Analysis of Female Labor Force Participation in Java Island Using Multiscale Geographically Weighted Regression with an Adaptive Bisquare Kernel

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ABSTRAK

Partisipasi kerja perempuan merupakan indikator penting dalam pembangunan ketenagakerjaan dan kesetaraan gender. Namun, Tingkat Partisipasi Angkatan Kerja Perempuan (TPAKP) di Pulau Jawa masih menunjukkan ketimpangan antarwilayah yang mengindikasikan adanya pengaruh spasial. Penelitian ini bertujuan untuk menganalisis faktor-faktor sosial ekonomi yang memengaruhi TPAKP di 119 kabupaten/kota di Pulau Jawa pada tahun 2024 menggunakan metode Multiscale Geographically Weighted Regression (MGWR) dengan kernel adaptive bisquare menggunakan Python. Data penelitian bersumber dari Badan Pusat Statistik (BPS) tahun 2024. Variabel penjelas yang digunakan meliputi Upah Minimum Kabupaten/Kota, jumlah penduduk miskin, Indeks Ketimpangan Gender, Produk Domestik Regional Bruto, persentase perempuan di parlemen, jumlah perempuan yang mengurus rumah tangga, dan Indeks Pembangunan Gender. Konstribusi penelitian ini terletak pada penerapan MGWR dengan kernel adaptive bisquare secara spesifik untuk wilayah Pulau Jawa yang memungkinkan estimasi parameter yang berbeda di setiap lokasi. Hasil penelitian menunjukkan adanya heterogenitas spasial yang signifikan. UMK merupakan variabel yang paling konsisten berpengaruh signifikan negatif di sebagian besar wilayah. Temuan ini berimplikasi pada perlunya kebijakan ketenagakerjaan dan pemberdayaan perempuan yang bersifat region-specific, tidak seragam di seluruh Pulau Jawa.

Kata kunci: Partisipasi Kerja Perempuan; MGWR; Kernel Adaptive Bisquare

ABSTRACT

Female labor force participation is an important indicator in labor development and gender equality. However, the Female Labor Force Participation Rate (FLFPR) in Java Island still shows disparities across regions, indicating the presence of spatial influences. This study aims to analyze the socio-economic factors affecting the FLFPR in 119 regencies/cities on Java Island in 2024 using the Multiscale Geographically Weighted Regression (MGWR) method with an adaptive bisquare kernel implemented in Python. The data used in this study were obtained from Statistics Indonesia (Badan Pusat Statistik) in 2024. The explanatory variables include the Regency/City Minimum Wage, number of poor population, Gender Inequality Index, Gross Regional Domestic Product, percentage of women in parliament, number of women managing households, and the Gender Development Index. The contribution of this research lies in the specific application of MGWR with an adaptive bisquare kernel for the Java Island region, which allows parameter estimates to vary across locations. The results indicate significant spatial heterogeneity. The minimum wage variable is the most consistently significant factor with a negative effect in most regions. These findings imply the need for region-specific employment and women's empowerment policies rather than uniform policies across Java Island.

Keywords: *Female Labor Force Participation; MGWR; Adaptive Bisquare kernel*

INTRODUCTION

Regression analysis is a widely used statistical approach to examine the relationship between a dependent variable and a set of explanatory variables, as well as to generate predictions based on these relationships [1]. The most commonly applied method is Ordinary Least Squares (OLS), which produces a single global model under the assumption that the effect of each explanatory variable is constant across the entire study area. In addition, OLS relies on classical assumptions such as homoskedasticity and independence of errors [2]. However, these assumptions are often violated when dealing with spatial data, where observations are influenced by location-specific characteristics.

In spatial contexts, variations across regions may lead to spatial heterogeneity, a condition in which the relationships between explanatory variables and the response variable differ across locations [3]. Such heterogeneity typically arises due to differences in socio-economic, demographic, and geographical conditions. Under these circumstances, global regression models such as OLS may be inadequate because they fail to capture local variations in relationships.

To address this limitation, Geographically Weighted Regression (GWR) was developed as a local regression approach that allows model parameters to vary spatially [4]. GWR estimates location-specific coefficients by applying spatial weights determined by a kernel function and a bandwidth parameter. However, GWR assumes a single bandwidth for all explanatory variables, implying that all variables operate at the same spatial scale. This assumption may not hold in practice, as different socio-economic factors often influence the response variable at different spatial scales. In addition, GWR may still be affected by local multicollinearity.

Multiscale Geographically Weighted Regression (MGWR) extends GWR by allowing each explanatory variable to have its own bandwidth, thereby capturing spatial processes operating at multiple scales [5]. This flexibility enables MGWR to provide a more accurate representation of spatial heterogeneity and to reduce local multicollinearity issues. Consequently, MGWR is considered more suitable for modeling complex spatial relationships compared to both OLS and traditional GWR.

Female Labor Force Participation Rate (FLFPR) represents an important socio-economic indicator with strong spatial characteristics. Increasing women's participation in the labor force is part of Indonesia's long-term development agenda under the Vision of Indonesia Emas 2045, with a target increase from 56.05% in 2023 to 58.38% in 2045 [6]. However, female labor force participation remains uneven across regions, particularly on Java Island. For instance, in 2023, the Special Region of Yogyakarta recorded a participation rate of 64.75%, while Banten Province recorded only 46.16% [7]. These disparities suggest that the determinants of FLFPR may vary spatially.

Previous studies have examined the determinants of female labor force participation using various approaches. A study by [8] applied panel data regression and found that socio-economic factors significantly influence FLFPR in Indonesia. Meanwhile, [9] utilized GWR with a fixed Gaussian kernel to analyze spatial variation in Aceh Province, demonstrating the importance of spatial modeling. In addition, [10] applied MGWR to analyze open unemployment rates in West Java, showing that MGWR can better capture spatial heterogeneity compared to GWR.

Despite these contributions, studies that specifically apply MGWR to analyze FLFPR at the regency/city level across Java Island remain limited. In particular, the use of an adaptive bisquare kernel to capture varying spatial densities has not been sufficiently explored in this context. Therefore, a more flexible spatial modeling approach is needed to better understand the spatial variation in FLFPR and its determinants.

Based on this research gap, this study aims to analyze the spatial variation in the influence of socio-economic factors on female labor force participation across 119 regencies/cities on Java Island in 2024 using the MGWR model with an adaptive bisquare kernel. The findings are expected to provide a more comprehensive understanding of spatial patterns in FLFPR and support the formulation of region-specific labor and gender empowerment policies.

METHOD

Data Sources and Research Variables

This study uses secondary data obtained from the Indonesian Central Bureau of Statistics (Badan Pusat Statistik). The unit of analysis consists of 119 regencies/cities on Java Island in 2024. Each observation is represented by geographic coordinates (u_i, v_i), corresponding to the centroid of each region. The dependent variable is the Female Labor Force Participation Rate (FLFPR), denoted by y_i. The independent variables are denoted by $x_{ik}, k = 1,2,\cdots 7$, representing socio-economic indicators as summarized in Table 1.

Table 1. Descriptive Statistics

Variable	Variable Name	Description
Y	Female Labor Force Participation Rate (FLFPR)	Percentage (%)
(X_1)	Regency/City Minimum Wage (UMK)	Rupiah/month
(X_2)	Number of Poor Population	Persons
(X_3)	Gender Inequality Index (GII)	Index (0-1)
(X_4)	Gross Regional Domestic Product (GRDP)	Billion Rupiah
(X_5)	Percentage of Women in Parliament	Percentage (%)
(X_6)	Number of Women Managing Household Activities	Persons
(X_7)	Gender Development Index (GDI)	Index (0-100)

Multiple Linear Regression Model

As an initial model, multiple linear regression is estimated using the Ordinary Least Squares (OLS) method to capture the global relationship between variables. The model is specified as: [11]:

$$y_i = \beta_0 + \sum_{k=1}^{p} \beta_k x_{ik} + \varepsilon_i, \qquad i = 1,2,\cdots,n \tag{1}$$

where:

y_i = FLFPR at location i

x_{ik} = value of the k-th explanatory variable

β_k = regression coefficients

Identification of Spatial Effects

To justify the use of spatial regression, spatial effects are examined through tests of heterogeneity and spatial dependence.

Spatial Heterogeneity

Spatial heterogeneity is tested using the Breusch–Pagan (BP) test [12]:

$$BP = \frac{1}{2}\sum_{i=1}^{n}\left(\frac{e_i^2}{\sigma^2} - 1\right)^2 \tag{2}$$

where e_i represents residuals from the OLS model. The null hypothesis assumes homoskedasticity. Rejection indicates heterogeneity across locations.

Spatial Dependence

Spatial autocorrelation is tested using Moran's I [13]:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{S_0\sum_{i=1}^{n}(x_i-\bar{x})^2} \tag{3}$$

where w_{ij} denotes the elements of the spatial weight matrix representing the proximity between locations i and j, and $\bar{x}$ is the mean of the residuals, and S_0 is the sum of all spatial weights. The spatial weight matrix is constructed using the K-Nearest Neighboor (KNN) approach. Several candidates value of k (3,4,5, and 6) are evaluated, and the optimal value is selected based on the highest Moran's I statistic. The optimal configuration in this study is KNN with $k = 4$.

Multiscale Geographically Weighted Regression (MGWR)

MGWR is employed to capture spatially varying relationships at multiple scales. The model is defined as [14]:

$$y_i = \beta_{bw0}(u_i, v_i) + \sum_{k=1}^{p} \beta_{bwk}(u_i, v_i)\, x_{ik} + \varepsilon_i \tag{4}$$

where $\beta_k(u_i, v_i; bw_k)$ represents location-specific coefficients with variable-specific bandwidths.

Bandwidth Selection

Parameter estimation is conducted using a backfitting algorithm, where coefficients and bandwidths are iteratively updated until convergence. The optimal bandwidth for each variable is selected by minimizing the corrected Akaike Information Criterion (AICc) [15]:

$$AICc = n\, ln\left(\frac{SSE}{n}\right) + 2k + \frac{2k(k+1)}{n-k-1} + n\, ln(2\pi) + n \tag{5}$$

The optimization process uses the golden section search method. Convergence is achieved when the change in estimates is below 10^{-5}.

Kernel Function

This study employs the Adaptive Bisquare Kernel:

$$w_i(u_i, v_i) = \begin{cases} \left[1 - \left(\frac{d_{ij}}{h_i}\right)^2\right]^2 & ,if\ d_{ij} \le h_i \\ 0 & ,if\ d_{ij} > h_i \end{cases}$$

(6)

where:

d_{ij} = distance between locations i and j

h_i = adaptive bandwith

The adaptive kernel ensures that each local regression uses the same number of nearest neighbors, making it suitable for uneven spatial distributions. All computations related to the kernel weighting and bandwidth selection were implemented using the MGWR library in Python, which provides built-in functions for adaptive kernel specification, distance calculation (including spherical coordinates), and iterative bandwidth optimization within the MGWR framework.

Model Evaluation

Model performance is evaluated using the coefficient of determination [16]:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (7)$$

A model with a higher R^2 value is considered to have better performance in representing the data. This evaluation is used to assess the superiority of MGWR compared to the global regression model.

RESULT AND DISCUSSION

Descriptive Statistics

Descriptive statistics are used to summarize the distribution, central tendency, and variability of all variables across 119 regencies/cities on Java Island in 2024. The descriptive statistics of the variables used in this study are presented in Table 2.

Table 2. Descriptive Statistics

	Min	Mean	Std. Dev	Max
Female Labor Force Participation Rate (Y)	40.01	58.38	7.44	82.93
Regency/City Minimum Wage (X_1)	2,038,005	2,987,941	1,027,479	5,343,430
Number of Poor Population (X_2)	2,410	103,563	74,443	446,790
Gender Inequality Index (X_3)	0.093	0.301	0.134	0.641
Gross Regional Domestic Product (X_4)	5.55	105.96	167.63	922.86
Percentage of Women in Parliament (X_5)	2.00	19.23	6.61	34.29
Number of Women Managing Household Activities (X_6)	3,168	143,823	96,475	543,138
Gender Development Index (X_7)	81.02	91.83	3.88	98.65

Data Source: Indonesian Central of Statistics (BPS), 2024.

Based on Table 2, the Female Labor Force Participation Rate (Y) ranges from 40.01% to 82.93%, with a mean value of 58.38% and a standard deviation of 7.44. This relatively wide range indicates substantial regional disparities in women's participation in the labor market. Such variation suggests that local socio-economic conditions may play an important role in shaping female labor force participation.

Among the explanatory variables, the Regency/City Minimum Wage (X_1) shows considerable variation, reflecting differences in regional economic structures and labor market conditions. Similarly, the Number of Poor Population (X_2) and Women Managing Household Activities (X_6) exhibit high variability, indicating that socio-economic inequality and differences in domestic responsibilities remain prominent across regions.

In contrast, the Gender Inequality Index (X_3) and Gender Development Index (X_7) display relatively lower variability, suggesting that gender-related development indicators tend to be more evenly distributed across Java. Meanwhile, Gross Regional Domestic Product (X_4) shows substantial dispersion, which likely reflects the contrast between highly industrialized urban areas and predominantly agricultural regions. These descriptive findings provide initial evidence that both economic and social factors may contribute to spatial differences in FLFPR.

Multiple Linear Regression Analysis

Prior to applying the Multiscale Geographically Weighted Regression (MGWR) model, a global regression analysis using the Ordinary Least Squares (OLS) method was conducted as a baseline model to examine the overall relationship between the explanatory variables and the Female Labor Force Participation Rate (FLFPR) on Java Island. The estimated model produced a coefficient of determination R^2 of 0.478, indicating that approximately 47.8% of the variation in female labor force participation can be explained by the independent variables included in the model. The simultaneous F-test yields an F-statistic of 14.50 with a p-value of 2.72×10^{-13}, indicating that the model is statistically significant. Table 3 presents the results of the OLS regression along with Variance Inflation Factor (VIF) values used to diagnose multicollinearity among the predictor variables.

Table 3. Multiple Linear Regression Analysis Results

Predictor Variable	Coefficient	t-statistic	p-value	VIF	Conclusion
Intercept	75.5388	3.826	0.000	-	Significant
X_1	-4.328×10^{-6}	-6.265	0.000	18.23	Significant
X_2	0.0074	0.608	0.545	6.25	Not Significant
X_3	-11.2304	-1.874	0.064	7.88	Not Significant
X_4	0.0060	1.282	0.202	3.31	Not Significant
X_5	-0.2478	-2.949	0.004	10.23	Significant
X_6	-1.789×10^{-5}	-1.900	0.060	8.65	Not Significant
X_7	0.0548	0.278	0.781	25.19	Not Significant

The results indicate that Minimum Wage (X_1) and Women in Parliament (X_5) significantly influence female labor force participation at the 5% significance level. The negative coefficient of the minimum wage variable suggests that higher minimum wages are associated with lower female labor force participation in the global model. This may reflect labor market adjustments where higher hiring costs reduce employment opportunities in sectors that typically employ female workers. Multicollinearity diagnostics show that several variables have VIF values exceeding the conventional threshold of 10, particularly Minimum Wage (X_1), Women in Parliament (X_5), and Gender Development Index (X_7). This indicates the presence of multicollinearity in the global regression model. However, this issue does not invalidate the subsequent analysis because the MGWR approach estimates local regression coefficients using spatially weighted subsets of observations, which generally reduces the impact of global multicollinearity.

Spasial Effects Testing

To determine whether spatial modeling is required, spatial diagnostic tests were conducted using the residuals from the OLS regression model.

Table 4. Spatial Effect Test Results

Test	Statistic	p-value	Conclusion
Breusch-Pagan	14.1593	0.0449	Spatial heterogeneity exists
Moran's I (KNN, k=4)	0.1718	0.0010	Positive spatial autocorrelation

The Breusch-Pagan test produces a p-value smaller than 0.05, indicating that the residual variance is not constant across regions. This result suggests the presence of spatial heterogeneity, meaning that the relationship between explanatory variables and FLFPR varies across locations. Meanwhile, the Moran's I test yields a value of 0.1718 with a p-value of 0.0010, indicating significant positive spatial autocorrelation in the residuals. This positive value suggests the existence of spatial clustering, where regions with similar levels of female labor force participation tend to be located near each other. The presence of spatial heterogeneity and spatial autocorrelation indicates that the global regression model is insufficient, thereby justifying the use of Multiscale Geographically Weighted Regression (MGWR).

MGWR Model Parameter Estimation

The MGWR modeling process begins with the determination of the geographical locations of each regency/city based on longitude and latitude coordinates. These coordinates are used to calculate the spatial distances between locations, which serve as the basis for constructing the spatial weighting matrix. Optimal bandwidth selection is then performed by minimizing the corrected Akaike Information Criterion (AICc) using the golden section search method. This study employs an adaptive bisquare kernel function, ensuring that the number of observations contributing to local parameter estimation remains consistent at each location, despite differences in data density across regions.

Table 5. Optimal Bandwiths

Parameter	Bandwith
β_0	49
β_1	118
β_2	118
β_3	118
β_4	118
β_5	118
β_6	60
β_7	83

As shown in Table 5, different optimal bandwidth values are obtained for each parameter, indicating that each variable operates at a distinct spatial scale. The intercept (β_0) has a relatively small bandwidth of 49, suggesting that the baseline variation in female labor force participation is more localized and influenced by nearby regional conditions. Most explanatory variables, including minimum wage (β_1), number of poor population (β_2), gender inequality index (β_3), GRDP (β_4), and women in parliament (β_5) have the largest bandwidth value of 118. This indicates that their effects tend to operate at a broader spatial scale and are relatively homogeneous across Java Island. The variable representing women managing household activities (β_6) has a bandwidth of 60, reflecting a medium-scale spatial influence, while the GDI variable (β_7) has a bandwidth of 83, indicating a wider spatial influence than β_6, but still allowing for noticeable local variation.

Table 6. Summary of MGWR Parameter Estimates

Variabel (Estimator)	Parameter Coefficient		
	Minimum	**Median**	**Maksimum**
Intercept	-0.806817	0.214989	0.714181
Minimum Wage	-0.264406	-0.226088	-0.166675
Number of Poor Population	-0.069548	-0.005858	0.019872
Gender Inequality Index	0.004010	0.065985	0.073094
Gross Regional Domestic Product	0.077001	0.168223	0.252766
Women in Parliament	-0.115268	-0.080036	-0.030030
Women Managing Household Activities	-0.590023	-0.314954	-0.093217
Gender Development Index	-0.230108	-0.095901	0.140749

Table 6 presents a summary of MGWR local parameter coefficients, including minimum, median, and maximum values for each variable. Variables such as minimum wage, poverty, and GRDP exhibit large bandwidths, indicating relatively global effects, while others, such as women managing household activities, operate at a more localized scale. The local coefficient estimates reveal important spatial patterns. Minimum wage (X_1) consistently shows negative coefficients across all regions, suggesting a stable inverse association with FLFPR, although the magnitude varies spatially. This indicates that the relationship between wage levels and female labor participation may depend on local labor market conditions.

In contrast, the Number of Poor Population (X_2) and Gender Development Index (X_7) exhibit both positive and negative coefficients, indicating spatially heterogeneous relationships. In some regions, higher poverty levels may encourage women to enter the labor force as a coping strategy, while in others structural barriers may limit such participation. The Gender Inequality Index (X_3) and GRDP (X_4) generally show positive associations with FLFPR, suggesting that improvements in economic development and gender-related conditions may be linked to higher female participation. However, these relationships should be interpreted as associations rather than causal effects. Meanwhile, Women in Parliament (X_5) and Women Managing Household Activities (X_6) consistently display negative coefficients. This may indicate that higher domestic burdens are associated with lower labor force participation, highlighting the importance of unpaid care work in shaping women’s economic engagement.

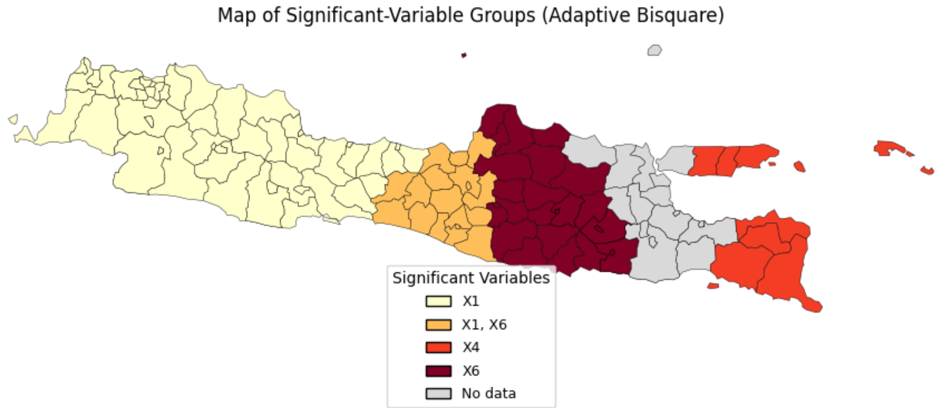

Figure 1. Map of Significant-Variable Groups

The MGWR significant-variable group map illustrates differences among regencies/cities on Java Island in terms of the combinations of variables that significantly influence female labor force participation. These differences indicate that the effects of explanatory variables vary spatially across regions. The grouping of regencies/cities based on significant variables is presented in Table 8.

Table 8. Significant Variables by Regency/City

Regency/City	Significant Variable
Banjarnegara, Kebumen, Purworejo, Wonosobo, Magelang, Boyolali, Klaten, Demak, Semarang, Temanggung, Kendal, Kota Magelang, Kota Salatiga, Kota Semarang, Kulon Progo, Bantul, Gunung Kidul, Sleman, Kota Yogyakarta	X_1, X_6
Pandeglang, Lebak, Tangerang, Serang, Kota Tangerang, Kota Cilegon, Kota Serang, Kota Tangerang Selatan, Kep, Seribu, Kota Jakarta Selatan, Kota Jakarta Timur, Kota Jakarta Pusat, Kota Jakarta Barat, Kota Jakarta Utara, Bogor, Sukabumi, Cianjur, Bandung, Garut, Tasikmalaya, Ciamis, Kuningan, Cirebon, Majalengka, Sumedang, Indramayu, Subang, Purwakarta, Karawang, Bekasi, Bandung Barat, Pangandaran, Kota Bogor, Kota Sukabumi, Kota Bandung, Kota Cirebon, Kota Bekasi, Kota Depok, Kota Cimahi, Kota Tasikmalaya, Kota Banjar, Cilacap, Banyumas, Purbalingga, Batang, Pekalongan, Pemalang, Tegal, Brebes, Kota Pekalongan, Kota Tegal	X_1
Jember, Banyuwangi, Bondowoso, Situbondo, Probolinggo, Sampang, Pamekasan, Sumenep	X_4
Sukoharjo, Wonogiri, Karanganyar, Sragen, Grobogan, Blora, Rembang, Pati, Kudus, Jepara, Kota Surakarta, Pacitan, Ponorogo, Trenggalek, Tulungagung, Blitar, Kediri, Nganjuk, Madiun, Magetan, Ngawi, Bojonegoro, Kota Kediri, Kota Blitar, Kota Madiun	X_6

Table 8 presents the spatial distribution of regencies/cities grouped according to the combination of variables that significantly influence female labor force participation. The spatial grouping of significant variables highlights substantial regional differences in the determinants of FLFPR. In industrialized regions such as Banten, DKI Jakarta, and West Java, minimum wage emerges as the dominant factor. This suggests that labor market regulations and industrial structures may play a key role in shaping female employment opportunities. In Central Java and the Special Region of Yogyakarta, both minimum wage and domestic responsibilities are significant, indicating that women's participation is influenced by both economic incentives and household constraints. In several agricultural regions of East Java and Madura, GRDP is the primary significant variable, suggesting that overall economic productivity may be more relevant than formal wage structures. These findings emphasize that the determinants of FLFPR vary across regions, and therefore policy interventions should consider local socio-economic contexts rather than applying a uniform national approach.

Model Evaluation

The MGWR model evaluation was conducted to assess its performance in explaining variations in female labor force participation across regencies/cities on Java Island. The evaluation metric used is the coefficient of determination (R^2), which indicates the proportion of variation in the response variable explained by the independent variables in the model.

Table 9. Model Evaluation

Evaluation Criterion	Value
R^2	0,7212

Based on Table 9, the R^2 value of 0.7212 indicates that approximately 72.12% of the variation in female labor force participation can be explained by the socio-economic variables in the MGWR model. This relatively high coefficient of determination suggests that the MGWR model provides strong explanatory power in capturing spatially varying relationships across regencies/cities on Java Island. Compared to the global multiple linear regression model, which produces a lower R^2 value, the MGWR approach better represents spatial heterogeneity in the data.

CONCLUSION

This study shows that the Female Labor Force Participation Rate (FLFPR) across 119 regencies/cities on Java Island in 2024 is influenced by spatially varying socio-economic factors. Spatial diagnostic tests indicate the presence of spatial heterogeneity (Breusch–Pagan p = 0.0449) and positive spatial autocorrelation (Moran's I = 0.1718, p = 0.001), confirming that a global regression model is insufficient to capture these relationships. The results from the Multiscale Geographically Weighted Regression (MGWR) model reveal that minimum wage (X_1) is the most consistently significant determinant, particularly in Banten, DKI Jakarta, West Java, and parts of Central Java. In Central Java and the Special Region of Yogyakarta, female labor force participation is jointly influenced by minimum wage and women managing household activities (X_6), while in several agricultural regions of East Java and Madura, Gross Regional Domestic Product (X_4) emerges as the primary driver.

Methodologically, the MGWR model with an adaptive bisquare kernel provides a better representation of spatial variation, achieving $R^2 = 0.7212$, which is higher than the global OLS model ($R^2 = 0.478$), and reveals that different variables operate at different spatial scales. These findings imply that policies aimed at increasing female labor force participation should consider regional economic structures and spatial heterogeneity rather than adopting a uniform approach. In industrial regions, policies may focus on balancing wage regulations with employment opportunities for women, while in Central Java and Yogyakarta reducing women's domestic burden through childcare support and family-friendly policies is essential. In agricultural regions of East Java and Madura, strengthening regional economic development and female entrepreneurship may be more relevant. Future research could extend this study by incorporating panel data, testing alternative kernel functions, and including additional socio-cultural variables to better understand spatial labor market dynamics.

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