such as enforcing equal pay laws and incentivizing diverse hiring, workplace initiatives like implementing transparent pay structures, and cultural shifts aimed at promoting gender equity and fair compensation practices. Together, these measures can help reduce systemic barriers, close wage gaps, and create an environment where fair compensation practices are prioritized.

A key limitation of this study is its reliance on educational attainment as the primary variable for understanding the GWG. While education is an important factor, this approach may overlook other critical influences such as occupational segregation, work experience, industry-specific wage disparities, and societal expectations around gender roles. Additionally, this study does not account for non-quantifiable factors like workplace discrimination or negotiation behaviors, which can also contribute to wage disparities. Another limitation is the geographical scope of the data, which may not capture regional differences within or across countries. These limitations suggest that a more comprehensive analysis incorporating a wider range of variables is necessary to fully understand the persistence of the GWG.

In conclusion, this study highlights the relationships between gender, education, and income disparities in the US and Puerto Rico workforce. By analyzing patterns of GWG across educational levels and states over time, we provide descriptive insights into the trends and disparities observed. While this information is valuable for informing discussions among policymakers and stakeholders, we acknowledge that our analysis does not identify causal relationships or specific variables driving the GWG. Moreover, while promoting educational attainment is often considered a pathway to economic equity, our findings suggest that the effectiveness of such interventions may depend on careful consideration of how existing inequalities intersect with educational access and outcomes. Hence, further research could explore the dynamics further, enabling more targeted and evidence-based policy to address GWG.

MATERIALS AND METHODS

Estimated AMI for men and women among people above 25 years of age categorized by education levels and 50 states, District of Columbia, and Puerto Rico were collected from the ACS using S1501: Education Attainment, ACS 1-Year Estimates Subject Tables (22). All 50 states, D.C., and Puerto Rico are referred to as states in this article. However, we acknowledge that Puerto Rico is not a state and has a distinct political status. The ACS, conducted by the US Census Bureau, provides comprehensive nationwide demographic, social, economic, and housing data. According to the US Census Bureau, AMI is defined as the midpoint of the household income distribution (23). The US Census Bureau categorizes income data by sex as ‘male’ and ‘female’. In this study, we use ‘men’ for ‘male’ and ‘women’ for ‘female’ to align with gender terminology.

We used Microsoft Excel for Mac, Version 16.82, for all the data analysis and visualization. Estimated AMI was considered as wage, and data was collected for 2010 to 2022. The GWG as a percentage was calculated using **Equation 9**, where *GWG*, I_M, and I_W represent GWG, estimated AMI for men, and estimated AMI for women, respectively.

$$\% \, GWG = \frac{I_M - I_W}{I_M} * 100 \tag{9}$$

Statistical significance was determined at a 90% confidence level using margin of error data and estimated median income for men and women from Table S1501 and as per ACS instructions (24). The data was deemed statistically significant if **Equation 10** was true. MOE_M, MOE_W, and Z_{CL} represent the margin of error for estimated AMI for men, the margin of error for estimated AMI for women, and critical value for confidence level, respectively. We used a critical value of 1.645 to calculate the 90% confidence level.

$$\left| \frac{I_M - I_W}{\sqrt{\left(\frac{MOE_M}{Z_{CL}}\right)^2 + \left(\frac{MOE_W}{Z_{CL}}\right)^2}} \right| > Z_{CL} \tag{10}$$

We excluded data that did not meet the criteria for statistical significance from the analysis. We considered the following education levels: less than high school graduate, high school graduate (includes equivalency), some college or associate degree, bachelor's degree, and graduate or professional degree. Less than high school graduate, high school graduate (includes equivalency), some college or associate degree, bachelor's degree, and graduate or professional degree were referred to as “< high school”, “high school”, “associate degree”, “bachelor’s degree” and “graduate degree”, respectively for simplicity. We used Microsoft Excel to generate the first - (linear) and second - (quadratic) order polynomial trendlines.

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