# Convergence of income across regencies in Central Java: spatial econometric approach

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**Abstract**

The development of an economy is oriented towards not only growth but also equality. Furthermore, economic interaction across regions has to be captured in a development analysis to avoid the possibility of biased results. This study analyzes Central Java, Indonesia's economic development, by considering spatial interactions across regencies. The Spatial Durbin Model (SDM) is used for the analysis. The results show significant spatial interaction across regencies/cities in Central Java in the spatial model and economic convergence that occurs faster than in the non-spatial model. Then, the mismatch between the curriculum of education and industry needs is a presumption illustrated in the insignificant relationship of human capital to income. And an anomaly occurs where physical capital has a negative impact on income.

***Keywords:*** *Economic convergence, Human capital, Per capita income, Physical capital, Spatial econometric, Spillover*

**JEL Classification:** D23, L83, M12

## INTRODUCTION

In essence, the concept of regional development cannot stand alone; there is a relationship with other regions and spatial dependence. This is due to the socioeconomic interaction across regions through trade, capital flows, migration, technological diffusion, and information exchange (Nijkamp & Poot, 1998). Neglecting the role of spatial dependence in the economic growth model will result in inefficient and even biased estimation of the parameters, which can be misleading in analyzing the economic growth of a region (Anselin, 2001). Socioeconomic interaction across regions resulting in spatial dependence must be considered in the economic growth model to avoid the possibility of variable omitted bias (Goetzke & Andrade, 2010).

The concept of development is not limited to economic growth but is also an effort to reduce inequality (Todaro & Smith, 2012), identic with the term convergence. Convergence is an economic inequality across regions that tends to shrink. Barro & Sala-I-Martin (1992) reveal economic convergence is how lower per capita income levels experience faster growth than higher levels of per capita income.

One of the neoclassical growth models is the Mankiw Romer Weil (MRW) model which has developed by Mankiw et al. (1992). The MRW model examines the augmented Solow growth model, which also analyzes convergence across countries. In the model, the output is generated from physical capital and human capital accumulation. The MRW model provides an excellent description of cross-country data.

Ertur & Koch (2007) used the MRW model by including a variable of technological dependence, using data of 91 countries from 1960 to 1995. The results have several implications: first, the state cannot simply observe freely spatially but must explicitly consider spatial interactions due to technological interdependence. Second, the theoretical results show that the Solow model is less precise because the spillover effect variables are omitted. Then Fischer (2011) developed a spatial augmented MRW model by considering spatial dependence, using the Spatial Durbin Model, which considers technological dependence across regions in 198 regions in 22 European countries during the 1995-2004 period.

Several studies have considered spatial dependence in analyzing the determinants and convergence of economic growth across regions. At the regional/continental level, Andreano et al. (2017) and Cartone et al. (2021) analyze the determinants and convergence of economic growth in Europe by considering the iterated spatially weighted regression procedure and spatial quantile regression, respectively.

At the country level, Lima & Silveira Neto (2016) examined regional growth in Brazil using the spatial augmented MRW model, and explicitly considering physical and human capital, the parameters of the Spatial Durbin Model (SDM) with fixed effects were estimated. Cosci & Mirra (2018) analyzed economic growth using spatial econometrics and found that road investment in Italy since 1960 has significantly reduced travel time between northern and southern Italy.

In China, empirical findings by Li & Fang (2018) from cross-sectional data and spatial panel data show that significant absolute β and conditional β convergence are present in gross domestic product per capita after controlling for investment return rate, human capital, savings rate, population growth, technology advancement, capital depreciation rate, and initial technology level. Sun et al. (2017), following Ertur & Koch (2007), developed a spatially-extended neoclassical Solow growth model to explore the spatial characteristics of regional economic growth at the prefecture-level over the period 1992–2010.

The analysis of spatial convergence is also applied to archipelagic countries such as Indonesia. Affandi et al. (2019) analyzed the role of human capital on economic growth in both quantitative and qualitative contexts using a production function estimation approach and conditional convergence equation estimation. Kurniawan et al. (2019) discussed the dynamics of socioeconomic inequality in Indonesia over the past four decades by testing the convergence of clubs on provincial panel data against four indicators of gross regional product per capita, the Gini coefficient, school enrollment rate, and birth rate. There is a link between economic growth and spatial dependence.

The spatial econometric model underwent development, as Aspiansyah & Damayanti (2019), who developed the Fischer (2011) using the SDM, found the existence of spatial dependence on Indonesia's regional economic growth based on panel data from all provinces in Indonesia during 1990–2015. In addition, the existence of spatial spillover, except for physical capital investment and human capital investment. In narrower areas, such as islands or provinces, they are considered to have a tighter dependence because they are connected through land infrastructure. Hidayat et al. (2022) built an economic growth model using Spatial Autoregressive and Spatial Error Models across 154 regions on the island of Sumatra and found convergence from 2010 to 2020. However, research by Tombolotutu et al. (2019) gave different results; there was no convergence of economic growth in the regencies/cities in Central Sulawesi.

This study adopts the research model of Fischer (2011) and Aspiansyah & Damayanti (2019), which will later be compared between the non-spatial model and the spatial model through the means developed by LeSage & Kelley Pace (2009) and Elhorst (2010). The object of this research is Indonesia, especially in Central Java Province. In addition to the lack of spatial convergence research at the provincial/regency level in Indonesia, the governance at the regencies/city level in Indonesia is autonomous (Law No. 23 of 2014), including in the regional budget allocation (APBD). So that regencies/city and provincial policies become very strategic in efforts to develop the economy.

## METHODS

This study used secondary data. The data sources from the BPS report include per capita income, the ratio of Gross Fixed Capital Formation (GFCF) to Gross Regional Domestic Product (GRDP), the ratio of school participation, and population growth. The data is panel data with 35 regencies/cities in Central Java from 2011-2019.

The Spatial Durbin Model (SDM) is a general model that the effect of spatial lag takes into account on the independent and dependent variables (LeSage & Fischer, 2008). The SDM takes the following forms:

$$Y = WY_{\rho} + \alpha\iota_n + X\beta + WX\theta + \varepsilon \quad \text{(1)}$$

where Y indicates the vector n × 1 of the observed per capita income growth rates (one observation for each spatial unit of the dependent variable); X is the matrix n × k of the explanatory variable n is the number of regencies/cities in Central Java; and k is the sum of the explanatory variables. Intercept vector, represented by ι. Matrix W is a matrix of non-stochastic and non-negative n x n spatial weights. The W element is necessary to indicate the structure of spatial dependence across observations. A vector or matrix multiplied by W indicates the spatial values, i.e., ρ, β and θ are the parameters of the response, and the ε is n × 1, which is normally distributed.

In the analysis, variables in the form of spatial weights are added to capture spatial effects, which describe the relationship across regions. A spatial weight matrix based on contiguity is a spatial weighting matrix based on the intersection of regional boundaries. Anselin (2001) states interconnectedness across adjacent regions is depicted by binary code in a matrix to express the relationship across spatial units. If it is directly adjacent, it is given a value of 1 and 0 for others. According to Lesage (1999), there are various types of interactions of the contiguity matrix, namely:

1. Linear contiguity, this spatial weight matrix defines code 1 for a region on the left or right edge of the neighboring region and code 0 for another region.
2. Rook contiguity, this spatial weight matrix defines code 1 for a region side by side with neighboring regions and code 0 for other regions.
3. Bishop contiguity, this spatial weight matrix defines code 1 for regions whose corner points (common vertex) meet the angle of their neighboring region and code 0 for other regions.
4. Queen contiguity (angular side intersection), this spatial weight matrix defines code 1 for the region that is side by side or whose corner point meets the neighboring region and code 0 for the other region.

Due to the irregular border area across regencies/cities in Central Java, this study uses queen contiguity as the default for weights to deal with potential inaccuracies such as rounding errors (Anselin & Rey, 2014).

The neoclassical theory of growth underlies the theoretical framework of this study. The neoclassical model is based on the Cobb-Douglas production function. This research model adopts from Fischer (2011) and Aspiansyah & Damayanti (2019) as the general model, which is compared with several alternative models through the means developed by LeSage & Pace (2009) and Elhorst (2010). The following is the SDM.

$$[\ln y_{it} - \ln y_{it-1}] = \beta_0 + \beta_1 \ln y_{it-1} + \beta_2 \ln s_{it}^K + \beta_3 \ln s_{it}^H + \beta_4 \ln(n_{it} + g + \delta) + \theta_1 \sum_{j=1}^{N} w_{ij} \ln y_{jt-T} + \theta_2 \sum_{j=1}^{N} w_{ij} \ln s_{jt}^K + \theta_3 \sum_{j=1}^{N} w_{ij} \ln s_{jt}^H + \theta_4 \sum_{j=1}^{N} w_{ij} \ln(n_{jt} + g + \delta) + \rho \sum_{j=1}^{N} w_{ij} \left[\ln y_{jt} - \ln y_{jt-1}\right] + \varepsilon_{it} \quad \ldots\ldots (2)$$

The variables contained in the equation are defined operationally as follows:

$y_{it}$ is a proxy income that we use as per capita income based on the constant price of the region (regency/city) i at the end of each period in the province of Central Java.

$y_{it-1}$ is the initial income proxy that we use as the per capita income based on the constant price of the region (regency/city) i at the beginning of the period in the province of Central Java.

$s_{it}^K$ is the level of physical capital investment in the region (regency/city) i of Central Java Province which is proxied using data on the ratio of Gross Fixed Capital Formation (GFCF) to Gross Regional Domestic Product (GRDP).

$s_{it}^H$ is a regional human capital investment (regency/city) i in the province of Central Java, which is proxied using school participation rate data.

$n_{it}$ is the region's population growth (regency/city) i in the province of Central Java. Meanwhile $y_{jt}$, $y_{jt-1}$, $s_{jt}^K$, $s_{jt}^H n_{jt}$ successively constitutes income, initial income, physical capital investment, human capital investment, and population growth of region j (neighboring).

$g + \delta$ is a variable that represents the growth rate of technology and the depreciation rate of capital which is assumed to be of constant and equal value for the entire region (regency/city) i of Central Java Province, which is 0.05 (see Mankiw et al., 1992; and Islam, 1995)).

$u_{it}$ is the error term

$\beta_0$ is the intercept, $\beta_{1\ldots4}$ are the coefficient of exogenous variables
$\beta_1$ as the basis for calculating the implied β or convergence rate (λ). $\beta_1 = 1 - e^{-\lambda t}$ where t is time (Barro & Sala-I-Martin, 1992).

$\theta_{1\ldots4}$ is the coefficient of the spatial variable X, ρ is the coefficient of the spatial variable Y

$w_{ij}$ is a spatial weight matrix.

## RESULT AND DISCUSSION

### Measurement model

Pesaran's Cross-Sectional Dependence (CD) test (Pesaran, 2004) is used to prove the presence or absence of spatial autocorrelation/dependence across regions; Table 1 showed that there is a spatial dependence across regencies/cities in the province of Central Java (p-value <0.05). The selection of the Spatial Econometric model used the Spatial Durbin Model (SDM) as an initial model compared to other alternative models (LeSage & Pace, 2009; Elhorst, 2010; Belloti et al., 2017). Model selection between SDM and SAR (Spatial Auto-Regressive) to test the value of θ (if θ≠0 the SDM model was selected), then compared the SDM with SEM (Spatial Error Model) to test the value of θ (if θ=-βρ SEM model was selected). Besides that, Belloti et al. (2017) suggested by looking at the smaller AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) in choosing a model. Furthermore, the Robust Hausman test was carried out in the panel data case to choose between fixed effects or random effects.

**Table 1.** Pesaran's cross-sectional CD test

| | **Pesaran's test of cross-sectional independence** | **Probability** | **Spatial Dependence** |
|---|---|---|---|
| **Regencies/Cities in Central Java** | 14.841 | 0.0000 | Yes |

Table 2 showed that the probability chi-square value of the model test comparing SDM vs. SAR and SDM vs. SEM were 0.0007 and 0.0012, respectively. It indicates the existence of spatial dependence both in terms of dependent variables and independent neighboring regions (regencies/cities) in Central Java. The Robust Hausman test showed a probability chi-square value of 0.000, so the model chosen was a fixed effect SDM.

**Table 2.** Spatial model selection

| | **SDM vs. SAR** | **SDM vs. SEM** | **Robust Housman Test** |
|---|---|---|---|
| Null Hypothesis | $\theta = 0$ | $\theta = -\beta\rho$ | |
| Chi-Square | 19.17 | 18.09 | |
| Prob> $x^2$ | 0.0007 | 0.0012 | 0.0000 |
| The selected model | SDM | SDM | Fixed Effect |

Then, this paper compared the spatial and no-spatial models (See Table 3). The MRW model emphasized that the initial per capita income had a significant influence, as well as population growth and technology to income growth. Meanwhile, physical capital investment and human capital investment were not significant.

**Table 3.** Regression analysis results

| $[\ln y_{jt} - \ln y_{jt-1}]$ | MRW Panel Fixed Effect | MRW Spatial Durbin Model (SDM) Fixed Effect |
|---|---|---|
| Constant | -1.548***<br>(0.4195) | |
| $\ln y_{it-1}$ | -0.06***<br>(0.017) | -0.1006***<br>(0.0192) |
| $\ln s_{it}^K$ | -0.0094<br>(0.0083) | -0.015**<br>(0.0078) |
| $\ln s_{it}^H$ | 0.0011<br>(0.0293) | 3.66E-05<br>(0.028) |
| $\ln(n_{it} + g + \delta)$ | -0.616***<br>(0.166) | -0.112<br>(0.2121) |
| $w_{ij} \ln y_{it-1}$ | | 0.0623**<br>(0.029) |
| $w_{ij} \ln s_{it}^K$ | | 0.0014<br>(0.0127) |
| $w_{ij} \ln s_{it}^H$ | | 0.105*<br>(0.0585) |
| $w_{ij} \ln(n_{it} + g + \delta)$ | | 0.056<br>(0.369) |
| $w_{ij}[\ln y_{jt} - \ln y_{jt-1}]$ | | 0.0504<br>(0.076) |
| AIC | -2005.006 | -2012.653 |
| Implied b (l) | 0.647% | 1.065% |
| Half-life convergence | 107.1 | 65.1 |

** significant by 10%; ** significant by 5%; *** significant by 1%. the standard error (). The implicated convergence (λ) speed (implied β) is calculated using the initial income formula where $\beta_1 = 1 - e^{-\lambda t}t$ is the number of periods.*

In the Spatial MRW Model, initial per capita income and physical capital investment were significant to income growth. Other variables, investment in human capital, population, and technology growth were not significant. The spatial model was more fit than the no-spatial model because the AIC value was smaller (see table 1). AIC was a relative measurement of an econometric model for a given data set. The AIC worked to balancing the trade-offs between the complexity of a particular model and its suitability that illustrated how well the model "fits" the data (Belloti et al., 2017). Furthermore, implied β showed a speed of convergence (λ) on the MRW Panel model (not a spatial model) of 0.65 % and the Spatial Durbin Model of 1.06%. This shows that the convergence speed is faster on the Spatial Durbin Model.

## Convergence analysis

The convergence of income growth in Central Java has occurred, which is indicated by the coefficient of initial per capita income ($\ln \mathrm{y_{it-1}}$) had significant and negative values in both spatial and non-spatial models. The speed of convergence (implied β) was 0.647% for the non-spatial model and 1.065% for the spatial model. The time required to cover half the gap (half-life of convergence) shown by the non-spatial model was 107 years, while the spatial model was 65 years.

The spatial model had a higher coefficient of initial per capita income ($\ln \mathrm{y_{it-1}}$) than the non-spatial model. This showed that spatial dependence or interregional linkages in Central Java support the convergence of regional economic growth. Spatial dependence was shown from the significant positive coefficients of the per capita income in other regencies/cities ($w_{ij} \ln y_{it-T}$) and the human capital investment in other regencies/cities ($w_{ij} \ln s_{it}^{H}$). The convergence has implications where poor areas experience faster economic growth than rich areas (Barro & Sala-I-Martin, 1992).

These results align with the findings of Hidayat et al. (2022) and Sun et al. (2017), whereby controlling for spatial heterogeneity in the model, the convergence speed is faster. The convergence that occurs implies a reduction in inequality. This is very important because inequality will interfere with poverty alleviation and sub-optimal economic growth (Fosu, 2017).

## Determinant of income growth and spatial analysis (direct and indirect effects)

### *Physical capital investment*

The result showed that the physical capital investment in both spatial and non-spatial models had a significant effect on income growth, but was negative. This differs from Solow's growth model and MRW model that physical capital investment positively affects income (Solow, 1956; Mankiw et al., 1992). This might happen because the economic growth of a region will stagnate and even negatively when the amount of investment cannot cover the amount of depreciated capital (Aspiansyah & Damayanti, 2019).

Figure 1. shows that the addition of physical capital in Central Java Province was volatile. It tends to increase, followed by adding per capita income every year. However, when physical capital was added at a higher point, the addition of per capita income at the same time tended to decrease and vice versa.

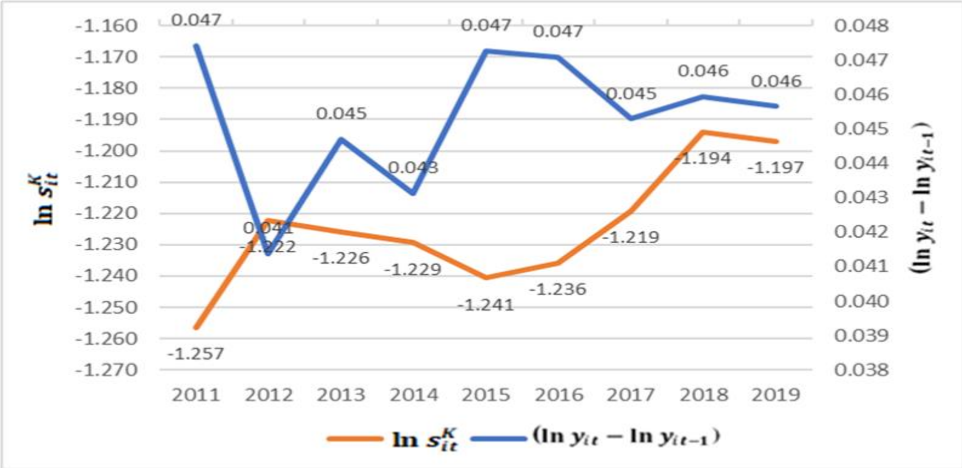



**Figure 1.** Growth per capita income $(\ln y_{it} - \ln y_{it-1})$ and physical capital investment $(\ln s_{it}^K)$

The negative effect of physical investment on income growth $(\ln y_{it} - \ln y_{it-1})$ is supported by figure 2b, where the regression line for each regencies/city is decreasing. However, the relationship between physical capital investment and income $(\ln y_{it})$ was positive (figure 2a). This suggests an alleged diminishing return due to physical capital investment being positive for total income but negative for income growth.

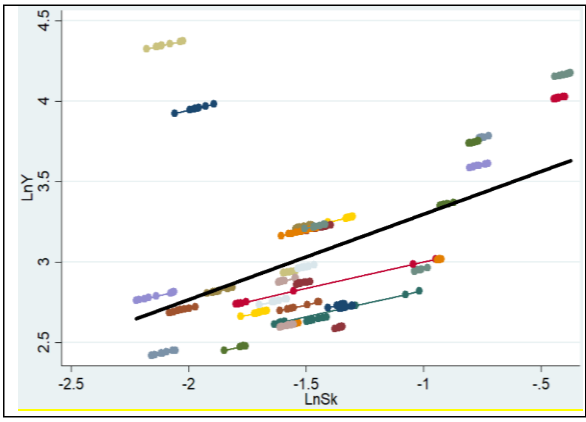



**Figure 2a.** Regression line physical investment $(Lns_{it}^K)$ to per capita income $(\ln y_{it})$

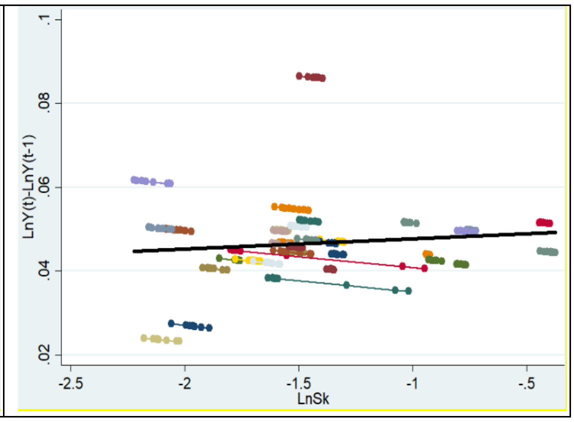


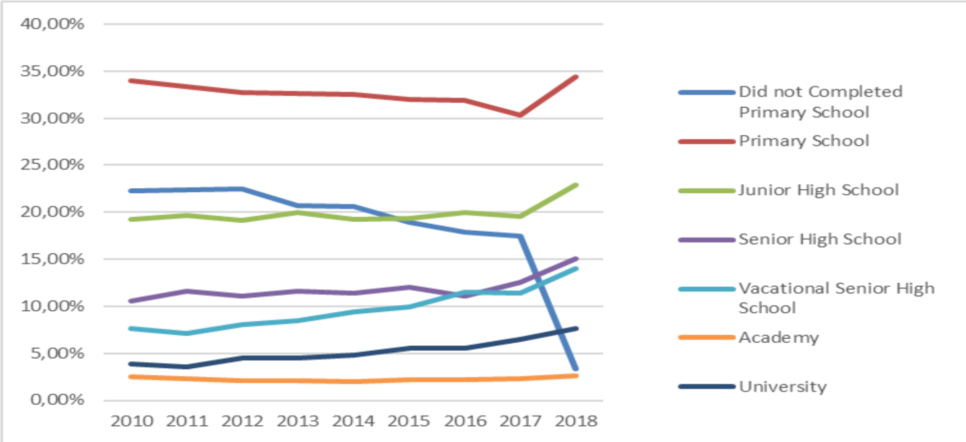

**Figure 2b.** Regression line physical investment $(Lns_{it}^K)$ to the growth of per capita income $(\ln y_{it} - \ln y_{it-1})$

Another conjecture is that there is a lag effect from physical capital investment, meaning that the physical capital investment carried out at this time does not directly impact increasing output but takes time. However, the cost of capital adjustment itself is less flexible when compared to others (such as labor) (Bar-Ilan & Strange, 1996).

This is reinforced by the problem of ease of doing business in Indonesia, which ranks 73 out of 190 countries and below other ASEAN countries (Singapore, Malaysia, Thailand, Brunei, Vietnam) (World Bank, 2020). Special attention must be paid to technical (such as technology) and non-technical (such as institutional) factors in creating an efficient business environment, which will also attract a lot of incoming investment.

***Human capital investment***

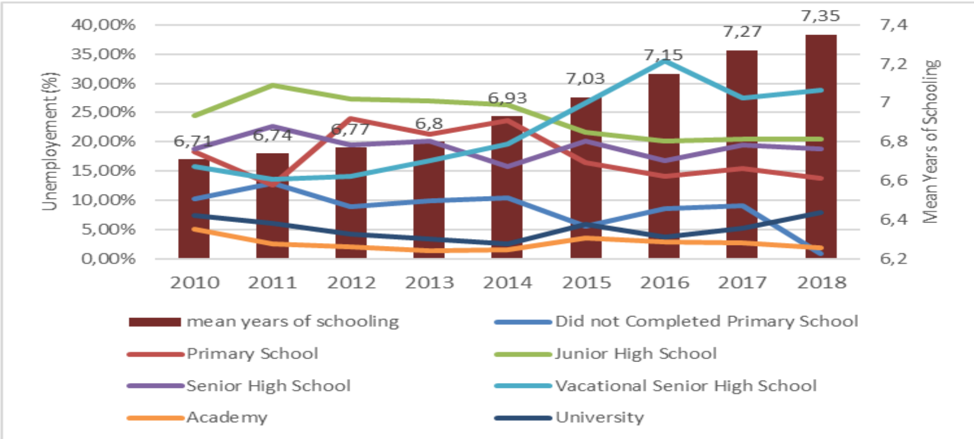
Human capital investment in the model was not significant, both when aspects of interregional linkages were ignored or incorporated. This was different from other studies that stated the strong positive influence of human capital investment on economic growth conducted by Lima & Silveira Neto (2016) on Brazil, Li & Fang (2018) on China, Affandi et al. (2019) on Indonesia and Fischer (2011) and Cartone et al. (2021) in European countries. However, it is the same as the findings of Hidayat et al. (2022) where human capital is not significant to economic growth on Sumatra Island.




*Source: Statistics of Central Java Province (jateng.bps.go.id)*

**Figure 3.** The percentage of the workforce according to Central Java Province education

This is possible because unskilled laborers dominate the labor force in Indonesia. Figure 3. shows that the Labor Force in the province of Central Java, on average from 2010-2018, is still dominated by the education level of unfinished primary schools (19%), primary schools (33%), and junior high schools around (20%).




*Source: Statistics of Central Java Province (jateng.bps.go.id)*

**Figure 4.** Percentage of unemployment based on education and the average study length of Central Java Province

In addition, this might happen because of the mismatch between the outcome of education in Indonesia and the needs of the industry in the field, so educated unemployment arises, which should be productive to improve the economy. Figure 4 shows precisely that the highest percentage of unemployment in 2018 is in vocational education at 28.85%, followed by junior high schools at 20.41% and senior high schools at 18.88%. The trend of the average length of schooling in Central Java province continues to increase from 2010-2018. Hasibuan & Handayani (2021) state that field of study mismatch occurs in 68.4% of the workforce in Indonesia and results in a wage penalty of around 6%.

***Spillover effect***

The initial per capita income of other regencies/cities ($w_{ij} \ln y_{it-1}$) positively affected to the income growth. This indicates that there is a spatial spillover of per capita income from regencies/cities to the income growth of other regencies/cities in Central Java. In line with research conducted by Basile (2008) in European countries, Sun et al. (2017) in China, and Aspiansyah & Damayanti (2019) in Indonesia. The interaction initial per capita income of other regions to income growth suggests that regions surrounded by wealth regions have a higher expected growth rate than regions surrounded by poor regions (Basile, 2008). When a region's income increases, it will increase demand and become an opportunity for other regions to fulfill it through trade (Capello, 2009).

The spillover effect also occurred from human capital investment. Human capital investment by regencies/cities will impact the regional economic growth of other regencies/cities in Central Java. This shows that human capital investment in one regencies/cities This shows that human capital investment in one area is also enjoyed by other regencies/cities in Central Java is also enjoyed by others. It is suspected that there are transmission channels, so educated workers migrate to other regions. In contrast, Olejnik (2008) says that the increase in human capital that is only enjoyed by its region is due to an educated workforce that does not migrate to other regions. Physical capital investment, economic growth, and population growth had no significant spillover effect to income growth of other regencies/cities in Central Java.

## CONCLUSION AND RECOMMENDATION

### Conclusion

This research uses the foundation of Solow growth theory in the Mankiw Romer Weil (MRW) model, plus the development of a model by Fischer that emphasizes dependence across regencies/cities in Central Java. In this case, the use of the Spatial Durbin Model was selected with the following findings:

a) Factors derived from one's territory that affected the income growth were the initial per capita income and physical capital investment. Interestingly, the anomaly that occurs from physical capital investment was detrimental to income growth.
b) The occurrence of spillover effects across regencies/cities on initial per capita income and human capital investment. A region's increased per capita income will increase the demand, which will be an opportunity for other regions, thereby increasing trade. Increased human model investment in one region will affect other regions when educated workers migrate to other regions.
c) Spatial dependence supported the convergence process of growth of per capita income in the Central Java.

### Recommendation

Based on the results of this study, the findings of a positive spillover effect on per capita income growth in Central Java need to be utilized, especially in the field of increasing human capital investment. The increase in human capital investment will improve the way of production which will improve the economy. Meanwhile, the insignificant human investment in per capita income growth needs to be reviewed by the curriculum or education and training system so that it is in sync/match with the needs of industry or the economy in increasing output. The importance of human investment is not only limited to education but also other aspects such as health.

The negative findings of physical capital investment on per capita income growth need to be studied in more depth, if the cause is an investment that cannot cover depreciation, it needs to be reviewed projects, especially the government, to produce products that have a longer economic life. If the problem is that there is a lag of investment on income growth, then policies are needed to increase certainty in investing because uncertainty will cause investment delays. Efforts that have been made through the issuance of Law Number 11 of 2020 concerning Job Creation and development of the Special Economic Zone (KEK) Kendal are expected to boost the economy.

And to take advantage of the spillover effect, infrastructure is needed to improve connectivity across regions, thereby facilitating the mobility of production factors and reducing transportation costs. The construction of toll roads and railway routes in Central Java is expected to accelerate spillover, resulting in equal distribution, and on the other hand, will also improve the economy.

The limitations of this study include not properly capturing the role of technology and the time lag assumptions in the model. It is hoped that future research can incorporate digitalization within the framework of an economic growth model.

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