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Article

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Regional business cycles and manufacturing productivity: empirical evidence in Colombia

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Abstract

Purpose – The aim of this paper is to disentangle the contemporaneous and non-contemporaneous relationship between regional business cycles and manufacturing productivity in a developing country, namely Colombia.

Design/methodology/approach – The methodology is quantitative. To deal with the problems of endogeneity in the production function and with the law motion of productivity (the Markov process), the authors obtain Total Factor Productivity (TFP) through the Wooldridge's two equations system that can be jointly estimated under the generalized method of moments framework (GMM). Secondly, to avoid bias we estimate regional business cycles through the Kalman filter. Subsequently, we implement an instrumental variables/generalized method of moments regression (IV/GMM) to capture the contemporaneous and endogenous TFP–GDP cycles' linkage at the regional level. Lastly, to deal with the non-contemporaneous link, the authors estimate a vector autoregressive model with exogenous variables (VARX) for each region. We also present the corresponding impulse–response functions.

Findings – The authors' general results suggest a remarkable causality, both contemporary and non-contemporary, from productivity to GDP (but not vice versa) in the most developed regions of the country. This implied productivity could influence in the economic growth of regions in short and long runs. These results are different than those expected by economic theory and should be considered by local economic policy makers.

Research limitations/implications – The authors consider that a more detailed analysis should be carried out at the level of each sector within the manufacturing industry to further clarify these findings.

Practical implications – The policy should be oriented to obtaining cutting-edge technologies through subsidies, and also should facilitate the access to financial capital and the investment in R&D laboratories. On the other hand, the link with international trade also must be reinforced because the importing of intermediate inputs and exporting of output allow the firms to obtain embodied technologies, also to incur on learning by exporting and importing processes and finally to gain experience and competitiveness in foreign markets.

Social implications – The causality in the region that provides more than 50% of economic activity within the country (Third region) is only in one directional, from TFP towards gross domestic product (GDP) and not vice versa. As the influence from GDP towards TFP is minimal in the remaining regions, the manufacturing productivity influences both short and long run regional economic growth in Colombia. This implies that economic policy at the level of macro-region must be modified; the government should give additional support to the manufacturing sector, especially in developed regions and for the small and medium-sized enterprises (SMEs) (which represent 92% of manufacturing firms) to increase economic growth in the future.

JEL Classification — D24, E32, P25, C33.

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Originality/value – The authors' contribution is threefold. First, they pay special attention to the contemporaneous cyclical relationship (i.e. pro-cyclical, counter-cyclical or acyclic) and the non-contemporaneous causality with productivity. Second, they estimate productivity with the GMM two equation system considering an endogenous Markov process. Third, to the best of their knowledge, at least in the case of Latin America, there are no studies in this direction combining these statistic methods, including that of Colombia.

Keywords Business cycles, Total factor productivity, Regional economy, Colombian manufacturing

Paper type Research paper

1. Introduction

Colombia is a country with heterogeneous regions, each one with different levels of development and economic growth. Historically, as a developing country, the agriculture sector has been the dominant economic activity sector in almost all regions, but after trade liberalization in the new millennium, other activities such as services or manufacturing started to gain an increasing percentage of the local gross domestic product (GDP). Currently, the manufacturing industry is the third most important sector in the country with an average of nearly 13% in the last two decades, only behind the service (16%) and financial (20%) sectors.

Nevertheless, the economic impact of this sector has been dissimilar in different regions of the country. The influence of local issues such as deficient infrastructure (airports, seaports and roads); topographic difficulties (the three mountain ranges of the Andes) and public order problems (presence of guerrillas), has not been homogenous; the effects depend on the region where the firms are located. Specifically, the regional differences in Colombia play a fundamental role to determine the performances of manufacturing firms. For instance, the absence of efficient transport prevents enjoying the profits of economies of scale due to the increase in the costs and consequently the reduction on firms' competitiveness in local and foreign markets. Topographic difficulties and a weak infrastructure road affect the final prices, and the presence of groups outside the law promotes not only extortion but also kidnapping of white collar workers.

In this sense, manufacturing firms' performance and/or productivity is divergent across the country (Nguyen, Nguyen, Ngo, & Nguyen, 2019) and hence the industry influence into regional economic growth and/or business cycles. It is worth mentioning that we are not going to delve into the contribution of regional analysis to understand the relationship between business cycles and manufacturing productivity because this is still a matter of debate (Baxter & Kouparitsas, 2005; Kehoe, Backus, & Kydland, 1995; Artis, Dreger, & Kholodilin, 2011, among others). Nonetheless, there appears to be an accepted consensus: regional economy, firms' productivity and business cycles are sides of the same coin despite the influence of non-economic local factors as migration, habits, heritage and culture (Artis *et al.*, 2011).

The link productivity-business cycles have been well studied the macro level, mainly in developed countries, with a special emphasis on causality.

The related literature documents a bidirectional causal link amongst business cycles and productivity [1]. Following Aghion and Saint-Paul (1998), the mechanisms of learning by doing and aggregate demand externalities boost economic expansions, and therefore have a positive long-run effect on TFP. But the opportunity cost of some productivity improving activities falls in a recession, and the expectation of future recessions reduces today's incentives for productivity growth. Nevertheless, the empirical evidence shows mixed results. Studies carried out by Maroto and Cuadrado (2012), Maroto (2011), Biddle (2014), Berger (2012), and Gali and Van Rens (2014), amongst others, suggest a counter-cyclical behaviour in Spain, Bulgaria and Slovakia, but a pro-cyclical one in the USA. It is important to mention that studies in these topics for emerging economies such as Colombia are quite scarce and even rarer when the regions are analysed.

As in macroeconomics, we consider that manufacturing productivity and regional economic cycles must also be closely related, but for different reasons, especially in regions where this activity is stronger. The manufacturing performance contributes to the evolution of regional GDP because this sector is linked to international markets through the importation of intermediate inputs and exportation of final goods and also due to expenditures in Research and Development (R&D) activities, introduction of innovations, the hiring of skill and unskilled labour, amongst others (Máñez & Love, 2020). But on the other hand, the growth of regional GDP incentivizes firms to increase output, hire more workers, pay higher wages and invest more financial resources because there is confidence in the economy and the expected demand is increasing. Therefore, the regional GDP affects manufacturing productivity and vice versa. All in all, the relationship between regional business cycles and sector performance is still unclear, and more so in emerging economic regions.

Therefore, the objective of this paper is to disentangle empirically the linkage between business cycles and manufacturing productivity in the geographical regions of Colombia. In doing so, we pay special attention to the contemporaneous cyclical relationship (i.e. procyclical, counter-cyclical or acyclic) and the non-contemporaneous causality in this link. To the best of our knowledge, in the case of Latin America, there are no studies in this direction or studies combining these statistic methods, including that of Colombia [2].

The data we use have been drawn from the Annual Manufacturing Survey (EAM) and the regional economic information published by the Colombian National Administrative Department of Statistics (DANE). After merging 26 EAM waves, we collapse by year and region to obtain the average TFP in the period from 1992 to 2018. We articulate this information with GDP and unemployment rate for each region, so we end up with information about five regions in 26 years. Nonetheless, to deepen our analysis, the full results of the country will also be shown.

To undertake this research, we proceed in several methodological steps. First, to deal with the problems of endogeneity in the production function (freely factors and unobserved productivity) and with the law motion of productivity (the Markov process), we obtain Total Factor Productivity (TFP) through the two equation system proposed by Wooldridge (2009) that can be jointly estimated under the GMM framework. Secondly, to avoid bias we estimate regional business cycles through the Kalman filter which is estimated by the Broyden–Fletcher–Goldfarb–Shannov (BFGS) algorithm. Subsequently, we implement an instrumental variables/generalized method of moments regression (IV/GMM) to capture the contemporaneous and endogenous TFP–GDP cycles’ linkage at the regional level. Lastly, to deal with the non-contemporaneous linkage, we estimate a vector autoregressive model with exogenous variables (VARX) for each region. In addition, we also present the corresponding impulse–response functions (IRF) [3].

Our general results suggest a remarkable causality, both contemporary and non-contemporary, from productivity to GDP (but not vice versa) in the most developed regions of the country. This implied productivity could influence in the economic growth of regions in short and long runs. These results are different than those expected by economic theory and should be considered by local economic policy makers.

The document is divided into six sections; this introduction is the first one. The rest of the paper is organized as follows: Section 2 summarizes the related literature and empirical studies. Section 3 describes the material and methods, including the descriptive analysis. Section 4 presents the calculations related to the econometric methodology. Section 5 displays the results and discussion. Finally, Section 6 presents the conclusions.

2. Theory

The review of previous studies reflects that the evolution of productivity is subject to the cyclical fluctuations experienced by practically all market economies (Basu & Fernald, 2001).

In recent decades, research has shown this correlation at the aggregate level, based on different measures of final production. Some of them have concluded that labour productivity has a pro-cyclical behaviour, while others have found that productivity behaviour may be counter-cyclical (Maroto, 2011), and others show inconclusive (acyclic) results.

In the 1960s, Hultgren (1960) and Kuh (1965) find that in the USA during the first half of the 20th century, labour productivity is pro-cyclical with GDP, that is, it increases in business expansions and decreases in recessions. Similar results were also found by Shapiro (1987), Shapiro (1993), Caballero & Lyons (1990), Okun (1962), Bils and Cho (1992), Solon, Barsky, and Parker (1994), Navarro and Soto (2001), Caruso (2002), Vecchi (2003), Wen (2004).

More recent articles such as those by Lama (2011), Chaves (2017) and Camino-Mogro, Armijos-Bravo, and Cornejo-Marcos (2018) found evidence on the pro-cyclical behaviour of productivity and the economic cycle. Lama (2011) assesses the types of models that could explain the fall in production in Latin America during the 2007 crisis, finding that the sources of fluctuations in production underlay TFP, specifically the labour factor; it also discusses the implications of these findings in policy analysis using stochastic dynamic general equilibrium models. Along this same line, there are Camino-Mogro *et al.* (2018) who analysed the production of the Ecuadorian manufacturing sector and generated a measure of provincial, regional business productivity and industrial activity for the period between 2007 and 2016. Through a dynamic model like the system generalized method of moments (GMM-SYS), which minimizes the problem of simultaneity and endogeneity, the study reveals that TFP presents a growth pattern that coincides with the movements of GDP throughout the period; there is evidence in favour of a positive relationship between TFP and the size of the firm and the region in which it is located. In the Colombian case, Chaves (2017) analyses the growth accounting in the agricultural sector in the period 1976–2013, finding a strong contribution of the labour factor and the growth of TFP, but a low contribution from the capital stock. The analysis of changes in the GDP cycle and each of its demand components in the sector shows that the aggregate variables of agricultural activity behave pro-cyclically.

On the other side, the recent counter-cyclical behaviour of the US labour productivity is also a puzzle and seems to be stimulating a reflection on how labour markets and macroeconomics work during cyclical recessions. Authors like Biddle (2014) found that, the US labour productivity, in the beginning of the last century, showed an opposite behaviour to the economic growth. Berger (2012), explains that the detriment of pro-cyclical US productivity resides in increasing firm inefficiency throughout expansions, while during recessions they rearrange the labour in order to become more efficient. Galí and Van Rens (2014) point to the surge of flexibility due to the decrease of the power of unions to explain the reduction of pro-cyclicality and the increase in the volatility of employment and wages with respect to output in the USA since 1984. Gordon (2010) found that the pro-cyclical productivity response of Okun's law has been outdated in US data since the mid-1980s. Daly, Fernald, Jordà and Nechio (2011) discuss how the institutional factors' other characteristics of the labour markets could affect the Okun coefficient. Rujiwattanapong (2018) found that unemployment benefits have caused half the drop in the positive correlation since 1985.

In the case of the economies of Spain, Bulgaria and Slovakia, Maroto and Cuadrado (2012) and Maroto (2011) found that there is no pro-cyclical behaviour, because in the global economic crisis of 2008 the productivity raised in these countries, showing the cycle was counter-cyclical. Maroto and Cuadrado (2012) found that productivity in Spain has had a significantly counter-cyclical behaviour. However, it could be inferred that said behaviour could have been influenced by the sector structure of the Spanish economy and by the possible differentiated responses of the different economic sectors to the economic cycle.

Likewise, there are bibliographic records that give ambiguous results. Levenko, Oja, and Staehr (2019) present growth accounting results for 11 European Union (EU) countries from Central and Eastern Europe for the years 1996–2016. Before the crisis, growth in TFP was the

main contributor to output growth in Slovenia, Hungary and Slovakia, while capital deepening was more important in the Czech Republic, Croatia and Poland. After the crisis, the contribution of TFP growth has been negligible in all the sample countries, coinciding with generally weak output growth. Studies for Latin America, such as that of [Garcia-Cicco, Pancrazi, and Uribe \(2010\)](#) who based on data from more than a century for the economies of Argentina and Mexico, found that the real business cycle model offers a weak explanation, not only in productive activity, but even in financial dynamics in emerging economies; they propose an increased model that incorporates financial friction. This provides a better explanation of the economic cycles in emerging markets and assigns an insignificant role to non-stationary productivity shocks.

Different studies have investigated the role of TFP and regional differences, such as those of [Li \(2009\)](#), [Miller and Upadhyay \(2002\)](#), [Marrocu, Paci, and Pala \(2000\)](#), [Beugelsdijk, Klasing, and Milionis \(2018\)](#), [Wei and Hao \(2011\)](#) and [Dettori, Marrocu, and Paci \(2012\)](#) have reported the relevance of this type of dis-aggregation to understand the contribution of TFP to the explanation of the disparity in regional growth. [Li \(2009\)](#), uses the relative variance method to compare the relative importance of output growth through input growth and productivity growth. The empirical findings show that, although post-reform production growth in China has largely contributed to by the growth of TFP, it finds that there are regional differences when looking at the performance of individual growth rates. [Miller and Upadhyay \(2002\)](#) studied the accumulation of human capital and its relationship with economic growth for 83 countries, grouped into regions and as a whole. Using determinants of TFP that include human capital, openness and distortion of domestic prices in relation to world prices, they find significant differences in the results between the general sample and the sub-samples of countries. Human capital plays a minor role in enhancing growth through TFP. [Marrocu et al. \(2000\)](#) have studied long-term production functions for 20 regions and 17 sectors in Italy during the period 1970–1994, since the Italian regions have experienced quite different and, in some cases, divergent development paths. They find that factor elasticities differ greatly between regions and sectors. This is an important result since most of the previous studies using unique national elasticities introduce severe bias in productivity comparisons. [Beugelsdijk et al. \(2018\)](#) argue that the large and persistent differences in economic development between the sub-national regions of the EU countries can be largely attributed to differences in TFP. They find that TFP differences are large even within countries and are closely related to economic geography and historical development trajectories. This suggests limited inter-regional diffusion of technology and efficient production practices. [Wei and Hao \(2011\)](#) studied the role of human capital in the growth of China's provincial TFP, and find differences in the regional impacts of human capital by levels of schooling. [Dettori et al. \(2012\)](#) studied the role that intangible factors (human capital, social capital and technological capital) play in TFP levels, by region in Europe. They find that a large part of the TFP differences between European regions is explained by the disparities in the endowments of these intangible assets.

Lastly, the empirical evidence for causality is scarce; in many of them only one-way causality was considered. [De Long and Waldmann \(1997\)](#) analysed whether labour productivity is pro-cyclical in response to demand shocks. They found evidence that pro-cyclical productivity is more than the consequence of supply-side shocks that are propagated through a standard real business cycle model. [Malley et al. \(1998\)](#) tried to model the dynamic interaction between TFP and employment in the USA (as a measure of business cycles). On one side, they found the productivity raises during economic expansions through learning-by-doing (LBD) effects. Moreover, the R&D expenditures have to be financed from retained profits; R&D activity is more likely to take place in booms than in recessions. On the other side, the impact of productivity on the business cycles is due to a standard shift effect on labour demand and the accompanying impact on capital accumulation. [Rafferty \(2003\)](#)

examined a possible link between business cycles and growth, through R&D expenses financed by the company. They found that R&D expenses are pro-cyclical due to the effects of cash flow. The results imply that recessions could reduce long-term growth by decreasing an important inventive contribution: R&D expenses. In the same vein, [Gutiérrez \(2011\)](#) analysed the relationship between information and communication technologies (ICT) investments and productivity in the Colombian manufacturing industry.

These contradictory outcomes are probably due to two main reasons. The use of labour productivity instead of TFP which is a better indicator of efficiency and the estimation of business cycles through the Hodrick–Prescott filter, which have problems since the *ex ante* determination of the smoothing parameter is defined at the discretion of the researcher, and the extremes of the trend are poorly defined, which induces spurious behaviours ([Gómez-Sánchez, 2011](#)).

3. Material and methods

3.1 Data mining

For this study, we have divided Colombia into five regions according to natural resource disposition and the similar production activities of goods and services (see [Figure 1](#)). Three of them are called Andean [\[4\]](#); Caribbean [\[5\]](#); and Pacific [\[6\]](#). To avoid *noise* in the estimates, the three zones with the highest economic activity in the country (Antioquia, Valle del Cauca and the capital district, Bogota) are grouped into a single one, namely the Third region. The remaining states are grouped in a fifth residual region called Others region [\[7\]](#). To deepen the analysis we include the full country as a sixth region [\[8\]](#).

To obtain TFP, the database of the EAM was used, broken down by state from 1992 to 2018 [\[9\]](#). The relevant variables for this study are in constant prices (2005); the outliers are eliminated, only taking the observations in relevant variables without missing data superior to centile 1 and inferior to centile 99. After merging 26 EAM waves, we collapse by year and region to obtain the average TFP in the period (1992–2018). We plug this information with those related to GDP, rate of unemployment, population, amongst others; we end up with 130 observations corresponding to five regions in 26 years (without including the Total region).

3.2 Descriptive analysis

In the top panel of [Table 1](#), we display the average of variables related to production function in the manufacturing industry and in the bottom panel some preliminary proxies of the firm's productivity, all broken down by regions. The figures suggest that the Third region shows the best performance in all variables analysed (labour, wages, capital, materials and energy), exceeding the national average. This is an expected result because most manufacturing firms are concentrated in this area.

The Andean region also shows a remarkable economic performance, exceeding the national average, as this region is the most developed one in the country. On the other side, the Caribbean region is more related to the national average figures, and finally, the Pacific and Others region are zones with the most discrete performance in the industry. With all the above, we can point out that there are three regional well-defined groups with similar characteristics in the manufacturing industry; the Third region and Andean region make up the first group, the second group by the Caribbean region, and the third group includes Pacific and Others regions. In fact, all variables are very similar within them but not amongst them. For instance, there is a great difference between the average wages in the Andean and others regions, but are close to the Third region. These results suggest that in Colombia there are marked differences in the manufacturing industry. The best performance is achieved in

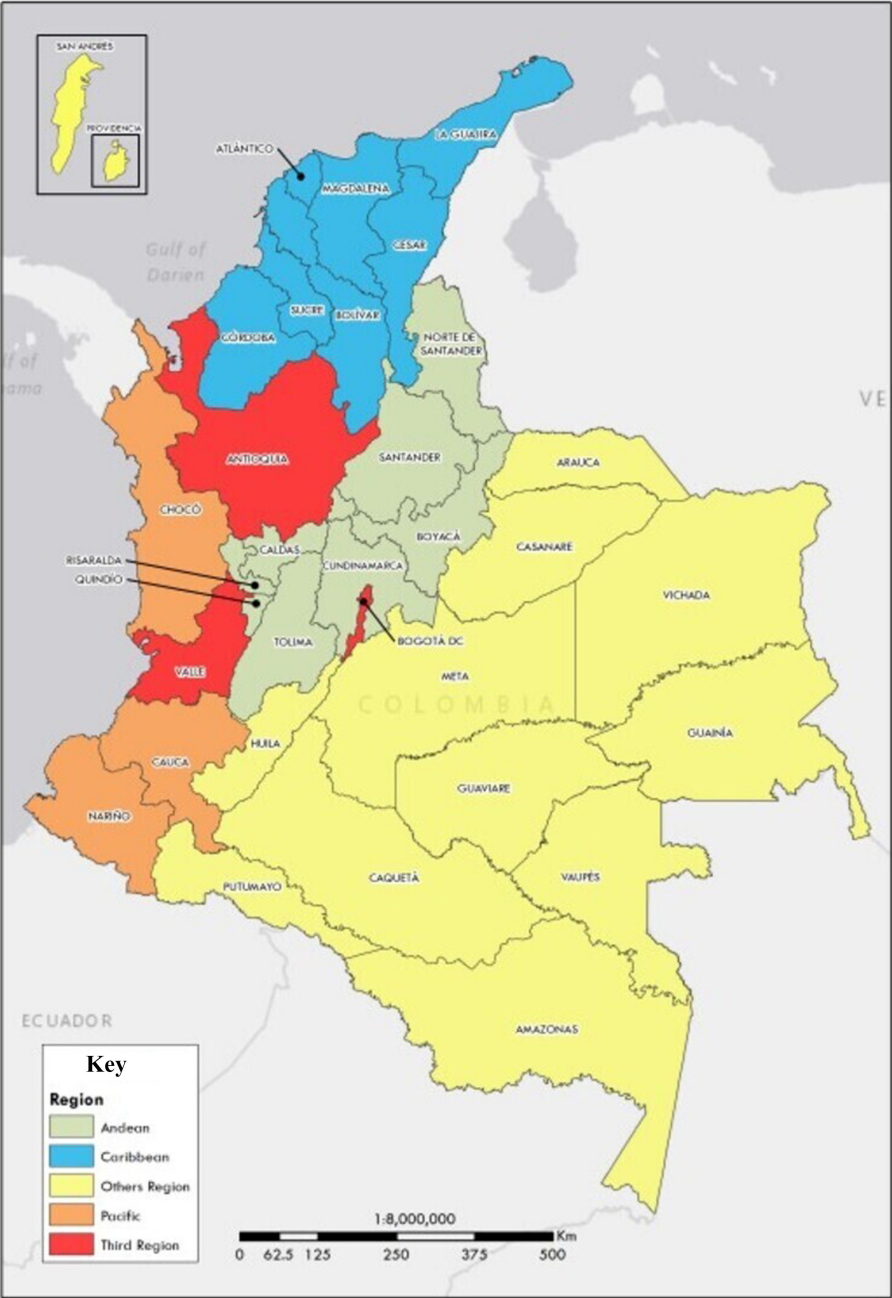


Figure 1.
Region classification

	Andean	Third	Caribbean	Pacific	Others	Total	Disentangling business cycles-TFP linkage
<i>Output/Inputs</i>							
Output	21.29	23.62	20.18	19.79	18.84	20.84	
Labour	9.060	11.84	7.950	7.880	6.650	8.700	
Wage	17.88	20.71	16.93	16.72	15.47	17.57	
Capital	21.13	23.54	20.41	19.81	18.95	20.85	
Materials	20.80	23.09	19.55	19.33	18.35	20.31	
Energy	19.08	21.21	18.40	17.60	16.04	18.66	
<i>Productivity</i>							
Capital/labour	12.07	11.70	12.45	11.92	12.30	12.14	
Capital/materials	11.74	11.25	11.60	11.45	11.70	11.60	
Output/labour	12.23	11.78	12.22	11.91	12.19	12.14	
Output/capital	11.24	10.91	11.38	10.91	11.19	11.20	
Labour/wage	8.810	8.870	8.980	8.840	8.810	8.870	
Observations	243	81	183	61	75	643	
Source(s): Authors' calculations							Table 1. Log means of factors and preliminary productivity measures

top regions located geographically in the inland regions, but both coasts and remaining regions show a distant pattern. This finding coincides with the localization of the highest levels of economic development and poverty in this country.

On the other hand, the near value amongst output and materials not only in the country but also in the regions is striking, which evidences the low added value generated in the manufacturing industry in Colombia for the analysed period. In addition, the Third and Andean regions' performance above the average, suggests that both largely boost the national performance of the industry.

At the bottom of the table, we account for some standard measures of productivity different than TFP. The capital-labour ratio shows high figures for Caribbean and Others region; conversely the Third region shows a discrete performance. On the other hand, the capital-materials and wage-labour ratio are quite similar amongst all regions; however, the average output per worker (output-labour ratio or labour productivity) is dominated by Andean and Caribbean region, and the same pattern is exposed for the output-capital proportion. These proxies for average firm's productivity by regions display dissimilar behaviours since some regions rule over others; therefore, we can point out that the initial pattern showed in the top of table is not the same.

Table 2 presents the mean in the log of GDP and rate of unemployment by regions. In the case of GDP, the pattern is similar to the upper part of **Table 1**. The Third and Andean regions have similar level of economic activity, as they lead the economic activity in the country, but it is different for the remaining regions. Lastly, the Pacific region has the worst performance.

On the other hand, the two main important regions display the same rate of unemployment (11.1%) and the Caribbean shows the higher rate. Surprisingly, the last two regions (with low GDP) show the lowest rate of unemployment (one-digit rate). The reason for this atypical behaviour is that zones with the highest population and activity economic levels in the country are located in the central regions, not in the coasts or remaining

Variable\Region	Total	Andean	Third	Caribbean	Pacific	Others	Table 2. Log means of GDP and mean rate of unemployment by regions
GDP	12.78	11.38	12.11	10.87	9.37	10.01	
Unemployment	9.26%	11.11%	11.11%	12.78%	9.93%	8.70%	
Source(s): Authors' calculations							

regions. All in all, there are differences not only in the approximate measures of productivity, but also in the level of economic activity and unemployment. For that reason, it is necessary to desegregate by regions to account for the unobserved heterogeneity of each zone; otherwise, the real impacts and behaviour of productivity would be hidden.

4. Calculation

With the purpose of disentangling the relationship between regional business cycles and manufacturing productivity, we follow four econometric steps: TFP is obtained under GMM two equation systems (Wooldridge, 2009) to avoid endogeneity problems in the production function. The Kalman filter algorithm is implemented and estimated by the BFGS algorithm to get regional business cycles to avoid biases; further, to capture contemporaneous and non-contemporaneous link between cycles and productivity an instrumental variables/generalized method of moments (IV/GMM) and a VARX model with endogenous and exogenous regressors are implemented, respectively.

4.1 Productivity estimation

We consider a Cobb–Douglas production function. The output (y_{it}) depends on the free (or variable) factors (labour l_{it} , materials m_{it} and energy ene_{it}) and state factors such as capital (k_{it}). The productivity that is only observed by the firm is denoted by w_{it} . Finally, ε_{it} is a standard independent and identically distributed (*i.i.d*) *error term* that is neither observable nor predictable by the firm.

$$y_{it} = \alpha_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_{mp} m_{it} + \beta_{ene} ene_{it} + \omega_{it} + \varepsilon_{it} \quad (1)$$

As w_{it} is observable by the firm, it impacts on the choice decisions of the free inputs. This fact leads to the endogeneity problem in the estimation of the production function; therefore, the estimation by ordinary least squares method (OLS) will be biased. Olley and Pakes (1996) and Levinsohn and Petrin (2003), propose a control function approach to resolve the problem by the materials' demand as a function of unobserved productivity and state variable.

$$m_{it} = m_t(\omega_{it}, k_{it}) \quad (2)$$

By assuming the demand for materials is a monotonous and strictly increasing function in w_{it} , it is possible to invert Equation (4) and express unobservable productivity in terms of the observable variables (or the firm's control variables):

$$\omega_{it} = h_t(m_{it}, k_{it}) \quad (3)$$

Following De Loecker (2007) and Máñez and Love (2020), we consider that firms having contact to foreign markets (exports and imports) and/or positive expenditures in R&D, use different production processes that affect the demands for materials and R&D inputs, compared to other firms that do not incur in these processes. This distinction helps to correct for unobserved productivity shocks correlated to innovation and internationalized status. Therefore, Equation (5) now is:

$$\omega_{it} = h_t(m_{it}, k_{it}, ird_{it}) \quad (4)$$

where ird is a dummy variable that takes value 0 for firms with no contact to foreign markets and/or null expenditures in R&D activities; and 1 otherwise, respectively. Then, substituting (4) in (1) we get the following:

$$y_{it} = \alpha_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_{mp} m_{it} + \beta_{ene} ene_{it} + h_t(m_{it}, k_{it}, ird_{it}) + \varepsilon_{it} \quad (5)$$

As the functional form h_t is unknown, the parameters α_0 , β_k , β_m are not identified. For that reason, we have to introduce another equation that deals with the law of motion of productivity, or the law that rules the evolution of productivity over time. [Olley and Pakes \(1996\)](#) assume an exogenous Markov process, i.e. the current productivity depends on past productivity lagged one period. But following [Doraszelki and Jaumandreu \(2013\)](#), we consider the current productivity depends not only on the past firm performance, but also on the past innovations and firm's internationalization strategies. Therefore, we endogenize the Markov process under this consideration. The law motion is as follows:

$$\omega_{it} = E[\omega_{it}|\omega_{it-1}, ird_{it-1}] + \eta_{it} = f(\omega_{it-1}, ird_{it-1}) + \eta_{it} \quad (6)$$

By replacing ω_{it-1} in (6) by the definition in (4), we obtain the following:

$$\omega_{it} = f(h_t(m_{it-1}, k_{it-1}, ird_{it-1}), ird_{it-1}) + \eta_{it} = g_t(m_{it-1}, k_{it-1}, ird_{it-1}) + \eta_{it} \quad (7)$$

Finally, by plugging (7) in (1), we get the following:

$$y_{it} = \alpha_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_{mp} m_{it} + \beta_{ene} ene_{it} + g_t(m_{it-1}, k_{it-1}, ird_{it-1}) + \eta_{it} + \varepsilon_{it} \quad (8)$$

Equations (5) and (8) form the two equations system proposed by [Wooldridge \(2009\)](#) that can be jointly estimated by the GMM framework. The unknown functions $h_t(\cdot)$ and $g_t(\cdot)$ can be approximated by third degree polynomials. Under the right choice of instruments, the unbiased parameters are estimated, and therefore, TFP is obtained as a residual as follows:

$$\omega_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_{ene} ene_{it} - \hat{\beta}_k k_{it} \quad (9)$$

4.2 Business cycles

To find GDP, TFP and unemployment cycles for each region, we use the Kalman filter framework [10]. The first step in this algorithm is to set the state-space model that estimates the trend. An unobservable vector of state variables β_t that defines a system at a given time is assumed by the filter. The scalar vector Y_t is known and is defined like a linear combination of state variables plus an error term. This equation is called the measurement equation. Therefore, β_t and Y_t establish the state-space model of the Kalman filter ([Montenegro, 2005](#)).

Following [Gómez-Sánchez \(2011\)](#), in the present case, we assume that the trend follows a local linear trend model defined by the following state variables:

$$Ln(T_{it}) = Ln(T_{it-1}) + Ln(\beta_{it-1}) + \omega_t \quad ; \quad \omega \sim N(0, \sigma_\omega^2) \quad (10)$$

Equation (13) shows the structure of the measurement equation. For the equation of state, we assume the β_t follows a first-order autoregressive process, AR (1). Thus

$$Ln(\beta_{it}) = Ln(\beta_{it-1}) + \varepsilon_t \quad ; \quad \varepsilon \sim N(0, \sigma_\varepsilon^2) \quad (11)$$

The process is estimated through maximum likelihood, under the optimization algorithm of BFGS. The cycle is obtained from the difference between the observed behaviour of the series and the trend. To extract the trend, four unobservable components in any time series must be taken into account: trend (T_t), cycle (C_t), seasonality (S_t) and an irregular or random component (U_t):

$$Ln(Y_t) = \alpha_1 Ln(T_t) + \alpha_2 Ln(C_t) + \alpha_3 Ln(S_t) + \alpha_4 Ln(U_t) \quad (12)$$

Introducing expected values:

$$E[Ln(Y_t)] = \alpha_1 Ln(T_t) + \alpha_2 Ln(C_t) + \alpha_3 Ln(S_t) \quad (13)$$

As we said before, the expected cycle of any time series is obtained from the difference between the value of the series and its trend as follows:

$$Ln(C_t) = (1/\alpha_2)E[Ln(Y_t)] - (\alpha_1/\alpha_2)Ln(T_t) - (\alpha_3/\alpha_2)Ln(S_t) \quad (14)$$

As the data used are annual, the seasonal component was removed with the X12 ARIMA method:

$$Ln(C_t) = (1/\alpha_2)E[Ln(Y_t)] - (\alpha_1/\alpha_2)Ln(T_t) \quad (15)$$

Equation (15) allows to obtain the cycle of GDP and TFP.

4.3 Contemporaneous causality

To deal with the contemporaneous causality between regional cycles and productivity, we use an IV/GMM estimation with endogenous regressors, because, as we pointed out before, GDP could influence the contemporaneous TFP and vice versa. We instrumented TFP through the capital–labor ratio and the product–labor ratio lagged in one and two periods. In the case of GDP, it is instrumented through GDP and electricity consumption also lagged in one and two periods [11]. In this vein, the two equation system is defined as follows [12]:

$$cltfp_t = \alpha_0 + \alpha_1 clgdp_t + \alpha_2 cluemp_t + \alpha_3 cluemp_{t-1} + \alpha_4 crisis_t + \alpha_5 clpop_{t-1} + \xi_t \quad (16)$$

$$clgdp_t = \lambda_0 + \lambda_1 cltfp_t + \lambda_2 cluemp_t + \lambda_3 cluemp_{t-1} + \lambda_4 crisis_t + \lambda_5 clpop_{t-1} + e_t \quad (17)$$

where $cltfp$ is the cycle of TFP; and $clgdp$ is the cycle of GDP. In the case of exogenous variables, in Equations (16) and (17) we include the contemporaneous and lagged rate of unemployment ($cluemp$); the *crisis* variable contains the global and local economic crisis that occurred in 1999 and 2009, which deeply affected the productive chains in manufacturing with many other economic sectors. Finally, it also contains the lagged population (pop) for each region. We suppose that error terms (ξ_t, e_t) are uncorrelated with exogenous variables in both equations and all periods.

4.4 Non-contemporaneous causality

We assume a VARX model of order p represented by a system of linear equations:

$$Y_t = AY_{t-p} + BX_{t-k} + \epsilon_t \quad (18)$$

where Y_t is a vector of dependent variables (GDP and TFP cycles); Y_{t-p} is the lagged endogenous variables; X_{it} is a vector of exogenous covariates (unemployment, crisis in 1999/2009 and population). The matrices A and B are parameters to be estimated. Lastly, we assume that the innovations ϵ_t have the following characteristics: $\epsilon_t \sim N[0, \Sigma_\epsilon]$; $E[\epsilon'_t \epsilon_t] = \Sigma_\epsilon$; $E[\epsilon_t \epsilon_{t-i}] = 0$.

To define the optimal lag order specification, we use Akaike, Bayesian and Hannan–Quinn information criteria. Lastly, to deepen our analysis, we include the IRF.

5. Results and discussion

5.1 Total factor productivity

Table 3 displays the factor elasticities by regions in Colombia obtained by the GMM two equation system of Wooldridge (2009). Under *ceteris paribus* conditions elasticity in general is not higher than one, so the output is somewhat sensitive to changes in the use of factors in all regions in Colombia. The output is most sensitive in the Caribbean region when the labour increases, and less sensitive in the Other region. In the Third region, the investment in capital

generates a notable increase in output; this happens mainly because the most important manufacturing activity in the country is concentrated in this region, and the enterprises import technology from abroad that is embodied in capital goods (Navarro & Soto, 2001). The materials are also mostly imported from developed countries, and as usual, show higher output elasticity.

The Wald test is highly significant for Caribbean and Other regions, so we reject the null hypothesis and conclude that these production functions do not exhibit constant returns to scale. In the remaining and most important regions, including full country (the Total region); the sum of the coefficients is near to one, so we find constant returns to scale.

Figure 2 displays TFP by regions according to two GMM systems proposed by Wooldridge (2009) [13].

As we expected, the Third region shows the best performance on productivity terms; the worst performance is related to the Pacific region. The Caribbean region performance is similar to the Third regions, and it is superior to the Andean and Other regions. Lastly, as we also expected, the Total region displays the best performance.

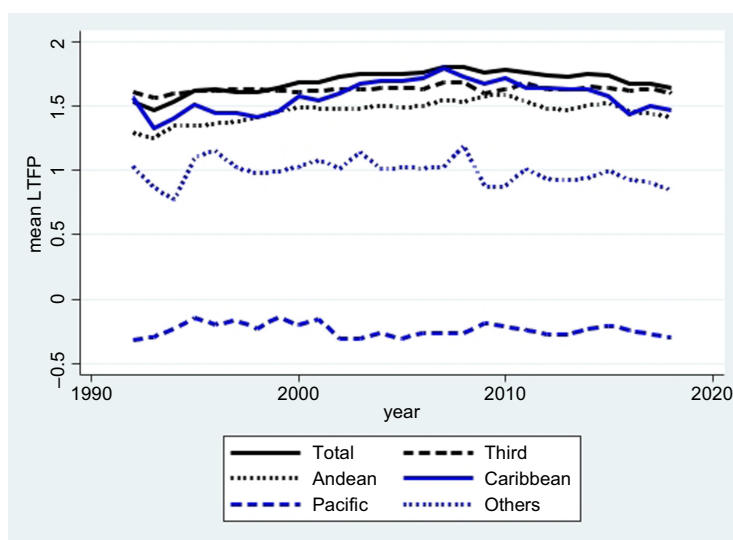
Nonetheless, there are two findings that are striking in the figure. First, the evolution of TFP by regions is constant in general, and even some more developed regions show a slight decrease after the global economic crisis in 2009. Secondly, the TFP figures are quite low; the

Variable/region	Third	Andean	Pacific	Caribbean	Others	Total
Labour	0.09**	0.13***	0.07***	0.18***	0.08***	0.08***
Capital	0.44***	0.06***	0.20**	0.18***	0.07*	0.26***
Materials	0.46**	0.79***	0.74***	0.69***	0.8***	0.65***
χ^2	0.03	0.02	0.1	4.25***	3.24*	1.47
Observations	206	66	158	50	62	542

Note(s): ***, **, * denote level of significance at 1%, 5% and 10 %, respectively

Source(s): Authors' calculations

Table 3.
Output elasticities by
regions



Source(s): Author's calculations

Figure 2.
Average PTF in log by
region 1992–2018

main regions fluctuate in the range of 1.0 and 1.8 over the 26 years. This can be explained by all the factors mentioned above, such as infrastructure, topographic and public order problems. All in all, we can conclude that the Third region is the one that has boosted TFP in Colombian manufacturing in the new millennium.

5.2 Cycles of TFP, GDP and unemployment

Figure 3 displays the standardized Kalman filter cycles of GDP, PTF and unemployment breakdown by regions. The cycle of GDP in all regions shows the same pattern as the national cycle: an expansion in the first half of the 1990s after a strong recession and further a recovery that is slightly affected by the economic global depression in 2009; finally, a decline in the last years. Basically, this is explained by the economic opening to international trade in the nineties and by the local economic crisis in the last years of the past century. On the one hand, the country was not prepared to face international trade since firms lacked cutting-edge technologies, skilled labour, and their productivity and performance were quite discrete. The only gains of international trade were associated with import activities. On the other hand, the local economic crisis was generated by the foreign deficit produced by economic opening and the excessive public spending and credit given to private sectors.

In the case of unemployment, its behaviour is counter-cyclical against GDP as we expected, but lagged; i.e. if the GDP cycle (unemployment) increases in t , in the $t+1$ a fall in unemployment (GDP) will be experienced.

Because the Andean and Third regions have the highest incidences in behaviour at the national level, they show a similar pattern as Total region. There are high volatilities before the new millennium and a subsequent stabilization, although unemployment increases and the performance of regional economies are affected for the years of the global financial crisis. Unemployment has a counter-cyclical relationship with GDP, especially at the end of the period analysed.

The remaining regions have different patterns. In fact, the *Pacific* region displays the most stable behaviour in all variables in the nineties decade due to the aforementioned Páez Law implemented in 1994. Later, unexpected social and economic phenomena emerged (in this region), an illegal money collection firm so-called “pyramids” that coincided with the world financial crisis (Miller & Gómez, 2011). This situation protected the economy of the region, but after its aggressive falls, the effect was much worse on the regional economies. The *Caribbean* region shows an instable GDP cycle along the analysed period, with a pattern of economic recession each five years on average; additionally, the two last global crises have deeply affected this economy. Finally, the Others region shows a volatile GDP before year 2000, and the cycles are very close fitting.

5.3 Contemporaneous causality

Table 4 shows the results of the IV/GMM model. For all regions, the first and second columns display the estimates for cycles of GDP and TFP equations, respectively [14].

In general, all equations fulfil the assumptions for IV regressions. In fact, in the lower panel of Table 4 the p -value of GMM/C (also known as a “GMM distance” or “difference-in-Sargan” statistic) does not reject the null hypothesis for all regions, so the instruments included are valid. In the case of p -value in Hansen’s J, we also cannot reject the null for the most estimates, so the over-identifying restrictions are valid. Lastly, the p -value for the Wald test is near zero, and the R^2 are not so high for some cases due to the deal with cycles’ data. With all the above, we can determine a good fit of the model.

The evidence suggesting the most significant impacts are displayed in the most developed regions (Andean, Third and Caribbean). Specifically, there is a remarkable contemporary

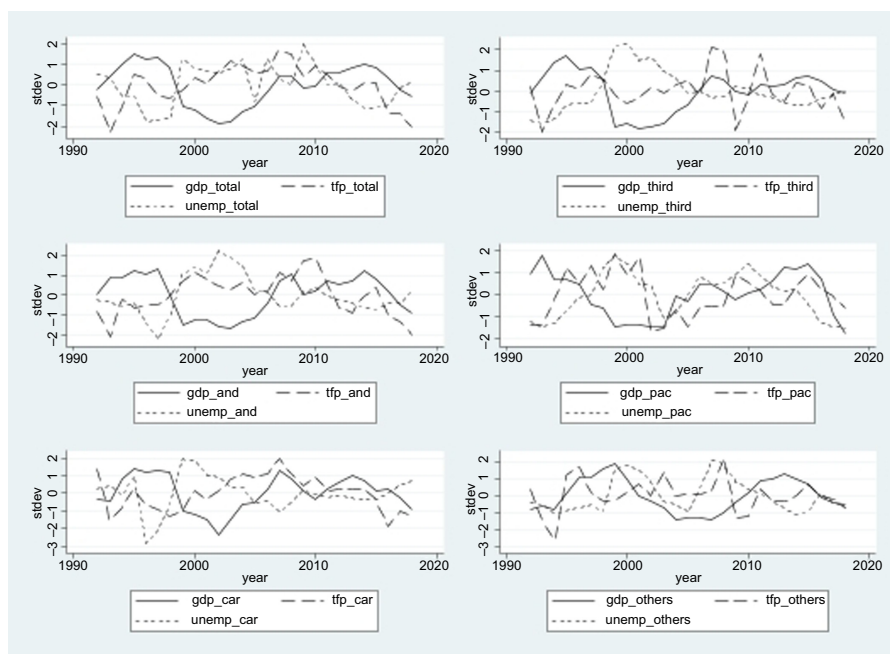


Figure 3.
Standardized Kalman
filter cycles of GDP,
PTF and
unemployment by
regions

causality from productivity to GDP in these regions. As the impact is positive and statistically significant, this reveals a pro-cyclical behaviour between them, i.e. an expansion in manufacturing productivity coincides with an increase in the regional GDP in the same period. Conversely, our results do not show a causality from GDP to TFP (excepting Others region). This implies the contemporaneous productivity of manufacturing firms boosts the contemporaneous regional GDP, but not vice versa.

These results are partially in line with the findings of [Malley *et al.* \(1998\)](#) and [Rafferty \(2003\)](#) for the US economy, because they found pro-cyclical behaviour between the cycles. Nonetheless, a comparison must be taken with caution as the sample, methodology and context are quite dissimilar. All in all, our findings are unexpected because the theory predicts a bidirectional influence, not a one-side effect.

In the less developed Pacific Region, the results are inconclusive as there are not statistically significant results. For full country (Total) the pattern is exactly the same. Therefore, according to the latest result, it is important to highlight that the analysed phenomenon must be broken down by region, since otherwise (by making a full country analysis) the causal relationships found would be hidden and the economic policy would be inadequate.

Finally, it is worth mentioning for exogenous variables, the current and lagged unemployment and also the economic crisis show, as we expected, a negative effect on current regional GDP and TFP; but the latter seems to have had no decisive impact on economic activity. This is probably explained by the emergence of the so-called “pyramids” in the Colombian economy exactly in the same year (an illegal practice to earn money through fraudulent Ponzi schemes) that protected the local economy and mitigated the effects of the world economic recession for several months ([Miller & Gómez, 2011](#)). The lagged population display impacts only in the more developed regions where most of it is concentrated.

Table 4.
Contemporaneous
causality: GDP and
TFP; IV/GMM

	Andean		Third		Caribbean		Pacific		Others		Total	
	<i>clgdp</i>	<i>cltfp</i>	<i>clgdp</i>	<i>cltfp</i>	<i>clgdp</i>	<i>cltfp</i>	<i>clgdp</i>	<i>cltfp</i>	<i>clgdp</i>	<i>cltfp</i>	<i>clgdp</i>	<i>cltfp</i>
<i>clgdp</i>												
<i>cltfp</i>	0.104** (0.051)	0.541 (0.797)	0.144* (0.082)	0.767 (0.500)	0.129* (0.083)	-0.345 (0.751)	0.256 (0.236)	0.806 (0.932)	0.119 (0.117)	2.814** (1.319)	0.070 (0.277)	-0.092 (0.878)
<i>cunemp</i>	-0.640** (0.272)	0.735 (0.854)	-1.546** (0.623)	0.402 (0.989)	-0.177 (0.157)	0.301 (0.733)	0.844 (0.871)	-0.673 (3.242)	-1.129 (1.150)	7.623* (4.726)	-0.237 (0.201)	0.172 (0.744)
<i>cunemp_{t-1}</i>	-0.054 (0.270)	1.616*** (0.575)	-0.844* (0.542)	-0.033 (0.853)	-0.181 (0.149)	0.549 (0.356)	-1.085 (0.915)	4.298** (2.590)	-2.367** (1.022)	13.242*** (4.966)	-0.047 (0.307)	1.005*** (0.361)
<i>Criss</i>	-0.008** (0.003)	0.038*** (0.006)	0.002 (0.003)	-0.018** (0.007)	0.001 (0.006)	-0.017 (0.015)	-0.009 (0.009)	0.018 (0.017)	0.011 (0.009)	-0.068*** (0.019)	0.001 (0.005)	-0.013* (0.007)
<i>clpob_{t-1}</i>	2.897** (1.392)	-12.423*** (3.390)	-1.045 (0.943)	4.427** (1.893)	-0.608 (2.361)	-2.048 (7.825)	1.640 (1.712)	-3.522 (6.938)	-0.311 (1.192)	2.525 (6.138)	0.199 (0.709)	2.941 (3.409)
Constant	0.001 (0.001)	-0.003 (0.004)	0.000 (0.001)	0.000 (0.003)	0.001 (0.002)	0.003 (0.006)	0.001 (0.002)	-0.003 (0.005)	-0.002 (0.002)	0.029** (0.011)	0.000 (0.001)	0.000 (0.003)
Obs	25	25	25	25	25	25	25	25	25	25	25	25
GMM/C	0.540	0.918	0.414	0.875	0.288	0.250	0.863	0.647	0.764	0.763	0.929	0.917
<i>p</i> -val												
Hansen J	0.028	0.170	0.139	0.332	0.554	0.561	0.132	0.121	0.809	0.809	0.041	0.351
<i>p</i> -val												
Wald <i>p</i> -val	0.008	0.000	0.004	0.009	0.323	0.027	0.010	0.186	0.156	0.000	0.312	0.014
<i>R</i> ²	0.391	0.445	0.340	0.398	0.006	0.111	0.643	0.102	0.366	0.443	0.176	0.125

Note(s): All estimates reported are adjusted for small samples. *** **, * denote level of significance at 1 %, 5 % and 10 %, respectively

Source(s): Authors' calculation

5.4 Non-contemporaneous causality and impulse-response functions

We devote this section to analyse the estimates of the VARX model (Equation 16) and the IRF for each region [15]. The maximum lag for any region is two, except the Pacific region (four lags). Table 5 shows the estimated VARX model [16].

At the top of Table 5 (endogenous GDP, $clgdp$) the results are mixed. In the case of the Andean and Pacific regions, the lagged TFP coefficients ($cltff_{t-k}$) are statistically significant but negative. At the bottom of Table 5 (endogenous TFP, $cltff$) the outcome reveals that previous GDP also negatively affects current TFP but only for Andean region. These findings are corroborated by the IRF in Figure 4 [17]. The left graph for both regions shows the confidence intervals, including zero line in all analysed periods; there is no influence on the TFP cycles by GDP shocks. Conversely, the right side graphs show that a shock in the current TFP cycle (an unexpected change in current productivity) decreases the GDP cycle in the next period, which starts to recover its stability only after four periods in the future.

We found manufacturing performance contributes negatively to future regional GDP due to dependence of this sector to national markets but do not to international ones. This prevents benefit from the purchase of materials; embodied technologies or hiring qualified labor; this without taking into account the uncertainty about the future behavior of the regional economy and the expected demand. In addition, the Andean region produces manufacturing mostly in low and med-low tech sectors such as food and beverages or paper. On the other hand, the negative influence of GDP on TFP could be explained by the types of employment created in the expansionary period of the GDP cycle that probably harmed the strongest manufacturing industries, preventing the growth of firms' productivity in these regions.

These outcomes are partially in line with those carried out by Maroto and Cuadrado (2012), Maroto (2011), Biddle (2014), Berger (2012), and Galí and Van Rens (2014) who suggest a counter-cyclical behaviour in Spain, Bulgaria and Slovakia, but a pro-cyclical one in the USA. Nonetheless, it is worth mentioning that these findings are contemporary, not lagged.

In the case of Third Region, Table 5 manifests a positive past influence of TFP on current GDP, but no influence of GDP on TFP. Despite this, Figure 4 displays bidirectional causality. In fact, a shock in lagged GDP causes an impact on the current TFP and vice versa. Nevertheless, the influences are different because in the first case, the GDP past shocks impact positively on the current TFP in the first year, but in the second case, the previous abrupt changes in productivity negatively affect the contemporaneous GDP in a more advanced period. It is worth mentioning both impacts only span a short time. This outcome is expected as this region includes bigger cities of the country and produces manufacturing in advanced sectors such as chemicals and machinery, electrical appliances and instrument making medical devices, which belong to med-high and high-tech industries.

The Others region demonstrates a negative effect coming from an unexpected change in lagged GDP towards contemporary TFP. Finally, in the Caribbean and Total region there is no evidence of any type of causality because the confidence intervals include the zero line in all analysed periods in both causalities [18].

6. Conclusions

The main objective of this paper is to disentangle the linkage between regional business cycles and manufacturing productivity in Colombia by following several econometric steps. TFP is obtained under Wooldridge's two-step GMM framework; the Kalman filter algorithm is implemented to get regional business cycles; further, to capture contemporaneous and non-contemporaneous linkage we use the IV/GMM and VARX models with endogenous and exogenous regressors, respectively.

Table 5.
Non-contemporaneous
causality: GDP and
TFP, and the
VARX model

	Andean	Third	Caribbean	Pacific	Others	Total
<i>Clpb</i>						
<i>clgadp_{l-1}</i>	-0.590*** (0.180)	-0.906*** (0.230)	-0.268 (0.184)	-0.879*** (0.233)	-0.740*** (0.174)	-0.872*** (0.193)
<i>clgadp_{l-2}</i>	-0.424** (0.190)	-0.452* (0.271)	-0.687*** (0.189)	-0.345 (0.279)	-0.691*** (0.183)	-0.583*** (0.191)
<i>clgadp_{l-3}</i>				-0.113 (0.261)		
<i>clgadp_{l-4}</i>				-0.255 (0.227)		
<i>cltftp_{l-1}</i>	0.046 (0.030)	0.119* (0.074)	0.024 (0.047)	0.061 (0.052)	-0.009 (0.023)	0.014 (0.031)
<i>cltftp_{l-2}</i>	-0.058* (0.030)	-0.059 (0.085)	-0.044 (0.044)	-0.083** (0.039)	-0.023 (0.026)	-0.038 (0.030)
<i>cltftp_{l-3}</i>				-0.090** (0.040)		
<i>cltftp_{l-4}</i>				-0.091** (0.040)		
<i>ccunemp_l</i>	-0.709*** (0.278)	-0.736 (0.551)	-0.269 (0.175)	-1.346* (0.698)	0.019 (0.920)	-0.326*** (0.121)
<i>ccunemp_{l-1}</i>	-0.630*** (0.264)	-1.088*** (0.410)	-0.400*** (0.139)	-1.130* (0.593)	0.020 (0.873)	-0.266*** (0.120)
<i>crisis</i>	-0.002 (0.002)	0.001 (0.004)	0.006 (0.005)	-0.004 (0.003)	0.002 (0.006)	0.003 (0.002)
<i>clcpob_l</i>	0.537 (1.996)	1.690 (1.676)	5.388** (2.253)	2.286 (2.003)	1.402 (2.179)	-0.168 (1.241)
<i>clcpob_{l-1}</i>	-0.03 (1.844)	-1.508 (1.548)	-6.249** (2.470)	-1.858 (1.943)	-0.175 (1.907)	-0.554 (1.197)
<i>clcpob_{l-2}</i>	0.000 (0.001)	0.000 (0.001)	-0.001 (0.002)	0.001 (0.001)	-0.001 (0.002)	0.000 (0.001)
<i>Cltp</i>						
<i>clgadp_{l-1}</i>	-0.590*** (0.180)	0.918 (0.766)	1.103 (0.842)	-1.870 (1.476)	-2.520* (1.429)	0.171 (1.086)
<i>clgadp_{l-2}</i>	-0.424** (0.190)	1.107 (0.904)	0.375 (0.862)	-1.315 (1.772)	-0.886 (1.495)	0.756 (1.075)
<i>clgadp_{l-3}</i>				1.678 (1.654)		
<i>clgadp_{l-4}</i>				1.409 (1.440)		
<i>cltftp_{l-1}</i>	0.046 (0.030)	-0.306 (0.248)	-0.329 (0.216)	-0.531 (0.329)	-0.053 (0.192)	0.100 (0.175)
<i>cltftp_{l-2}</i>	-0.058* (0.030)	-0.642** (0.285)	-0.580*** (0.199)	-0.123 (0.245)	-0.291 (0.209)	-0.536*** (0.166)
<i>cltftp_{l-3}</i>				-0.738*** (0.256)		
<i>cltftp_{l-4}</i>				-0.605** (0.256)		
<i>ccunemp_l</i>	-0.709*** (0.278)	-3.373* (1.934)	-0.841 (0.800)	-3.39 (4.429)	6.281 (7.531)	-0.411 (0.680)
<i>ccunemp_{l-1}</i>	-0.630*** (0.264)	-0.305 (1.366)	-0.44 (0.635)	-3.09 (3.763)	10.164 (7.153)	0.303 (0.676)
<i>Crisis</i>	-0.002 (0.002)	-0.001 (0.013)	-0.019 (0.021)	0.031 (0.020)	-0.084* (0.046)	-0.005 (0.012)
<i>clcpob_l</i>	0.537 (1.996)	0.86 (5.584)	12.462 (10.300)	5.401 (12.709)	21.344 (17.844)	6.446 (6.976)
<i>clcpob_{l-1}</i>	-0.03 (1.844)	1.695 (5.158)	-18.063* (11.291)	-0.734 (12.334)	-9.035 (15.613)	-6.248 (6.731)
<i>clcpob_{l-2}</i>	0.000 (-0.001)	0.001 (0.004)	0.005 (0.008)	-0.008 (0.008)	0.019 (0.017)	0.002 (0.004)
Observations	25	25	25	23	25	25
Log-Likelihood	183.3	178.1	152.5	157.4	128.3	190.1

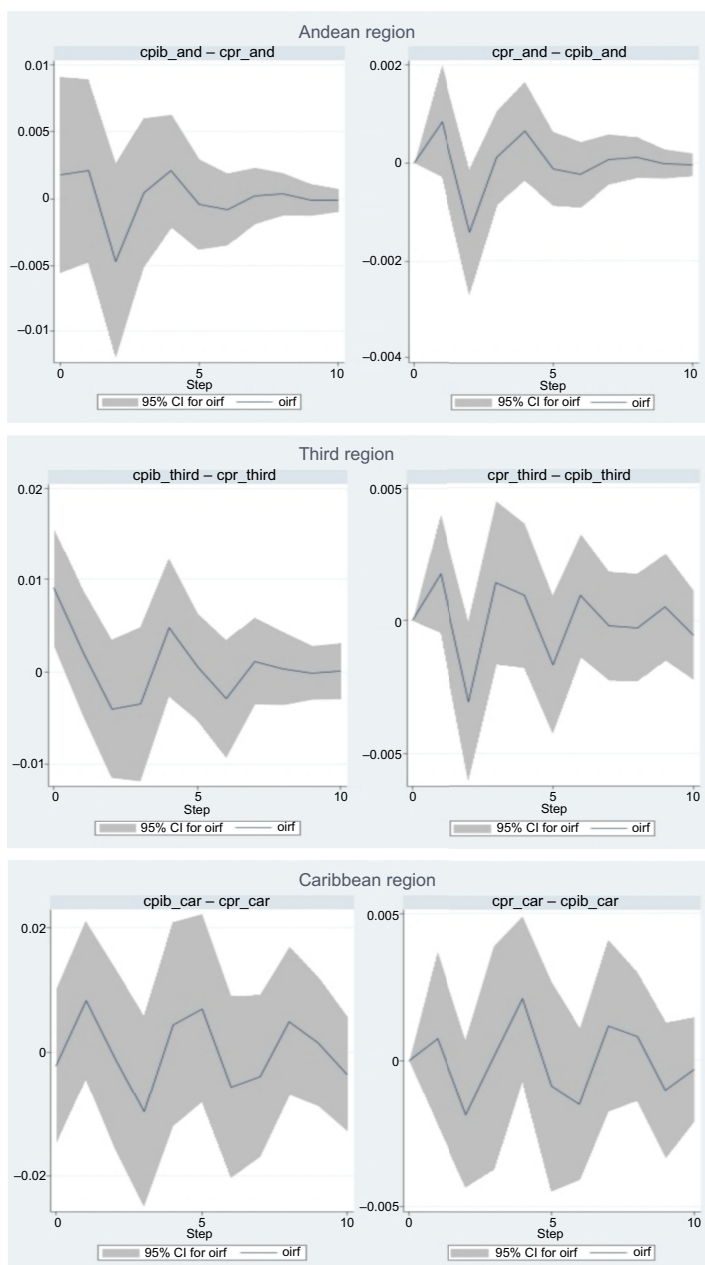


Figure 4.
IRF by regions
(continued)



Figure 4.

Note(s): cltfp: cycle of TFP; clgdp: cycle of GDP
Source(s): Author's calculation

There is a marked pro-cyclical contemporary and non-contemporary causality from TFP to GDP (but not vice versa) in the most developed region of the country (Third region). For the Andean region, the evidence also suggests a contemporary pro-cyclical relationship from productivity to GDP, but unlike the previous one, it shows a counter-cyclical double causality. In the Caribbean and Pacific regions, productivity also affects GDP, but in the former it happens in a contemporary and pro-cyclical way, while in the latter it happens in a non-contemporary and counter-cyclical form. The Others region is particular because the effect is in a single direction from GDP to TFP in both scenarios, but the influence is contemporary and pro-cyclical, and counter-cyclical when we introduce dynamics. Finally, when the country as a whole is analysed, (Total Region), the evidence does not suggest any relevant causality. Therefore, it is worth mentioning that the phenomenon analysed must be broken down by region, since otherwise the causal relationships found would be hidden and the economic policy would be inadequate or mistaken.

These findings differ partially with the theoretical predictions because the causality in the region that provide more than 50% of economic activity within the country (Third Region) is only in one direction, from TFP towards GDP and not vice versa. As the influence from GDP towards TFP is minimal in the remaining regions, the manufacturing productivity influences both short and long run regional economic growth in Colombia. This implies that economic policy at the level of macro-region must be modified; the government should give additional support to the manufacturing sector, especially in developed regions and for small and medium-sized enterprises (SMEs, which represent 92% of the manufacturing firms) to increase economic growth in the future.

In this sense, the policy should be oriented to obtaining cutting-edge technologies through subsidies, and also should facilitate the access to financial capital and the investment in R&D laboratories. On the other hand, the link with international trade also must be reinforced because the importing of intermediate inputs and exporting of output allows the firms to obtain embodied technologies, also to incur on learning by exporting and importing processes, and finally to gain experience and competitiveness in foreign markets.

Lastly, we consider that a more detailed analysis should be carried out at the level of each sector within the manufacturing industry to further clarify these findings.

Notes

1. In times of economic recession, the productivity reduced but when there is a boom, it rises in the same period, or vice versa. The main explanations are pro-cyclical technology shocks, widespread imperfect competition, increasing returns to scale, variable utilization of inputs over the cycle and resource reallocations (Basu & Fernald, 2001). The labour productivity decreases when output falls because firms retain more workers than required to produce low current output. They do this to avoid the costs of laying workers off now and hiring replacements in the future when economic activity recovers (De Long & Waldmann, 1997).
2. We consider this country an interesting case to study for several reasons. First, Colombia is one of the most important economies in Latin America after Brazil, Argentina and Mexico. In fact, in the past five years Colombia has achieved an average economic growth near to 5%, figures higher than countries such as Chile (4.1%), Argentina (3.2%), Mexico (2.9%) and Brazil (2.2%). Second, the recent peace process with the "Fuerzas Armadas Revolucionarias de Colombia" FARC guerrilla has increased foreign investment and has boosted many economic sectors including manufacturing due to the increasing confidence in the local economy. Other reason is the trade liberalization that has allowed the manufacturing firms to increase the connection to foreign markets in the new millennium. In this sense, we consider that these reasons are changing the business cycles and firms productivity in this country.
3. Our contribution is at least threefold. First, as far as we know, this is the first research that considers the linkage business cycles and manufacturing productivity at the regional level, at least in

emerging economies. Second, these methodological steps guarantee to avoid any type of bias in the estimations. Finally, this methodology can be replicated in other emerging economies to capture the role of sector productivity in the regional economic growth.

4. This includes the states of Boyacá, Caldas, Cundinamarca, Huila, Norte de Santander, Quindío, Risaralda, Santander and Tolima.
5. The states are Atlántico, Bolívar, Cesar, Córdoba, La Guajira, Magdalena and Sucre.
6. This region includes the states of Cauca, Choco and Nariño.
7. The states included are Arauca, Meta, Casanare, San Andres, Amazonas and Putumayo.
8. A few states were excluded due to low statistical representativeness and/or lack of information.
9. This survey is reported by the DANE. The EAM is an annual census of enterprises of ten or more workers, or also of firms whose annual production value is equal to or greater than a specified value for each reference year, indexed by the product price index (PPI). The survey has annual data on value added, number of employees, energy consumption, amongst others. It is constituted by all the industrial establishments that operate in the country and that, according to international standard industrial classification (ISIC) Revision 3 adapted for Colombia, they are identified as industrialists.
10. We do not use the traditional Hodrick–Prescott filter because the extremes of trends are poorly defined and induce spurious cyclic behaviour in data, and the *ex ante* determination of the smoothing parameter depends on the discretion of the researcher (Montenegro, 2005).
11. It is important to mention we do not consider a co-integration analysis because the cycles are $I(0)$ by definition (Gómez-Sánchez, 2011).
12. All variables are in logs.
13. The results of the output elasticities are not shown, but they are available by request.
14. Due to the small sample, we use the Stata option *d/k*, making small-sample degrees-of-freedom adjustments.
15. Table A1 in Appendix displays the lag selection for each region.
16. It is worth mentioning that selected Vector autoregression (VAR) is stable, as all the eigenvalues lie inside the unit circle, so the panel VAR is invertible and the estimated IRF are not explosive (see, Table A2 in Appendix).
17. The functions display the 90% confidence intervals based on 200 Monte Carlo simulations. The graphs in the left side display the response of GDP cycle to one standard deviation innovation in regional TFP cycle for each region; conversely, the graphs in the right side show the response of the TFP cycle to one standard deviation innovation in regional GDP cycle.
18. The Granger causality test and the forecast error variance decomposition were also estimated, but are not shown here. These are available by request.

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(The Appendix follows overleaf)

Appendix

Region	lags	LL	LR	FPE	AIC	HQIC	SBIC
Andean	0	141.199		1.90E-08	-12.1043	-12.0794	-12.0055
	1	143.787	5.1759	2.20E-08	-11.9815	-11.907	-11.6853
	2	157.382	27.191	9.40E-09	-12.8159	-12.6917	-12.3222*
	3	161.915	9.0654	9.30E-09	-12.8622	-12.6884	-12.171
Three	4	167.718	11.606*	8.3e-09*	-13.019*	-12.7955*	-12.1303
	0	138.415		2.40E-08	-11.8622	-11.8373	-11.7634
	1	143.205	9.5791	2.30E-08	-11.9308	-11.8563	-11.6346
	2	155.368	24.327	1.1e-08*	-12.6407	-12.5165*	-12.147*
Caribbean	3	158.52	6.3036	1.20E-08	-12.5669	-12.3931	-11.8758
	4	163.811	10.583*	1.20E-08	-12.6792*	-12.4557	-11.7906
	0	120.495		1.10E-07	-10.3039	-10.2791*	-10.2052*
	1	122.19	3.3898	1.40E-07	-10.1035	-10.029	-9.80727
Pacific	2	128.662	12.943*	1.1e-07*	-10.3184*	-10.1942	-9.82471
	3	130.818	4.3133	1.40E-07	-10.1581	-9.98429	-9.46694
	4	133.985	6.3339	1.60E-07	-10.0857	-9.86218	-9.19703
	0	125.496		7.40E-08	-10.7388	-10.714	-10.6401*
Others	1	131.304	11.616	6.40E-08	-10.896	-10.8215	-10.5998
	2	134.633	6.6578	6.80E-08	-10.8377	-10.7135	-10.344
	3	138.055	6.8433	7.40E-08	-10.7874	-10.6135	-10.0962
	4	145.671	15.232*	5.6e-08*	-11.1018*	-10.8783*	-10.2132
Total	0	98.9389		7.50E-07	-8.42947	-8.40464	-8.33073
	1	102.202	6.5271	8.00E-07	-8.36543	-8.29094	-8.06922
	2	117.887	31.369*	2.9e-07*	-9.38146	-9.2573*	-8.88777*
	3	122.013	8.2523	3.00E-07	-9.39243*	-9.2186	-8.70126
	4	123.239	2.4526	4.00E-07	-9.15124	-8.92775	-8.26259
	0	153.8		6.30E-09	-13.2	-13.1752	-13.1013
	1	157.141	6.682	6.70E-09	-13.1427	-13.0682	-12.8465
	2	167.087	19.892*	4.1e-09*	-13.6597*	-13.5356*	-13.166*
	3	170.63	7.0855	4.30E-09	-13.62	-13.4461	-12.9288
	4	172.322	3.3851	5.60E-09	-13.4193	-13.1958	-12.5307

Note(s): Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC) and the Hannan and Quinn information criterion (HQIC)

*Lag selection

Source(s): Authors' calculation

Table A1.
Lag selection

Region	Eigenvalue		Modulus
Andean	-0.0145472	+0.6540739i	0.654236
	-0.0145472	-0.6540739i	0.654236
	-0.1907773	+0.3160755i	0.369188
	-0.1907773	-0.3160755i	0.369188
Three	-0.5801856	+0.5851278i	0.824008
	-0.5801856	-0.5851278i	0.824008
	-0.0255073	+0.7230632i	0.723513
	-0.0255073	-0.7230632i	0.723513
Caribbean	-0.0300042	+0.8473473i	0.847878
	-0.0300042	-0.8473473i	0.847878
	-0.268619	+0.7105238i	0.759605
	-0.268619	-0.7105238i	0.759605

Table A2.
Eigenvalue stability
condition

(continued)

				Disentangling business cycles-TFP linkage
Region	Eigenvalue		Modulus	
Pacific	−0.6830663	+0.5592495i	0.882802	87
	−0.6830663	−0.5592495i	0.882802	
	0.1795503	+0.8583787i	0.876956	
	0.1795503	−0.8583787i	0.876956	
	0.5752978	+0.5995435i	0.830915	
	0.5752978	−0.5995435i	0.830915	
	−0.7771136	+0.2800637i	0.826039	
	−0.7771136	−0.2800637i	0.826039	
Others	−0.3982269	+0.7778873i	0.873895	
	−0.3982269	−0.7778873i	0.873895	
	0.00186623	+0.4863054i	0.486309	
	0.00186623	−0.4863054i	0.486309	
	−0.4630697	+0.6442987i	0.793445	
Total	−0.4630697	−0.6442987i	0.793445	
	0.07684267	+0.7322195i	0.736241	
	0.07684267	−0.7322195i	0.736241	
Source(s): Authors' calculation				Table A2.

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