Empirical evidence for Okun's law in Colombia: an analysis of rural areas at the region level

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Abstract

This article analyses the relationship between income and unemployment, controlling for the variable of human capital, in rural areas of four Colombian regions. The objective is to test for the existence of the empirical regularity known as Okun's law and thereby measure income's impact on unemployment by region. The analysis is based on a monthly series for the period 2010–2022, and the methodologies used to determine the behaviour of this relationship include ordinary least square differences, dynamic ordinary least squares, and error correction and vector autoregressive models, establishing the existence of equilibria in the short and long terms. The results are found to be consistent with Okun's law, showing a negative relationship between real income and unemployment and a positive one between unemployment and human capital.

Keywords

Economic growth, unemployment, labour market, income, productivity, rural areas, Colombia, Latin America and the Caribbean

JEL classification

E24, E60, C32

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I. Introduction

The principal goal of economic policy is to boost economic growth by ensuring the efficient use of factors of production. One difficulty in this regard relates to the efficient use of installed capacity (productivity): insufficient resources increase the unemployment rate, a common feature of developing economies (Flórez, Pulido-Mahecha and Ramos-Veloza, 2018; García-Luna and Cardoso-López, 2020; Kendrick, 1961).

In view of this, the information provided by economic growth and unemployment indicators is a critical input in the choice of public policies aimed at increasing productivity in such economies. Okun (1962) argues that there is an inverse relationship between real GDP growth and the unemployment rate. There can be no doubt that the dynamics of this relationship impact national and regional productivity levels. Furthermore, the nature of this relationship in an economy tends to change depending on whether the economy is expanding or contracting (i.e. over the business cycle), which shows that there is an inversely proportional relationship between economic growth and the unemployment rate (Dixon, Lim and Van Ours, 2017).

In this connection, there are factors that can reduce domestic production in a region or country and increase the negative effects caused by unemployment. Thus, according to Porras-Arena and Martín-Román (2019), two of the principal factors supporting this negative relationship are the market for goods and the labour structure, with regional income growth being affected by lack of specialization and a production value added composition that relies on low-productivity employment. This characteristic of productivity perpetuates periods of uncertainty in markets. According to Grant (2018), economic uncertainty also increases negative coefficients in the relationship between real GDP and the unemployment rate.

A related process which helps to reduce unemployment is human capital formation, especially in rural areas. Thus, the presence of institutions providing education and vocational training in rural areas enhances the dynamics of production and the creation of value chains (Gordon, 2010; Salido and Bellhouse, 2016; Otero-Cortés, 2019).

This study focuses on rural areas because the relationship with low income is prevalent there. These areas tend to have lower incomes than urban areas, so that poverty reduction is usually slower. Explanations for this include the lack of high-technology and high-value-added production there and the failure to pursue and implement decent work policies, resulting in slow job creation and revenue declines (ECLAC/ILO, 2016b).

Another persistent characteristic of rural as compared to urban areas is the slower accumulation of productive knowledge and management techniques, resulting in lower marginal returns for rural producers and thus lower household income and greater job instability in these areas (Laszlo, 2008).

In Colombia, unemployment rates tend to be lower in rural than in urban areas, but so do household incomes. Thus, although unemployment is low, revenue growth is also lower, being influenced by the levels of informality in these areas (Otero-Cortés, 2019). In addition, we observe that there was a disparity of approximately 2 percentage points in the unemployment rate across Colombia's regions in the period from 2010 to 2018, but this disparity has been diminishing owing to a dynamic of convergence between rural and urban areas (Otero-Cortés, 2019).

Colombia's rural areas have also been shown to have a lower level of knowledge (human capital) than urban areas, and this is particularly true of areas that tend to lag economically. According to Tenjo Galarza and Jaimes (2018), the low levels of education in the rural areas of the country's

departments have set off a chain reaction of decreasing returns to education, mainly owing to a lack of technical support and human capital accumulation in these areas, so that output remains persistently below potential.

The main objective of this study, then, is to test for the existence of the empirical regularity known as Okun's law in rural areas of the Colombian regions. This is the empirically estimated relationship, in the short and long terms, between unemployment and household income, controlling for a variable such as human capital. We use household income as a proxy for production, since there is very little information on the value of rural production over the years studied (2010 to 2022), and what does exist is annualized. Studying rural areas is a worthwhile pursuit, as there is insufficient research on the relationship between unemployment and household income in rural contexts. There is potential to extend the inference to urban areas of the country or to the economy in general (Ramos, 2017; Flórez, Pulido-Mahecha and Ramos-Veloza, 2018; Ortiz, Jiménez and Uribe, 2020).

Again, disaggregating the analysis at the region level allows us to capture the heterogeneity of Colombia's internal labour markets. It is also important to show that the relationship proposed by Okun (1962) is consistent not only at the macro level, but also at the meso or regional level. As far as the authors are aware, there are no papers analysing this relationship in rural areas and at the region level in Colombia.

To analyse the relationship, we begin by identifying the behaviour of the model estimation coefficients using first a differential version and then a dynamic version of linear regression as an instrument to determine deterministic relationships. Lastly, the vector autoregressive (VAR) model and the error correction model (ECM) support the short- and long-term analyses. The short-term assessment is built up through the evaluation of Granger causality, impulse-response functions and the variance decomposition analysis. We use regional monthly data for rural areas of Colombia, running from 2010 to 2022 and based on the Large Integrated Household Survey (GEIH) of the National Administrative Department of Statistics (DANE).

The results show a strong negative relationship between real rural household income and family unemployment. Furthermore, the accumulation of human capital has a positive effect on unemployment in all rural areas of the Colombian regions. Another aspect derived from the estimation processes is that we identify the long-term effects of the variables with respect to the unemployment rate.

In addition, there are short-term relationships between the real income variables and rural unemployment in most regions. Similarly, by subjecting the data to causality analysis, we demonstrated that there were causal relationships between all the variables and unemployment in rural areas. Lastly, in the impulse-response analysis and the decomposition of the variance, the Central and Eastern[1] regions were found to be the least likely to evince sudden changes in the unemployment rate in the event of movements in the other variables.

This document is structured as follows. Section II presents a review of the literature on Okun's law and regional case studies, with a focus on rural areas, and uses monthly statistics to examine the performance of the economic growth structure and the evolution of a number of labour market indicators in Colombia's rural areas. Section III describes the methodology, presenting data and descriptive statistics. Section IV gives the empirical results from the estimation process. Lastly, section V presents conclusions.

[1] The regional classification established by DANE in Colombia, given the availability of data on 24 of the 32 departments, is: Caribbean, containing the departments of Atlántico, Bolívar, Cesar, Córdoba, Sucre, Magdalena and La Guajira; Eastern, containing the departments of Norte de Santander, Santander, Boyacá, Cundinamarca and Meta; Central, containing the departments of Bogotá D.C., Caldas, Risaralda, Quindío, Tolima, Huila, Caquetá and Antioquia; and Pacific, containing the departments of Chocó, Cauca, Nariño and Valle del Cauca.

II. Literature review

1. Determinants of the relationship between production and unemployment

It is well known that Okun's law postulates an inverse relationship between production and unemployment. Thus, Okun (1962) and Malley and Molana (2008) posit that a fall in production in a country or region is accompanied by a significant increase in unemployment rates. Mendonça and Oliveira (2019) argue that this inverse relationship is determined by the costs entailed by inefficiency, with these costs determining the number of people seeking employment and the duration of recessions.

Examining the geographical composition of such inefficiency costs, Schettini and Azzoni (2018) find that the costs of production inefficiency, as reflected in the composition of unemployment, tend to be uneven across regions, owing to the heterogeneity of different areas. Therefore, the inverse relationship between income (along with productivity) and unemployment also tends to differ across geographical areas.

As determinants of these differences between regions, Villaverde and Maza (2009) establish that they are due to increases in productivity, which respond in different ways to Okun's law, since regions with optimal production and resource utilization will evince only slight differences in income and unemployment. In addition, an asymmetrical relationship between these variables in different regions shows the degree to which structural instabilities, represented in terms of inefficiency costs, have become entrenched (Durech and others, 2014; Tang and Bethencourt, 2017).

Elshamy (2013) adds that a key factor driving these differences between regions, and negatively heightening this relationship, is the installed capacity of the labour market. According to Durech and others (2014), an increase in the population's general skills, which is something that companies call for, will increase production, reducing unemployment and poverty rates. Also, generating specializations among the population will increase human capital and cushion the negative effects of poverty deriving from any decrease in real wages due, for example, to unemployment (Marth, 2015).

Asymmetries between the supply of and demand for labour provide an overview of the production capacity of an economy. When companies can identify valuable employees of the kind they require for their production activities, their loss aversion decreases. This process increases firm investments, employee numbers and, finally, real wages (Kölling, 2018). However, reforms that make the relationship between buyers and sellers more rigid create distortions in production and increase unemployment (Dal Bianco, Bruno and Signorelli, 2015).

Regarding Latin America, Jiménez Villavicencio and Ochoa Moreno (2017) assert that the countries of the subregion lack the market capacity to adequately increase employment and production, while identifying a significant inverse relationship between unemployment and economic growth. At the same time, the unemployment rate shows lags between periods that influence future unemployment rates and create intertemporal dependence.

Similarly, Briceño, Dávila and Rojas (2016), analyse the relationship between production and unemployment globally and for the Latin America subregion from 1991 to 2014. They find that this relationship lacks significance in Latin America but is statistically significant at the global level. A literature review conducted by Pizzo (2019) for Latin America and the Caribbean reveals consensus that production has been held back by structural shocks, creating a tendency towards lower employment.

There are numerous studies, using data from many countries over different time periods, which confirm that better-educated people earn higher wages and experience less unemployment than their less educated counterparts (Card, 1999). In addition, lower incomes negatively impact individuals' skills, something that in turn is positively related to unemployment (Cingano, 2014).

There is literature on the long-term relationship between production and unemployment in Colombia. For example, Ramos (2017) shows that when production increases by 1%, there is a reduction of 0.45 percentage points in the unemployment rate. Ortiz, Jiménez and Uribe (2020) argue that the structure of the relationship between economic growth and unemployment is partly contingent on factor costs, with additional factors influencing income imbalances.

Flórez, Pulido-Mahecha and Ramos-Veloza (2018) propose a nonlinear model capturing the cointegration relationship to describe the relationship between the rate of income growth and the unemployment rate in Colombia from 1984 to 2016. Their study confirms the inverse relationship and identifies gaps between the two rates at different speeds of growth (rapid growth in periods of change in economic regimes and low growth in periods preceding economic reforms in the country).

2. Characteristics of rural areas in Colombia

This section describes the socioeconomic characteristics of rural areas within a more general context. A number of authors have indicated that rural areas tend to have lower incomes and be less developed than urban areas (Alpízar and others, 2020; Anríquez and Stamoulis, 2007) and that this characteristic is heightened in developing countries. The explanations given for this include demographic, cultural and geographical aspects, economic conditions and, in part, the inner dynamics of rural areas themselves (FAO, 2019; Tickamyer, 2006).

The gap between rural and urban areas is attributable to the size and degree of informality of their labour markets, the specialization of production and demand, and institutional and social factors (FAO, 2019). In the case of Colombia, we emphasize the size of the rural labour market because this is the focus of the study. ILO (2019) confirms that levels of social protection and decent work tend to be lower in rural than in urban areas, resulting in lower real incomes and a larger gap between these areas.

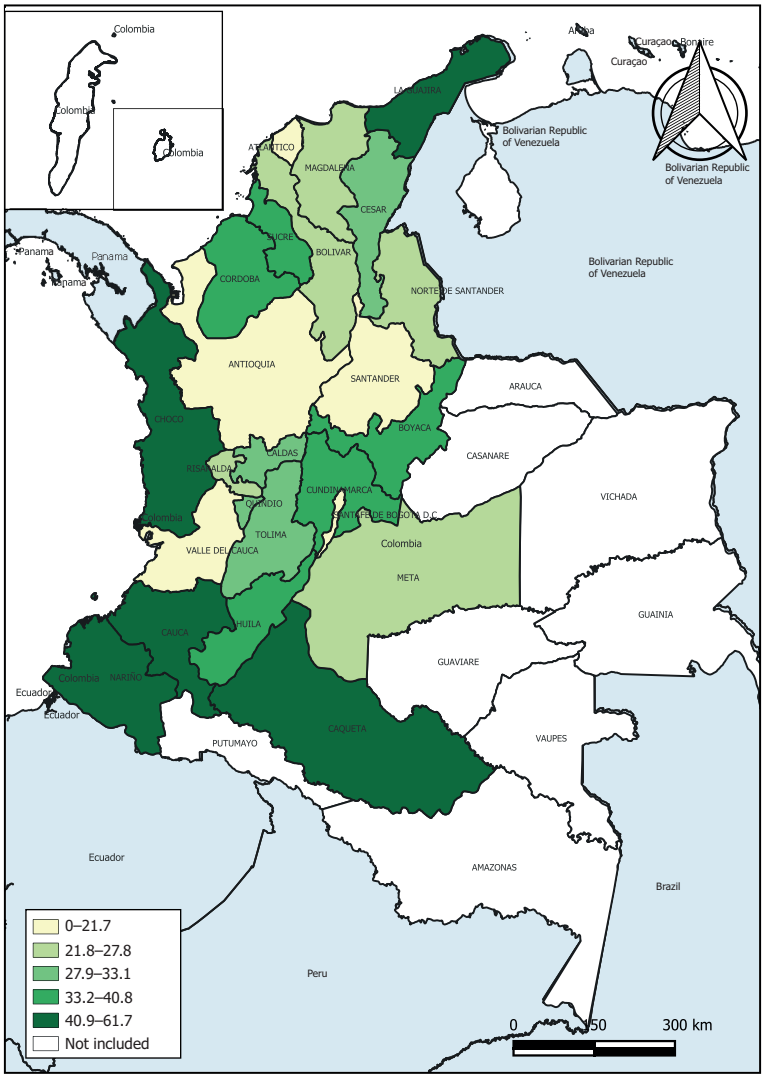
A key factor that impairs the quality of the labour market and weakens economic growth in rural areas is the low rate of job creation, negatively impacting wage growth and unemployment rates. In the view of ECLAC/ILO (2016a), this factor exists because of rural areas' dependence on market demand for commodities. Thus, a negative shock to demand for rural goods, which are intensive in raw materials, reduces consumption of these and thence rural employment.

In addition, rural employment is concentrated in low-specialization sectors. This characteristic means that workers are employed as labourers, own-account workers or the like, occupational categories in which pension system contributions are lower than in other categories or non-existent. This situation entrenches labour informality (Merchán Hernández, 2015; Otero-Cortés, 2019).

Another socioeconomic factor linked to the stock of workers that affects production in rural areas is the regions' capacity to retain population in rural areas. According to Vargas Urrutia (2013), Colombians seeking to improve their income migrate from the countryside to urban areas. This constant process generates serious difficulties in the labour market because it drains talent away from local rural production and sets up a vicious circle in which workers' bargaining power decreases and the potential for innovation in rural production diminishes.

Map 1 uses data from the Large Integrated Household Survey of the National Administrative Department of Statistics (DANE, 2020) to show the distribution of the rural population, as a percentage of the total population, by department. The map shows that, for the period from 2008 to 2022, the departments with the lowest densities of rural inhabitants were Bogotá, D.C. (Central region) and Atlántico (Caribbean region). In contrast, the departments of Nariño, Cauca and Chocó (Pacific region) had the greatest densities of rural inhabitants.

Map 1
Colombia: rural population by administrative department, 2008–2022
(Percentages of total population)



Source: Prepared by the authors.
Note: Simple averages for the period. The departments of Arauca, Amazonas, Casanare, Guainía, Guaviare, Putumayo, Vichada and Vaupés are excluded from the analysis for lack of information.
The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

One factor restricting the capacity of rural areas to generate income is the lack of knowledge accumulation. According to Laszlo (2008), the returns to education in rural areas derive from an increase in remuneration from hourly wages; these should be the drivers of long-term income growth. From an income and consumption perspective, human capital formation has a positive effect on employment in rural areas, strengthening wage bargaining power, allowing individuals to enjoy greater consumption and generating productivity growth (Laszlo, 2008).

Another factor that negatively impacts working conditions is limited adoption of technology in rural areas. Sinyolo (2020) argues that the implementation of technologies which improve the productive capacity of rural areas has a positive effect on food security and the real incomes of employed people living in rural households.

There are exogenous factors that perpetuate job insecurity and increasingly keep incomes low in rural areas, for example gender gaps in labour demand, armed groups, labour force migration, lack of physical infrastructure, weak institutions and governance, and environmental risks that negatively affect crop productivity (Arias, Ibáñez and Zambrano, 2019; Farah and Pérez, 2003; Klugman, 2002; Tenjo Galarza and Jaimes, 2018). All these factors are common in rural areas, but they vary in their intensity and consequences between rural areas and regions.

III. Methodology

The methodology employed here to determine the relationship between the unemployment rate and production, or real income, follows the approach of Sadiku, Ibraimi and Sadiku (2015), who use four models to estimate Okun's law for the North Macedonian economy in the period 2000–2012, determining short- and long-term relationships.

To employ the real income series, we assume that the economy follows a classic paradigm whereby the production of a nation (Y_{it}) depends mainly on the amount of consumption by households (C_{it}), and these households in turn are the owners of the capital employed (I_{it}) (Sala-i-Martin, 2000), with i being the region of analysis and the time period, while Δ is the difference between the current period (t) and the preceding period $(t-1)$. This assumption is made mainly because there are no monthly data on the aggregate production of rural areas by region in Colombia; accordingly, we use the aggregate real income of those employed in rural areas.

Below, we explain the analyses carried out by different econometric methods, namely difference analysis, dynamic analysis, ECM analysis and VAR analysis (Sadiku, Ibraimi and Sadiku, 2015).

1. Difference analysis

Equation (1) presents the classical form of Okun's law, in which the linear relationship between the rate of change in the number of unemployed, measured in logarithmic difference (ΔU_{it}), as an endogenous variable, and other exogenous variables, like the rate of change in real incomes (ΔY_{it}) and the difference of the logarithm of the number of individuals with higher education and technical skills (ΔH_{it}). Lastly, ε_t is the stochastic error, made up of all those variables not observed by the model.

$$\Delta U_{it} = \beta_0 + \beta_1 \Delta Y_{it} + \beta_3 \Delta H_{it} + \varepsilon_t \quad (1)$$

2. Dynamic analysis

Equation (2) captures the same relationship as is established in the differential version, but with the addition of a lag for each variable to observe its evolution over time; this equation allows us carry out a short- to medium-term analysis.

$$\Delta U_{it} = \beta_0 + \beta_1 \Delta Y_{it} + \beta_3 \Delta H_{it} + \beta_4 \Delta Y_{it-1} + \beta_6 \Delta H_{it-1} + \beta_7 \Delta U_{t-1} + \varepsilon_t \quad (2)$$

It is important to mention that the negative relationship of the variables with respect to unemployment is preserved, except for the lag of unemployment.

3. Error correction model

This method makes it possible to model variables that do not have stationary properties, allowing for cointegration and long-term analysis (Stock and Watson, 2012). To establish the long-term relationship, it is necessary to determine whether the estimates cointegrate or not, for which we use the classic Engle and Granger method. We consider a set of variables to establish that the relationship is a long-term one, meaning that these variables do not tend to increase with time. This is because they are the product of a vector of variables and their estimated coefficients are equal to 0 $(\varphi X_{kt} = 0)$, so that, in turn, the errors derived from the estimation processes must be equal to $\varepsilon_{kt} = \varphi X_{kt} = 0$.

For this, we estimate an ordinary least square model with lagged study variables and proceed to derive the residuals from the estimation process, with stationarity of the residuals meaning that the variables are related in the long term, while the dependent variable is the differential of the logarithm of the number of unemployed (ΔU_{it}). Next, we use the augmented Dickey-Fuller (ADF) test to check whether the errors (τ_{it-1}) are stationary. Lastly, we check the other variables in differences and calculate the lagged errors present in the cointegration processes, deriving long-term estimates that are structured as follows:

$$\Delta U_{it} = \beta_0 + \beta_1 \tau_{it-1} + \gamma \Delta X_{tk} + \varepsilon_{it} \tag{3}$$

where $\tau_{it-1} = U_{t-1} - \rho_0 - \rho_1 X_{tk-1} - \rho_2 T$ and $X_{tk} = Y_{it}$ and H_{it}. We carry out the estimation with each exogenous variable to determine the existence of long-term relationships for rural areas in each region of Colombia. Again, if τ_{it-1} is equal to zero, then there will be long-term equilibria. The application of this test and of the short-term analyses emerges as a method or approach for determining the possible presence of causal processes in the estimation by means of VAR models.

4. Vector autoregressive model

Regarding the specification of VAR models, Hansen (2016) and Wooldridge (2010) describe them as multivariate time series which include a dependent variable and a finite number of independent and lagged variables, forming a finite system of equations defined by a vector. This methodology is used because it allows us to observe the movements and past behaviour of the variables and identify some type of causal relationship between them, in addition to observing their movements in the short term.

For that reason, the approach used in this study is to examine three series: (i) the logarithm of the number of unemployed, (ii) the logarithm of real family income and (iii) the logarithm of human capital, all for rural areas in the regions specified. We estimate the equations simultaneously, choosing the best specification on the basis of its lags, so that:

$$U_{it} = \alpha_0 + \sum_{i=1}^{k} \alpha_n U_{it-n} + \sum_{i=1}^{k} \beta_n Y_{it-n} + \sum_{i=1}^{k} \delta_n H_{it-n} + \varepsilon_{1it} \tag{4}$$

where U_{it}, Y_{it} and H_{it} are the study variables. The same variables are included as lagged terms, repeated times, and lastly the error terms are found, with mean 0 and constant variance. We make the optimal choice of lags in the VAR model in relation to the behaviour of the Bayesian information criterion[2] (Lütkepohl, 2005).

[2] The Bayesian information criterion is calculated using the formula: $BIC = ln\left|\sum_{u}\widehat{(m)}\right| + \frac{lnT}{T} mK^2$.

We perform the Granger causality test and the impulse-response function to determine the effects of innovations in the independent variables on the dependent ones, showing the movement of these shocks. We also observe variance decomposition to assess the contribution of shocks in the independent variables to movements in the dependent variables. The analyses focus on unemployment because this is the variable of interest in this article.

IV. Data and descriptive statistics

As already mentioned, this study aims to test the relationships formalized in Okun's law from a rural and segmented perspective across the main regions of Colombia from January 2010 to December 2022, with data extracted from the DANE Large Integrated Household Survey. The unemployment variable is the total number of persons without jobs in the economically active population, the income variable is real income in Colombian pesos and the human capital variable is the total number of people educated to a technical, bachelor and graduate level. A series of descriptive statistics showing how rural the regions being studied are will now be presented.

The analysis of descriptive statistics reveals that the Pacific and Central regions have higher levels of rural unemployment than the other regions. As regards real income, the Central region accounts for the most income of all the rural areas. Lastly, the rural area of the Central region has the largest amount of human capital, as measured by the proportion of individuals with higher or technical studies (see table 1).

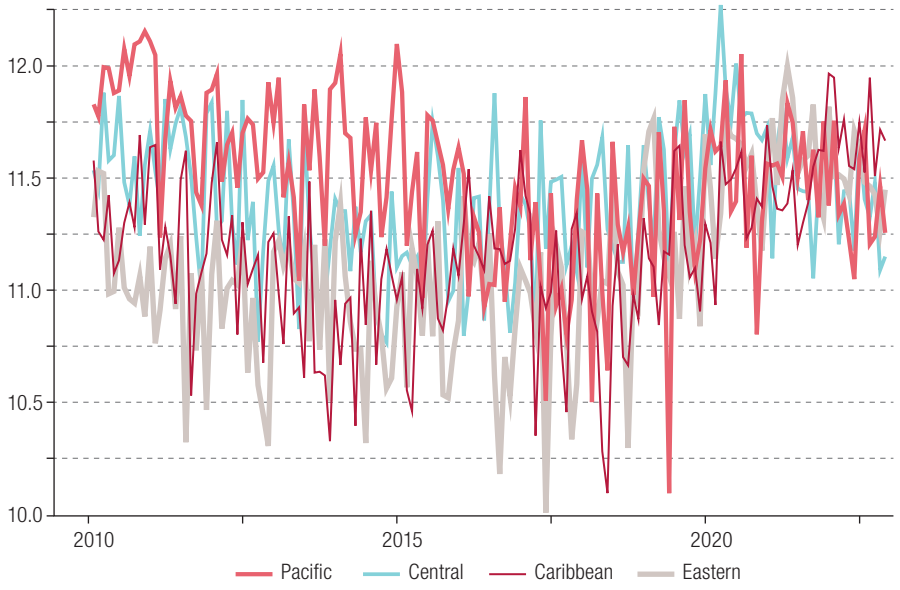
Table 1
Colombia: descriptive statistics for the variables by region, 2010–2022
(Logarithms)

Caribbean				Pacific			
	Observations	Average	Standard deviation		Observations	Average	Standard deviation
U_{it}	155	11.17	0.35	U_{it}	155	11.50	0.36
Y_{it}	155	26.96	0.24	Y_{it}	155	26.90	0.27
H_{it}	155	11.65	0.37	H_{it}	155	11.60	0.40
Central				Eastern			
U_{it}	155	11.40	0.30	U_{it}	155	11.10	0.38
Y_{it}	155	27.17	0.24	Y_{it}	155	27.01	0.22
H_{it}	155	11.67	0.37	H_{it}	155	11.63	0.43

Source: Prepared by the authors.

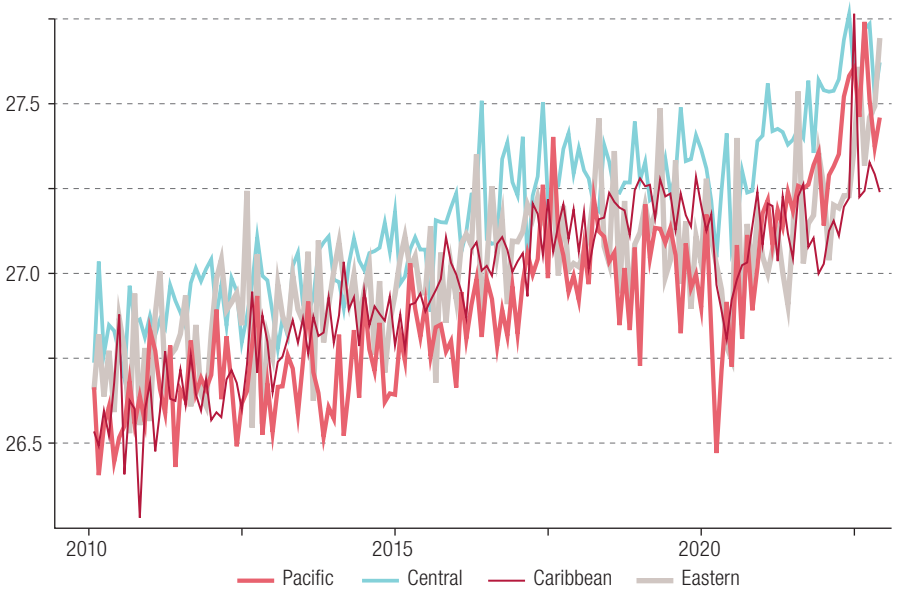
Estimating the logarithm of unemployment for rural regions over time, we find behaviour that is similar across regions but divergent between unemployment and the other variables (see figure 1). In the case of income, for example, the Central region is the best performer of all the regions (see figure 2). Where human capital accumulation is concerned, there is a growth trend across the regions, with the Central region accumulating the largest proportion of individuals with higher and technical studies (see figure 3).

Figure 1
Colombia: rural unemployment, by region, 2010–2022
(Logarithms)



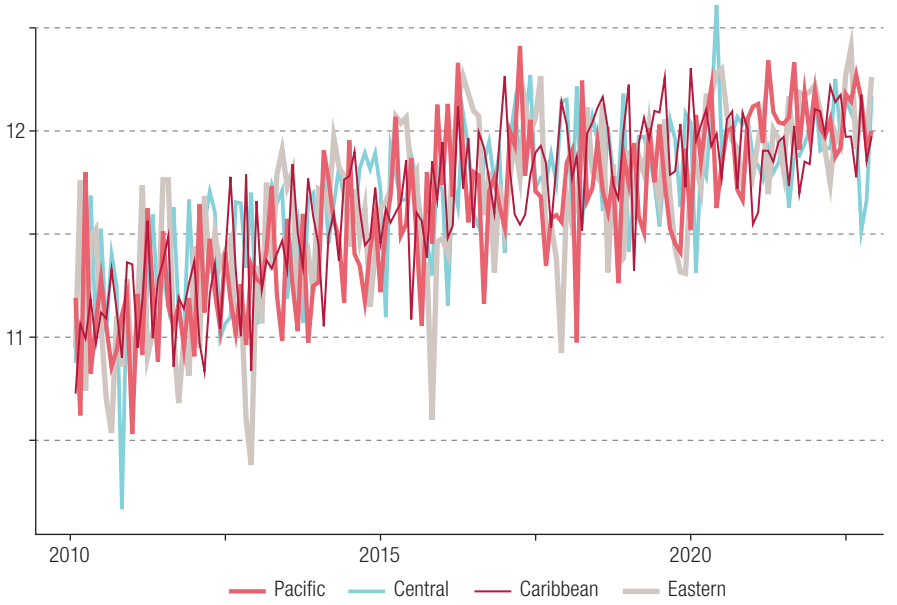
Source: Prepared by the authors.

Figure 2
Colombia: real monthly incomes in rural areas, by region, 2010–2022
(Logarithms)



Source: Prepared by the authors.

Figure 3
Colombia: human capital accumulation in rural areas, by region, 2010–2022
(Logarithms)



Source: Prepared by the authors.

V. Results

In this section, we present the results of the Okun's law estimates for rural areas in the Colombian regions. The calculations are structured in the form of logarithms, so that to begin the analysis of the study series it is necessary to establish stationarity in the series, as the presence of this would imply that time was not significant in the formation of the series and that the variation in the series was constant as time went on (Stock and Watson, 2012).

To this end, the test applies unit roots using the parameters set by the analysis of the ADF test to determine whether or not the data series is stationary, before estimating the models proposed by the methodology. We observe seasonal behaviour in the series in a generalized way when the analysis in differences is carried out, finding that the unemployment and real income data are not stationary in levels in most rural regions but become seasonal when differences are applied (see table 2).

Table 2
Colombia: analysis of stationarity in levels and differences for rural areas, by region, 2010–2022

Variable	Caribbean	Central	Pacific	Eastern
	Levels			
U_{it}	0.559	0.218	0.211	0.048
Y_{it}	0.069	0.535	0.454	0.301
H_{it}	0.010	0.018	0.010	0.010
	Differences			
ΔU_{it}	0.010	0.010	0.010	0.010
ΔY_{it}	0.010	0.010	0.010	0.010
ΔH_{it}	0.010	0.010	0.010	0.010

Source: Prepared by the authors.
Note: The figures are the p-values derived from the stationarity test, where the null hypothesis *(H_0)* is the absence of seasonality in the series, with the alternative hypothesis *(H_a)* applying otherwise. The test used is the augmented Dickey-Fuller test.

Reviewing the results of the estimation of Okun's law in its differenced version, we observe an effect of the independent variables on the dependent ones (see table 3). Specifically, rural income shows a statistically significant inverse relationship with unemployment in the Caribbean, Central and Eastern regions. In the case of the Pacific region, however, while the relationship is positive, it is not significant.

Table 3
Colombia: coefficients of the model in differences for rural areas, by region, 2010–2022

	Caribbean	Central	Pacific	Eastern
ΔY_{it}	-0.740***	-1.119***	0.111	-0.550***
	(0.24)	(0.26)	(0.20)	(0.15)
ΔH_{it}	0.157*	0.173**	0.302***	0.209**
	(0.06)	(0.08)	(0.09)	(0.07)
Constant	0.003	0.002	-0.007	0.002
	(0.03)	(0.03)	(0.03)	(0.03)
Observations	155	155	155	155
R^2	0.095	0.148	0.096	0.094
Adjusted R^2	0.083	0.137	0.084	0.082

Source: Prepared by the authors.
Note: Standard errors are shown in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

For the human capital data, the ratio is clearly positive in the formation of the logarithm of unemployment and is significant for the Caribbean and Eastern regions. This characteristic is due to the intensive use of unskilled labour, with an increase in skill levels leading to the labour supply becoming disconnected from the production requirements of these rural areas (Otero-Cortés, 2019).

In the dynamic version of the model, we observe that the real income and human capital variables perform similarly. The income variable in its differenced version has a negative effect on the endogenous variable in differences in the remaining regions (i.e. Caribbean, Central and Eastern), being highly significant (see table 4).

Table 4
Colombia: coefficients of the dynamic model for rural areas, by region, 2008–2022

	Caribbean	Central	Pacific	Eastern
ΔY_{it}	-0.788***	-1.191***	-0.029	-0.366***
	(0.24)	(0.26)	(0.21)	(0.21)
ΔH_{it}	0.263***	0.227***	0.261***	0.233**
	(0.09)	(0.08)	(0.10)	(0.09)
ΔU_{it-1}	-0.440***	-0.374***	-0.445***	-0.422***
	(0.08)	(0.08)	(0.07)	(0.07)
ΔY_{it-1}	-0.044	-0.384	-0.513**	-0.131
	(0.22)	(0.23)	(0.21)	(0.17)
ΔH_{it-1}	0.186***	0.241***	0.232**	0.186**
	(0.09)	(0.08)	(0.09)	(0.09)
Constant	0.002	0.002	-0.006	0.0002
	(0.02)	(0.03)	(0.03)	(0.03)
Observations	154	154	154	154
R^2	0.283	0.300	0.318	0.257
Adjusted R^2	0.258	0.276	0.295	0.232

Source: Prepared by the authors.
Note: Standard errors are shown in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

In addition, including the lagged difference of the natural logarithm of unemployment in the modelling reveals an inverse relationship with the endogenous variable. This result demonstrates the impermanent character that production may have in rural areas, governed as it is by changes in market conditions for labour-intensive goods (Otero-Cortés, 2019). Lastly, we find that the lagged human capital variable has a positive relationship with the dependent variable, an atypical result which probably arises because rural areas do not have the productive capacity to employ highly qualified workers (see table 4).

The ECM for rural areas of the Caribbean region shows variables cointegrating with the differenced logarithm of unemployment. The statistically significant coefficients and their signs show that production adjusts faster than unemployment (Sadiku, Ibraimi and Sadiku, 2015). In addition, they are significant enough to establish a short-term relationship between rural real incomes and unemployment. Compared with the other iterations of the variables, the short-term relationship is significant throughout the analysis for rural areas (see table 5).

Table 5
Colombia: Granger causality test coefficients for rural areas, by region, 2010–2022

	Caribbean			Central		
	ΔU_{it}	ΔY_{it}	ΔH_{it}	ΔU_{it}	ΔY_{it}	ΔH_{it}
ΔU_{it}		0.524	0.007		0.002	0.021
ΔY_{it}	0.301		0.850	0.000		0.023
ΔH_{it}	0.044	0.202		0.0005	0.007	
	Pacific			Eastern		
	ΔU_{it}	ΔY_{it}	ΔH_{it}	ΔU_{it}	ΔY_{it}	ΔH_{it}
ΔU_{it}		0.223	0.010		0.005	0.269
ΔY_{it}	0.003		0.031	0.045		0.155
ΔH_{it}	0.029	0.531		0.036	0.001	

Source: Prepared by the authors.
Note: The figures in parentheses represent the p-values derived from the Granger causality test. This test evaluates two hypotheses, namely the null hypothesis (H_0) that one variable does not Granger-cause another and the alternative hypothesis (H_a) of Granger causality, with n lags being used to maximize causal relationships in the analysis.

There are also regions, such as the Central and Caribbean regions, where long-term relationships can be observed. We see that the independent variables tend to adjust more rapidly in the long term than the unemployment variable, owing to the nature of their signs. In the case of the Pacific region, there are both short-term and long-term relationships, with short-term interactions being positive in the cases of production and human capital. In the long-term analysis, it shows similar behaviour to the other regions (see table 6).

Lastly, short-term relationships in rural areas of the Eastern region are found to evolve comparably to those in the Caribbean and Central regions. In the long term, its dynamics continue to parallel those of rural areas in other regions of Colombia. It is important to mention that these short-term relationships tend to be deterministic, featuring in the causality analysis as approximations to the VAR estimates.

The last step in the analysis of short-term relationships are the results of the VAR model, Granger causality test and impulse-response functions. The Granger causality test shows that all the variables present a causal relationship in the short term, except for the differenced logarithm of human capital in rural areas of the Caribbean region. Real income by region is found to have a Granger-causal relationship with the other variables in the short term (see table 5).

Table 6
Colombia: coefficients for the error correction model in rural areas, by region, 2008–2019

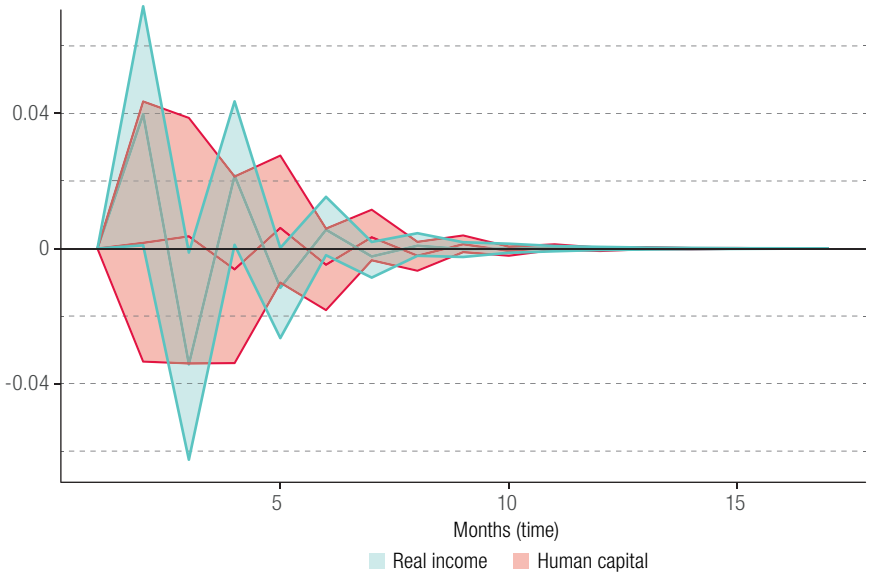
	ΔU_{it}							
	Caribbean		Central		Pacific		Eastern	
ΔY_{it}	-0.824***		-0.974***		0.454**		-0.316**	
	(0.19)		(0.19)		(0.16)		(0.12)	
ΔH_{it}		0.174*		0.015		-0.289***		0.069
		(0.08)		(0.07)		(0.07)		(0.06)
τ_{it-1}	-0.414***	-0.433***	-0.383***	-0.395***	-0.458***	-0.454***	-0.402***	-0.457***
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)	(0.08)	(0.07)
Constant	0.004	-0.001	0.003	-0.002	-0.006	-0.005	0.002	-0.0002
	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.07)
Observations	152	152	152	152	152	152	152	152
R^2	0.230	0.199	0.248	0.157	0.226	0.280	0.208	0.211
Adjusted R^2	0.220	0.188	0.232	0.146	0.216	0.271	0.198	0.201

Source: Prepared by the authors.
Note: Standard errors are shown in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

VAR is estimated by region as part of the impulse-response function analysis. First, we analyse short-term relationships and the impacts of innovation on unemployment. Unemployment is a key variable in this study, and it is necessary to observe the dynamics of its response to innovations in other variables, for which we use impulse-response functions to assess the relationships between unemployment and the other variables. In addition, we use variance decomposition to determine the proportions of the derived effect attributable to all the exogenous and endogenous variables.

For the Caribbean region, we used a maximum of two lags (based on the Bayesian information criterion) to examine the effects on the dependent variable and observed that both positive and negative effects were highly significant but tended to tail off from the tenth period (see figure 4).

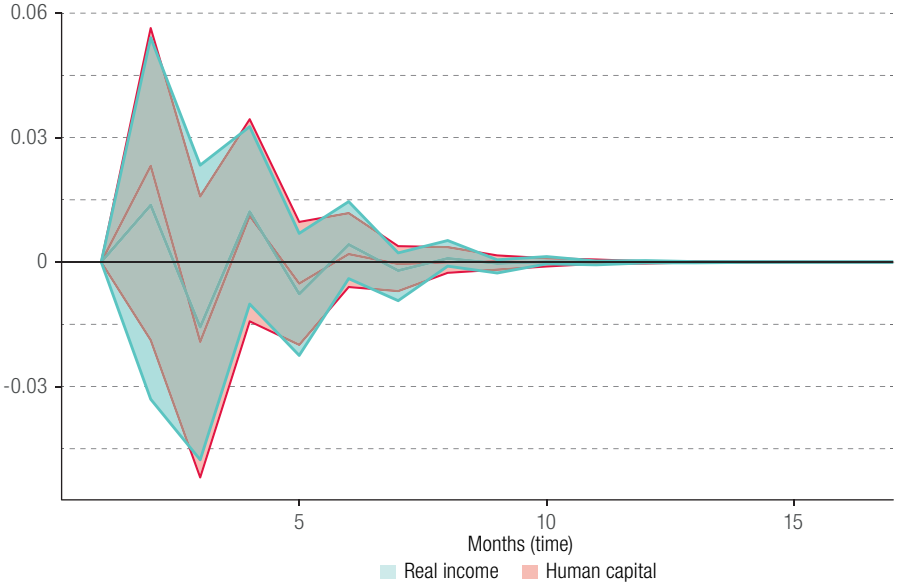
Figure 4
Colombia: impulse-response functions for unemployment shocks in rural areas of the Caribbean region



Source: Prepared by the authors.
Note: The horizontal line represents the impulse-response relationships, and the surrounding lines indicate the confidence intervals at the estimated levels. The bootstrap estimation periods cover 16 months.

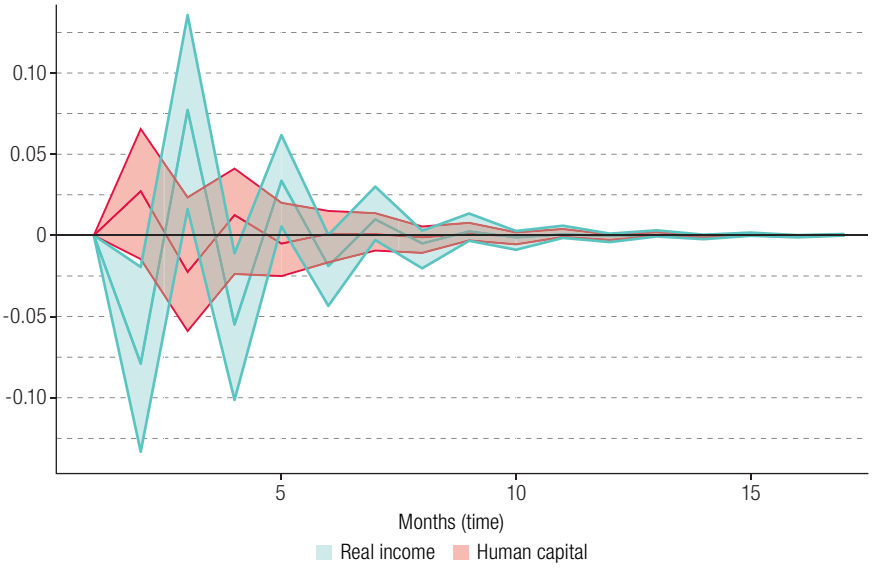
Impulse-response movements in the Central region are found to resemble those in the Eastern region, with the impact on unemployment tailing off (see figure 5). In the Pacific region, changes in unemployment are like those in the Caribbean region, which is possible because other variables have an impact on the number of unemployed in the short term (see figure 6). However, as the periods lengthen towards the long term, the impulse-response effect tails off. This interference tends to be less in the Eastern region, with the result that short-term flows do not vary significantly (see figure 7).

Figure 5
Colombia: impulse-response functions for unemployment shocks in rural areas of the Central region



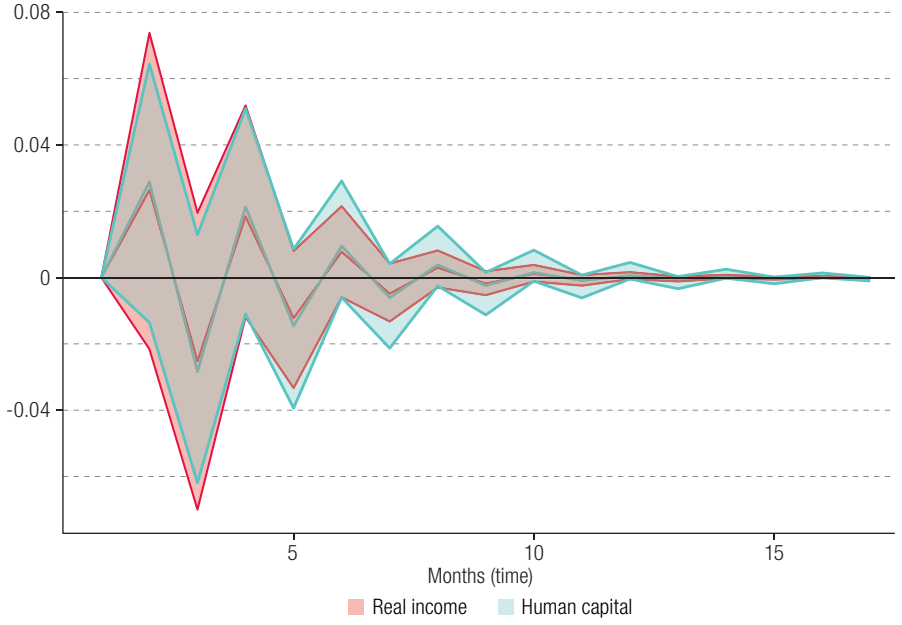
Source: Prepared by the authors.
Note: The horizontal line represents the impulse-response relationships, and the surrounding lines indicate the confidence intervals at the estimated levels. The bootstrap estimation periods cover 16 months.

Figure 6
Colombia: impulse-response functions for unemployment shocks in rural areas of the Pacific region



Source: Prepared by the authors.
Note: The horizontal line represents the impulse-response relationships, and the surrounding lines indicate the confidence intervals at the estimated levels. The bootstrap estimation periods cover 16 months.

Figure 7
Colombia: impulse-response functions for unemployment shocks in rural areas of the Eastern region



Source: Prepared by the authors.
Note: The horizontal line represents the impulse-response relationships, and the surrounding lines indicate the confidence intervals at the estimated levels. The bootstrap estimation periods cover 16 months.

From the above, it can be argued that this initially unsmoothed movement in the Caribbean and Pacific regions is due to the differences in the principal economic activities of their departments. Human capital characteristics have a similar effect, presenting shocks or innovations with significant repercussions in the short term but tending to normalize in the long term (Otero-Cortés, 2019). The interference from these innovations in the Eastern and Central regions is normalized in the short term, which may be due to the small impact that the remaining variables have on movements in the unemployment variable, as seen in the variance decomposition analysis.

To conclude the analysis, we show the variance decomposition, which allows us to compute the proportional impact of each of the variables on changes in the variable analysed, identifying causal dependencies for short-term movements (Johnston and DiNardo, 1997; Stock and Watson, 2012). Table 7 shows the variance decomposition at the region level. In all the regions of Colombia, changes in the natural logarithm of unemployment have a significant impact on its own future movements.

Table 7
Colombia: 12-period estimated variance decomposition for rural areas, by region
(Percentages)

	Caribbean	Central	Pacific	Eastern
ΔU_{it}	97.09	98.61	89.03	96.82
ΔY_{it}	2.08	0.534	10.09	1.78
ΔH_{it}	0.11	0.854	0.863	1.39

Source: Prepared by the authors.

VI. Conclusions

The aim of this article is to analyse the relationship between income and unemployment in rural areas of Colombia's regions from 2010 to 2022 in relation to Okun's (1962) law. We first identify a robust inverse relationship between income and unemployment in almost all rural regions of Colombia. These results show that, in rural areas, economic growth and related increases in real incomes are followed by a reduction in unemployment.

Conversely, increases in human capital in rural areas lead to higher unemployment. Rural demand for workers is oriented towards individuals with lower levels of qualifications, since production specializes in low value added goods. The results reveal a degree of regional homogeneity in rural areas (Merchán Hernandez, 2015; Otero-Cortés, 2019).

Using the ECM, we find a statistically significant long-term relationship between unemployment and all the variables at the region level. Where short-term relationships are concerned, there is a negative relationship between unemployment and real income in the Caribbean, Central and Eastern regions, but not in the Pacific region. This is consistent with previous results (Sadiku, Ibraimi and Sadiku, 2015).

The Granger causality test identifies short-term causal relationships for almost all the variables in the different regions. The impulse-response function results show that the impact of innovations on unemployment produces movements or changes in the logarithm of the number of unemployed in rural areas. These movements are abrupt and are most volatile in the short term. As time goes on, the effect decreases, for example in the Caribbean and Pacific regions. The strength of these movements is due to the weight of the variables concerned in the variance decomposition.

These results have major economic and social policy implications in rural areas of the Colombian regions. This study allows us to derive the causal and deterministic relationships linking real income and human capital accumulation to unemployment in both the short and long terms. It also makes it possible to state that productivity and economic diversification have positive effects on real income.

Regarding human capital, we show that economic diversification and productivity have a positive impact on its utilization. Concerning the relationship between human capital and rural unemployment, the point can be made that the education system ought to be attentive to labour market needs. More work-based training would increase the use of human capital in productive activities, and increasing the number of formal jobs available would positively impact cumulative work experience. Policies of this type should have the effect of decreasing unemployment among highly skilled people in these labour markets. We conclude that all these actions in combination would promote economic growth and development in rural areas.

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