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Mexico and the forum for economic cooperation, Asia-pacific, 1990-2019: Determinants of the sustainable productivity of the wood industry

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ABSTRACT

The purpose of this research is to identify the determinants of the productivity of the wood industry for the economies that make up the Asia-Pacific Economic Cooperation Forum (APECF) in the period 1990-2019. As a dependent variable, a sustainable productivity index is created to measure this productivity. Using the econometric method of panel data, the impact of employment, capital stock, and innovation on the sustainable productivity of the wood manufacturing industry is found. The variable capital stock (SC) is estimated using the Perpetual Inventory Method (PIM) and incorporating an adjustment factor for the absence of the first observation. The findings indicate that there is a significant relationship between the sustainable productivity index and the variables employment, innovation, and capital stock. The study's findings demonstrate that productivity exists when there is a balance in the use of resources or public goods. The contribution that is made to the literature is about authentic productivity that promotes the improvement of the quality of life of the population as well as the responsible use of finite resources. This research examines the practical implications of sustainable forest resource utilization, specifically focusing on sustainable productivity.

Contribution/ Originality: This kind of research is crucial because it demonstrates the existence of productivity that coexists with a balance in the use of resources or public goods—such as land and water—and not at their expense. It says authentic productivity is achieved by applying a robust methodology.

1. INTRODUCTION

Today, the concern for the sustainable conservation of forests has taken on great international relevance, and derived from this situation, there are more and more studies with proposals to reduce their degradation (Becker & León, 2000; Cardozo, 2018; González-García, Berg, Feijoo, & Moreira, 2009; Luthra, Garg, & Haleem, 2015; Romagnoli, Fragiacomo, Brunori, Follesa, & Scarascia-Mugnozza, 2019). At the same time, measures and policies on the subject of environmental responsibility continue to be implemented in order to preserve biodiversity (Daian & Ozarska, 2009; Elias, Donadelli, Paiva, & Araujo, 2021; Santos, Carvalho, Barbosa-Póvoa, Marques, & Amorim, 2019; World Bank, 2022).

The conservation objectives have shown their priority in preserving areas of high biodiversity, specifically primary forests. It is important to note that globally, the decrease in forest area has been 0.11% in the last 10 years. This is mainly because of the reclassification of primary forest to "other naturally regenerated forest" (World Bank,

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2022). Uncontrolled and clandestine logging, lack of forest planning, and uncontrolled forest expansion have significantly reduced the net loss of forest area worldwide (Aquino, 2006; Arias, 2014; López & Muñoz, 2017; Ortega & Mantilla-Meluk, 2008; Quevedo, 1986).

The wood industry has increased its participation in world trade because of its commercial model, seeking to obtain comparative advantages and trying to include added value in its raw materials to have a better position in the markets. This generates a better position for the industry, generating more employment (FAO, 2019; Haro Pacheco et al., 2015; López & Muñoz, 2017; Naranjo & Chávez, 2019).

Various studies have been carried out on the manufacturing industry, some evaluating labor productivity and its relationship with trade openness, such as the case of Cameron, Proudman, and Redding (1999); Powell and Wagner (2014) and Nolazco (2020); as well as those who analyze Total Factor Productivity TFP and its relationship with trade policies such as tariffs and trade liberalization, as is the case of Ahmed, Khan, Mahmood, and Afzal (2017); Amiti and Konings (2007); Bas, Johansson, Murtin, and Nicoletti (2016); İşcan (1998) and Pavcnik (2002). Some other authors analyzed the productivity of the manufacturing industry by applying econometric models with panel data to contrast TFP with Investment & Development I&D (Cin, Kim, & Vonortas, 2017; Frantzen, 2003; Los & Verspagen, 2000; Narayanan & Sahu, 2014; Schumacher, 1999) and some other authors contrasted labor productivity with the use of technologies and innovation using a Cobb-Douglas production function (Apergis, Economidou, & Filippidis, 2008; Chun & Lee, 2015; Iregui, Melo, & Ramírez, 2006; Kılıçaslan, Sickles, Atay Kayış, & Üçdoğruk Gürel, 2017; Raymond, Mairesse, Mohnen, & Palm, 2015; Singh & Nautiyal, 1986; Villarroya, Visús, & López-Pueyo, 2006).

Other studies focused on labor productivity in the manufacturing sector (Fleisher et al., 1996; Jones, Kalmi, Kato, & Mäkinen, 2017; Konings & Vanormelingen, 2015; Pérez, Díaz, & Salazar, 2020), which analyzed the impact of both training and wages on labor productivity.

Concern for climate change has increasingly become a research interest in the academic community (Badeeb & Lean, 2017; Farhadi, Islam, & Moslehi, 2015; Roy, 2018; Topp & Kulys, 2013), who studied the productivity of natural resources using a Cobb-Douglas production function.

Research was also carried out on the productivity of the wood industry (Barreto, Amaral, Vidal, & Uhl, 1998; Borger & Buongiorno, 1985) using econometric methods. On the other hand, Singh and Nautiyal (1986) analyzed the evolution of the partial productivity of the factors for the Canadian paper industry using a translog cost function, in the same way McCarthy and Urmanbetova (2011) and Stier (1982) analyzed the growth of the paper industry in the United States, also using a translog cost function.

The research gap covered by this study is related to the analysis of productivity, but taking into account the changes in the use of natural resources for production or changes in their quality can affect the added value of the industries that sustain themselves from the use of common resources and therefore affect their productivity (Fajnzylber, 1992).

The contributions of Fajnzylber (1992) were very important for the detection of spurious and authentic sources of productivity, as well as the contributions of Grossman and Krueger (1995) when considering environmental deterioration and its relationship with the level of economic activity; other authors who made contributions in this direction were Chudnovsky and Porta (1991); Padilla (2006); and Lugones (2001). The theoretical contributions indicated above serve as the basis for this research, and with the results obtained in the analysis of productivity in the wood industry, guidelines are established for a sustained and sustainable study in this industry.

The objective of this research is to identify the determinants of sustainable productivity in the wood industry for the economies that make up the Asia-Pacific Economic Cooperation Forum (APEC) in the period 1990–2019. This research hypothesizes that the labor factor, capital, and innovation were the main factors that influenced the sustainable productivity of the wood industry in Mexico and the member economies of the Asia-Pacific Economic Cooperation Forum during the period 1990-2019.

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This work is structured in six sections: first there is the introduction; later, in Section 2, the materials and methods are presented. In section 3, the development of the model is presented, and later, in section 4, are the results. Next, in section 5, is the discussion of the results, and finally, in the last section, are the conclusions.

2. REVIEW OF LITERATURE

Productivity is the efficient use of resources to produce goods and/or services; in quantitative terms, it is the ratio between the quantity produced and the inputs used (Sumanth, 1994). Whereas, sustainable productivity is the efficient use of factors to produce goods and/or services without compromising the base of available resources (Fajnzylber, 1988).

Ricardo (1959) mentions in his work that production costs will increase over time as the deposits of natural resources are depleted, and the effect of this scarcity limits the possibilities of economic growth. In this sense, Leontief (1970) addressed the issue of environmental repercussions on the economic structure, pointing them out as undesirable by-products that depend on the technological characteristics of each industry and uncontrolled economic growth, and tries to incorporate these "externalities" into the conventional analysis of input-output.

With the objective of evaluating the pollution generated, Leontief (1970) in his work Environmental Repercussions and the Economic Structure: *An Input-Output Approach*, proposed adding to the matrix of technical coefficients a set of coefficients for the generation and/or elimination of pollution generated by each productive sector. This model allows for estimating the total direct or indirect emissions generated to satisfy the demand for each productive factor.

Grossman and Krueger (1995) and Panayotou (1993) developed a study of environmental degradation (ED) and its relationship with the economy. This analysis was carried out based on the levels of economic growth, delimiting the empirical verification of the indicators of per capita income and environmental degradation. The hypothesis was called the Environmental Kuznets Curve (EKC).

The Environmental Kuznets Curve (EKC) suggests a functional relationship with an inverted U shape between environmental degradation and per capita income. This implies that environmental deterioration increases with the level of economic activity up to a critical income threshold, beyond which higher income levels are linked to progressively improved environmental quality (Grossman & Krueger, 1995).

In the initial phases of the growth process in developing countries, the quality of the environment deteriorates. As the exploitation of natural resources intensifies, efficient and clean technologies are not available, and the extraction of resources is proportionally greater than their conservation, which has a negative impact on the amount of waste.

The EKC hypothesis holds that those developing economies show a positive slope of the curve. This is because they implement strategies and public policies that favour their growth; however, this has a consequence, which is the deterioration of the environment. However, they try to implement policies that improve the quality of the environment and protect their natural resources, and these actions cause degradation to decrease (Andreoni & Levinson, 2001; Nahman & Antrobus, 2005).

According to Stern (2004), the most important impact is the change in the composition of the product in favor of industry and service sectors. Within the economy, the branches of economic activity have different intensities of pollutant emissions, and by modifying the structure in favor of these sectors with lower emission intensities, a change towards cleaner technologies is promoted. These modifications favor the production; consequently, environmental deterioration stops and then begins to reverse.

In this way, the inverted U is a consequence of the positive elasticities between income and environmental quality, of changes that favor the environment, as well as the implementation of new technologies, constant information of people, education in environmental matters at all educational levels, and finally public policies that promote the conservation of natural resources (McConnell, 1997; Selden & Song, 1994).

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For Arrow et al. (1996), it is the institutions that, as a consequence of the application of environmental reforms, have achieved the reduction of pollutants with incentives that reduce this type of negative impact; therefore, they establish that the way to solve the problem of environmental degradation is through the implementation of reforms that force all companies to take care of environmental resources as well as become aware of the social costs that their actions entail.

From an economic point of view, environmental quality can be seen as a normal good, and its demand rises as per capita income rises. This is shown by a change in the demand structure in favour of goods that have less of an effect on the environment and by more people calling for stricter environmental laws (Arrow et al., 1996).

Analysis of the relationship between economic growth and the environment has continued to be carried out by various authors such as Ahmed et al. (2022); Hussain, Li, Sattar, and Ilyas (2023); Nezhad-Afrasiabi, Kimiagari, and Ebrahimi-Sadrabadi (2019) and Merlin and Chen (2021) who through their research have been able to verify that the use of renewable energies has a positive impact on economic growth.

2.1. The Notion of Authentic Competitiveness

In an effort to carry out a conceptualization of the factors of gain or loss of competitiveness in industrialized countries and to derive from this analysis a proposal for Latin America, Fajnzylber (1988) started with the recognition that in industrialized countries, productive restructuring. It is linked to the need to gain competitiveness in international markets. For this author, the heart of said restructuring is the diffusion of information technologies and their incorporation into the productive system.

The concept of productivity has been especially considered by Fajnzylber (1988) who highlights it as a key element in the problem of competitiveness by pointing out that "there is a high consensus regarding the existence of a solid link between competitiveness, incorporation of progress technique, industrial dynamism, and increased productivity" (Fajnzylber, 1988).

Fajnzylber (1988) examines competitiveness as "a country's capability to maintain and broaden its involvement in international markets while concurrently enhancing the standard of living for its population. Achieving this necessitates heightened productivity and, consequently, the integration of technical progress". He emphasizes the dichotomy between "spurious" or transient competitiveness and what is termed authentic competitiveness.

Competitiveness, called "spurious" by the author, refers to the capture of greater surpluses by the dominant sectors on the basis of a devaluation of the labor force, the intensification of work rhythms, and/or the depredation of the environmental market. In the case of those gains that are obtained easily and quickly through these tools and that are present immediately but cannot be sustained in the medium term, they generate a regressive impact on the level of income and its distribution (Fajnzylber, 1988).

This type of competitiveness (the authentic one) is achieved based on increases in productivity, which requires continuous technical progress, greater product differentiation, improvements in labor productivity, capital or the use of productive inputs, the introduction of new forms of business organization, and the linkage of production chains so as to increase the efficiency of the production cycle (Fajnzylber, 1988).

It is from the categorical arguments of Fajnzylber (1988) that other authors have provided conceptual elements and have argued that in achieving competitiveness, it is necessary to consider the multiple factors that affect it. In this regard, in 1990, within the framework of the Productive Transformation with Equity project, Economic Commission for Latin America and the Caribbean (ECLAC) (1996) adopted this vision of competitiveness and introduced it as a definition of the authentic competitiveness of an economy: "the ability to increase, or at least sustain, participation in international markets with a simultaneous rise in the standard of living of the population" (Economic Commission for Latin America and the Caribbean (ECLAC), 1996).

In this way, the Economic Commission for Latin America and the Caribbean (ECLAC) (1996) highlighted that the generation of authentic competitiveness depends on the possibilities of raising productivity to the level of the best

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international practices. He argues that this vision of competitiveness is closely linked to the micro vision since, in order to achieve greater weight in the world market and improve the standard of living, it is necessary to resemble the patterns of efficiency in the use of resources and quality of products that have the most successful countries.

Casar (1993) suggests that it would be necessary to distinguish between the improvements in competitiveness associated with the depression of internal demand and the increase in idle capacity, as well as the depression of wages, from those that are compatible with the growth of the level of employment and activity and with the expansion of wages. In addition, he points out that this distinction is assimilable with the vision of spurious and legitimate (authentic) competitiveness in the sense presented by Fajnzylber (1989) and the Economic Commission for Latin America and the Caribbean (ECLAC) (1996).

This vision of competitiveness is not limited to developing countries; on the contrary, Kennedy (2003) points out that an extension of it has now become the "consensus vision" on a global scale. The definitions of the Organization for Economic Cooperation and Development (OECD), the Industrial Competitiveness Commission of the United States, and the European Commission agree that the competitiveness of a nation is not limited to selling abroad and maintaining a commercial balance (export performance), but that successful performance is related to an increase in employment and real income to increase the well-being of current and future generations.

For his part, Padilla (2006) also considers competitiveness, called by the author "ephemeral, artificial, or spurious," as associated with low wages, unsustainable exploitation of natural resources, inadequate working conditions, and based on static comparative advantages. On the other hand, for the author, "real or authentic" competitiveness is associated with the adoption of new and better products, the increase in productive capacity, new forms of business organization and dynamic competitive advantages that allow increasing the salary level and the standard of living of the population.

Under this perspective, the notion of well-being can be extended to include environmental goals, since the abundance of natural resources and their use as a factor that generates competitiveness is a resource through which increases in profitability can be obtained in the short term without neglecting the preservation and defense of natural resources in the long term. This can be carried out with the use of sustainable strategies and by ruling out indiscriminate exploitation or environmental degradation (Lugones, 2001).

In order to incorporate genuine sources into the analysis of productivity as a determinant of competitiveness, as mentioned by Fernández and Curado (2019) and Coy and Chacón (2022). For these authors, it is important to differentiate natural resources from spurious sources, and this involves the need to take into account the elements that allow a higher level of employment and income without compromising the resources available.

2.2. Contributions towards the Definition of Authentic Productivity

Labor productivity has traditionally been seen as a determining factor of competitiveness, and the authors such as Puyana and Romero (2006), Porter (1990) and Economic Commission for Latin America and the Caribbean (ECLAC) (1996) reflect on the link between said competitiveness and the increase in the standard of living of the population, that is, on authentic competitiveness. Chudnovsky and Porta (1991) argue that it is therefore important to consider "genuine" increases in productivity, and for these to occur, technological and organizational changes are necessary, as well as a progressive transformation of industrialization patterns in their "spurious" form associated with advantages of a static type such as the cost of labor, variations in the exchange rate, etc. (Vázquez-López, 2021).

Gurmendi (2023); Ziesemer (2020); and Soete, Verspagen, and Ziesemer (2020) study the factors that impact productivity changes, and they identify that there may be authentic or spurious productivity -obtain productivity through negatively impacting society. In the same address, Bianco (2007), García, Tumbajulca, and Cruz (2021) and Purbowati et al. (2021) mention that it can have a spurious dynamic vision when compromising the environmental resource base involved in production.

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2.3. Empirical Evidence: Distinguishing Spurious and Authentic Sources

The studies identified in which productivity increases have been analyzed, have focused mainly on pointing out that, for these increases not to be spurious, they require technological and organizational changes within the establishments (Chudnovsky & Porta, 1991).

In the case of competitiveness in the Mexican manufacturing industry, Casar (1993) explains that the increase in efficiency in the allocation of resources implied by openness and internal stabilization has been supported, among other things, by the exchange rate policy. The author explored the importance of competitiveness, making a distinction between spurious and legitimate competitiveness for 36 branches of manufacturing, and only in 17 cases was a significant correlation found between the efficiency indicator and export performance. However, changes in relative labor costs do not adequately explain exports in the most competitive branches due to labor productivity.

In the work of Puyana and Romero (2006) it is established that the phenomenon of commercial opening since 1980 in the Mexican economy has been accompanied by a significant educational improvement of the workforce, but with a general stagnation of wages for both skilled and unskilled labor and a slight increase in capital gains. The authors concluded that the considerable increase in registered qualified employment was not due to technological change but rather a way of competing in the labor market; thus, attention to investments in human capital to increase productivity may not be efficient.

In the work carried out by Puyana and Romero (2006) the Manufacturing, Maquiladora, and Export Services Industry Program (MMEXIP) was studied based on the general idea that only productivity can raise income in a sustained manner, and without these constant increases in productivity, no true competitiveness is feasible. It is noted that the limits to productivity growth are given by the weight that wages represent in their added value, a relationship that suggests a very low capital-labor relationship and, therefore, low labor productivity.

For Cuevas (2008) manufacturing exports are a key factor for economic growth and the generation of stable and well-paid jobs. In his research on the effects of labor productivity on Mexican manufacturing exports, using a vector auto-regression (VAR) dynamic analysis model, he concluded that policies to stimulate labor productivity (training, machinery, and equipment) can significantly increase exports from the manufacturing sector, reduce the vulnerability of the national economy, and promote competitiveness with long-term effects.

2.4. Empirical Methods

The literature names panel data in different ways: pooled time series, cross-sectional data, pooled data, micro-panel data, and longitudinal data, among others (Baltagi, 2008; Greene, 2012; Gujarati, 2003). The characteristic of panel data econometric models is that they combine time series and cross sections (Greene, 2012).

This methodology can be applied to examine a particular situation or a series of events over time. In recent years, the application of panel data models has increased using economic variables, where long periods of time are combined with cross-sectional analysis units, which are also increasingly larger (Greene, 2012).

Micro and macro panel models require distinct econometric approaches (Baltagi, 2008). Specifically, asymptotic analysis in micro panels is conducted for large N and fixed T, whereas in macro panels, it involves letting both N and T approach infinity (Phillips & Moon, 1999). However, addressing non-stationarity issues typical of time series analysis becomes crucial when dealing with a large T in a macro panel.

2.5. Cross-Dependence Test

The econometric theory was based on the independence of the panel units, a situation that is rarely verified in the empirical study of macro panels. The absence of independence between the units is known in the literature as cross-section dependency, and this situation is common due to the type of data that is handled. If you don't take into account cross-section dependency (CSD), the parameter estimators will be wrong, which means the theoretical

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proposal in panel data models isn't valid (Banerjee & Carrion-i-Silvestre, 2011; Kapetanios, Pesaran, & Yamagata, 2011).

Perturbations in panel data models are generally assumed to be cross-sectional independent. This situation can be affirmative with long panels with cross-sectional units (N) (Pesaran, 2004). In the case of short panel data models, they can show a cross-dependence in disturbances (Sarafidis & Robertson, 2009).

Recent research on panel data has determined that panel data models exhibit significant cross-dependence in errors. This phenomenon can arise from the existence of common shocks and unobserved components that become part of the error term (Anselin, 2001; Baltagi, 2005; Pesaran, 2004; Robertson & Symons, 2000).

Cross-dependency tests are important for fitting models to panel data. Lagrange Multiplier (LM) test, can be used when T > N, it was developed by Breusch and Pagan (1980).

The LM statistic is given by:

$$LM = T \sum_{I=1}^{N-1} \sum_{J=I+1}^{N} \hat{P}_{IJ}^{2} \qquad (1)$$

Where $\hat{P}_{IJ}^{2}$ is the sample estimate of the pairwise correlation of the residuals:

$$\hat{p}_{ij} = \hat{P}_{ji} = \frac{\sum_{t=1}^{T} \hat{u}_{it}\hat{u}_{jt}}{(\sum_{t=1}^{T} \hat{u}_{it}^{2})^{1/2} (\sum_{t=1}^{T} \hat{u}_{jt}^{2})^{1/2}} \qquad (2)$$

$\hat{u}_{it}$ is the estimate of $\hat{u}_{jt}$ in (1). LM is asymptotically distributed as $\chi 2$ with $N\,(N-1)/2$ degrees of freedom.

When T < N, the LM test lacks the required statistical properties. Hence, for panels with a large N and small T, the recommended tests for dependence is the cross-sectional dependency (CD) test by Pesaran (2004);

2.6. Pesaran Scaled Lagrange Multiplier (LM)

Pesaran (2004) developed a standardized version of the LM statistics that is applicable in a large dimension of cross section.

$$LMs = \sqrt{\frac{1}{N\,(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij} \hat{p}_{ij}^{2} - 1) \qquad (3)$$

Where LMs presents an asymptotically normal distribution as $T_{ij} \rightarrow \infty$ y N→ ∞ regardless of the order. But the biggest gap in this test is that it is distorted for short size T_{ij} and the distortion worsens for larger N.
To mitigate size-related distortions, Pesaran (2004) introduced a distinct statistical test known as the Pesaran CD test. This test can be used with different types of panel data, such as those with unit root and stationarity in dynamic heterogeneous panels with short T and large N. It works by finding the average of the pairwise correlation coefficients from the OLS residuals in each regression within the panel T. The method integrates elements from Breusch and Pagan (1980) approach and Pesaran (2004) scaled LM test.

$$CD = \sqrt{\frac{2T}{n}} \sum_{j=1}^{n} \hat{p}\, j \sim N\,(0,1) \qquad (4)$$

Where $\hat{pj}$ is the estimate of the pairwise Pearson correlation of the residuals of the Dickey-Fuller equation for each individual in panel $\hat{pj}$, ,$j = 1 \ldots n$; $n = N(N-1)/2$, subsequently added and appropriately rescaled under the null hypothesis ($H0$) that the series are independent, the CD converges towards a normal distribution (0,1) while, under the alternative hypothesis ($H1$) there is evidence that the series are dependent on each other, that is, that there is some relationship between the economies that make up the panel (Pesaran, 2004).

2.7. Unit Root Tests

In panel data models, unit root analysis has become increasingly relevant, being applied to various fields of economics, for which reason they have evolved more and more, giving a different treatment when the panels present a cross-sectional dependency.

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Because of this change, second-generation unit root tests were created, which take into account cross-sectional dependence. The initial panel unit root tests, constituting the first generation, operated under the assumption of cross-sectional independence. These tests include those developed by Levin and Lin (1992); Levin, Lin, and Chu (2002); Harris and Tzavalis (1999); Im, Pesaran, and Shin (1997); Im and Pesaran (2003); Maddala and Wu (1999); Choi (2001); Choi (2002) and Hadri (2000).

If first-generation tests are applied to models that present transversal dependencies, it leads to spurious, biased, and inconsistent results (Banerjee, Marcellino, & Osbat, 2000; Strauss & Yigit, 2003). Given the need to perform unit root tests when there is transversal dependency, various tests called second generation were developed. The author Quah (1994) mentions that if there are transversal dependencies in the models, the calculations are complicated because there is no natural ordering in the observations.

Hence, numerous tests were suggested by various authors, including Bai and Ng (2004), Phillips and Sul (2003), Moon and Perron (2004), Choi (2002); Phillips and Ploberger (2002), Moon, Perron, and Phillips (2007); Chang (2002) and Pesaran (2007). In the literature, two distinct approaches have been identified. The first is rooted in the factor structure approach (Bai & Ng, 2004; Choi, 2002; Moon & Perron, 2004; Pesaran, 2007; Phillips & Sul, 2004). The second approach involves imposing minimal or no restrictions on the covariance matrix of the residuals (Chang, 2002). Owing to cross-dependency, the author found it practical to employ instrumental variables to address problematic parameters.

The proposal by Pesaran (2007) considers a single unobservable common factor (element that generates the dependency), assuming that it is stationary. Pesaran (2007) shows that it is possible to capture the common factors by calculating the cross-sectional means of the individuals for each period of time based on the following estimation:

$$\Delta y_{i,t} = \delta_i y_{i,t-1} + \sum_{K=1}^{P_i} \gamma_{i,k} \Delta_{i,t-k} + \alpha_{mi} d_{mt} + c_i \bar{y}_{t-k} + \sum_{k=1}^{Pi} \vartheta_{i,k} \Delta \bar{y}_{t-k} + \varepsilon_{i,t} \quad (5)$$

In this context, Pesaran (2007) calculates the test statistic: *Cross-Sectionally Augmented Dickey-Fuller* (CADF), that is, the standardized *t-ratio* of δi. He tests the unit root hypothesis $H0$: $\delta = 0$ against the alternative where the panel units are (0) that is, stationary.

When there is more than one common factor, the test statistic is calculated with the average of the *cross-sectionally augmented* ADFs ($CADF$) as denoted below.

$$CIPS = \frac{\sum_{i=1}^{N} CADF}{N} \quad (6)$$

People who use the ADF test also use the cross-sectional means of the levels and the lagged first differences of the individual series as regressors. These are called CADF regressions.

2.8. Cointegration Test

Different cointegration tests were used to find the long-term balance between the variables, but they were mostly made for first-generation models and couldn't handle cross-dependency. Tests such as Larsson, Lyhagen, and Löthgren (2001); McCoskey and Kao (1998); Pedroni (1999); Pedroni (2004) and Westerlund (2005) are suitable when cross-sectional units exhibit independence; otherwise, the results obtained may be inconsistent.

Due to this situation, proposals have recently been developed to perform cointegration tests when there is cross-dependency. Westerlund (2006) is one of the authors who developed a model for panels that present this dependency. Groen and Kleibergen (2003) for their part, propose a model that relaxes the assumption of cross-sectional independence and presents a test based on unrelated regressions.

The contrasts described above do not contemplate the possibility of cross section dependency between the units of the panel. When we find ourselves in this situation, there is a risk of concluding that there are more cointegration relations than actually exist. For this reason, the Westerlund and Edgerton (2008) test is incorporated into the analysis, which allows for said dependency.

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Westerlund and Edgerton (2008) start with the specification of a panel of this type.

$$y_{it} = \alpha_i + \eta_i^t + \delta_i D_{it} + x_{it}\beta_i + (D_{it}x_{it})'\gamma_i + z_{it} \quad (7)$$

$$x_{it} = x_{it-1} + w_{it} \quad (8)$$

The k-dimensional vector x_{it} contains the regressors and evolves as a pure random walk process. Meanwhile, D_{it} is a scalar dummy variable defined as $D_{it} = 1$ if $t > T_i$ and 0 otherwise. In this setup, α_i and β_i denote the intercept and slope before the breakout, while δ_i and γ_i represent the change in these parameters at the time of the breakout.

The z_{it} disturbance is assumed to have the following data generation process that allows for cross-dependence by using unobserved common factors:

$$z_{it} = \lambda'_i F_t + v_{it} \quad (9)$$

$$F_{jt} = \rho_j F_{jt-1} + u_{jt} \quad (10)$$

$$\phi_i(L)\Delta v_{it} = \phi_i v_{it-1} + e_{it} \quad (11)$$

Where $\phi_i(L) := 1 - \sum_{j=1}^{pi} \phi_{ij} L^j$ is a scalar polynomial in the lagging operator, L, F_t is an r-dimensional vector of unobservable common factors F_{jt} with $j=1, \ldots, r$ and λ_i is a vector composed of load parameters. Assuming that $\rho_j <$ 1for all j, we ensure that F_t is strictly stationary, which implies that the order of integration of the error composite z_{it} depends only on the degree of integration of the disturbance v_{it} Thus, in this data generation process, the relationship in Equation 3 is cointegrated if $\phi_i < 0$ and is spurious if $\phi_i = 0$ (Westerlund & Edgerton, 2008).

2.9. Long-Term Regression Model Augmented Group of Means

When there is a long-term relationship between the variables, a model continues to be applied to estimate the long-term coefficients. Several factors must be taken into account in order to perform these calculations. First, the size of the panel, because if the temporal dimension (T) increases, the probability that the slope coefficient is different for each of the cross-sectional units also increases.

When working with conventional methods (such as fixed effects and random effects), it means that the parameters are the same for all cross section units because these estimators only allow differentiation between intersections, and all other error coefficients and variances are the same between the groups (Pesaran, Shin, & Smith, 1999). The second problem is cross section dependency. If there is a correlation between the units of the cross section, an estimator must be chosen that is robust to the dependence of the cross section.

It is not as reliable for first-generation estimators like the mean group (MG) case (Pesaran & Smith, 1995), and the combined mean group (PMG) estimator (Pesaran, 1997), is compromised. Several proposals have been introduced to address cross-dependency models, with one notable second-generation estimator being the Augmented Mean Group (AMG) (Eberhardt & Bond, 2009; Eberhardt & Teal, 2010). Eberhardt and Bond (2009) emphasize that failure to employ appropriate estimators in the presence of cross-sectional dependence may lead to biased results. Therefore, they advocate for the use of the AMG estimator.

The model proposed by Eberhardt and Bond (2009) is the following

$$Y_{it} = \beta_i' x_{it} + u_{it} \quad u_{it} = \alpha_i + \lambda_i' f_i + \varepsilon_{it} \quad (12)$$

$$x_{mit} = \pi_{mi} + \delta'_{mi} g_{mt} + \rho_{1mi} f_{1mt} + \cdots + \rho_{nmi} f_{nmt} + v_{mit} \quad (13)$$

$$m = 1,\ldots k \text{ y } f_{mt} \subset f_t \quad (14)$$

$$f_t = \phi f_{t-1} + \varepsilon_t \quad y \quad g_t = k g_{t-1} + \varepsilon_t \quad (15)$$

Where:

$i=1,\ldots,N$ y $t=1,\ldots T$, x_{it} is a vector of the observable variable.

β_i' is the parameter of the specific slope of the observed regressor.

u_{it} includes the unobserved factors and ε_{it} are the error terms.

αi is the combination of group-specific fixed effects.

f_t is a set of common factors.

λi are the specific factor loadings of the cross-section units.

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λ_i, δ_i and ρ_i. are the country-specific factor loadings.

In Equation 15, f_t and g_t are common factors that affect all cross sections and cannot be observed. This equation gives a representation of the k regressors, which are modeled as linear functions of these common factors.

The estimation using the AMG estimator is carried out in two stages (Eberhardt & Bond, 2009). The first stage is the following:

$$\Delta y_{it} = b'\Delta x_{it} + \sum_{t=2}^{T} c_t \Delta D_t + e_{it}$$
$$\Rightarrow \hat{c}_t \equiv \hat{\mu}^{\cdot}_t \qquad (16)$$

In the first stage, which is Equation 16, the model is estimated using the first differences of the variables. That is because those unobservable factors and non-stationary variables are supposed to bias the estimates in the regression model. Then, the coefficients of the dummy variable for the years indicated by $\hat{\mu}^{\cdot}_t$

In the second stage, the model is estimated as follows:

$$y_{it} = \alpha_i + b'_i x_{it} + c_i t + d_i \hat{\mu}^{\cdot}_t + e_{it}$$
$$\hat{b}_{AMG} = N^{-1} \sum_i \hat{b}_i \qquad (17)$$

In the second stage, which is in Equation 17, $\hat{\mu}^{\cdot}_t$ is added in the regression for each unit in the cross section. A linear trend term is also included in the regression. The AMG calculations are derived from the average of the estimates for each unit of analysis.

3. RESEARCH DESIGN AND IDENTIFICATION

In order to calculate sustainable productivity, we begin with the equation of the panel data model, which is derived from a production function developed by Jorgenson and Griliches (1967). Their selection is the result of the link between the variables introduced in said equation and the variables selected in this study.

The production function proposed by Jorgenson and Griliches (1967) is expressed as follows:

$$\text{IPS} = \alpha_0 + \beta_1 log\left({}^{K}/_{L}\right)_{ij} + \beta_2 \, logL_{ij} + \sum_h \beta_h Z_{hij} + d_i + d_j + u_{ij} \qquad (18)$$

Where:

L = Labor

K = Capital.

Z_{hij} = Various measures for the quality of labor and capital.

d_i y d_j = Coefficients of industry and country *dummy* variables by region.

u_{ij} = Stochastic error term.

The subscript i refers to the type of industries and j to the number of observations.

$h = a_k + a_1 - 1$ is a coefficient measuring the significance of economies of scale.

The estimation, for the present investigation, is made using a panel data model, for 8 cross sections corresponding to economies that make up the Asia-Pacific Economic Cooperation Forum for the period 1990-2019. With the panel data model, we have cross-sectional information (i = 8 countries) and time series (t = 1990-2019), which significantly increases the sample size.

For the elaboration of the econometric model to be developed, it is important to point out that the series could be considered for 8 economies: Canada, Chile, Korea, the United States, Japan, Malaysia, Mexico, and New Zealand. This is due to the absence of historical records in some periods, without which it was not possible to complete a panel for a greater number of observations.

The estimated equation for productivity is the following:

$$\text{SPI} = \alpha_0 + \beta_1 log\left({}^{K}/_{L}\right)_{ij} + \beta_2 \, logL_{ij} + \sum_h \beta_h Z_{hij} + d_i + d_j + u_{ij} \qquad (19)$$

Where:

SPI = Sustainable Productivity Index.

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log = Logarithm.

α = Intercept.

K = Capital stock.

L = Labor.

Z= Control variables: Innovation (INN).

U_{it} = Error term.

The variables involved can be expressed as follows:

$$Y_{it} = a_{it} + \beta_1 K_{it} + \beta_2 L_{it} + \beta_3 Inn_{it} + u_{it} \tag{20}$$

Where:

Y = SPI (Sustainable productivity index).

X_1 =Capital.

X_2 =Labor.

X_3 =Innovation.

3.1. Indicators of the Functional Form

Sustainable productivity. It is the endogenous variable and is obtained from the product divided by the factors of production, total employment, the stock of capital, and the proposed sustainable productivity index.

Labor. Total employment is considered, which is understood as the number of formal employees employed in the wood industry for each of the economies.

Capital. The capital stock (CS) is considered, estimated with the perpetual inventory method (PIM), and incorporated with an adjustment factor for the absence of the first observation (PIMA).

Innovation. In the case of innovation, this is expressed in terms of the number of patents registered in various countries to protect the invention. The series of patents registered in three of the most recognized patent offices, known internationally as Triadic Patent Families: The European Patent Office (EPO), the Japan Patent Office (JPO), and the United States Patent and Trademark Office (USPTO), are considered.

The SPI was created using past data on biocapacity and the ecological footprint to create the Environmental Regeneration Index (ERI), which is one of its parts. The other part came from partial labour productivity, and multiplying the two gives us information on sustainable productivity (Navarro, Hernández, & García, 2022).

For capital, the Gross fixed capital formation (GFCF) is initially considered and its subsequent use as a fixed capital stock, using the Perpetual Inventory Method (PIM), which takes into account the depreciation rate of the assets of given fixed capital plus a series of "investments" that accumulate for the period to be analyzed, the equation is Loría and Jesús (2007):

$$KS_t = (1 - \delta)^* KS_{t-1} + I_t \tag{21}$$

Where:

KS_t: Real capital stock.

δ = Depreciation.

I_t= Real total investment (which is presented as gross capital formation)

A problem that arises in Equation 21 is obtaining the value of KS_{t-1}, i.e., where it will start counting. The calculation is usually started when it is assumed that $CS_0 = 0$ (1990), $CS_{1991} = I_{1990}$ for the second observation, and capital begins to accumulate from observation 3, adding the investment. Some authors, to avoid $CS_0 = 0$ decide to go back to one observation, that is, if it is required to estimate KS for the period 1990-2019, extended it to 1989-2019. Thus, 1989 = 0 and 1990 will take the value of the real investment of that observation, so the series for the period 1990-2019 will no longer start from zero (Loría & Jesús, 2007).

Shiau, Kilpatrick, and Matthews (2002) mentioned that in the first observation, the value of real capital stock is zero and increases until, after approximately 10 observations, it stabilizes, which represents a technical disadvantage

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because investment and depreciation begin to accumulate after several observations. Therefore, Shiau et al. (2002) propose to incorporate an adjustment factor (PIMA) to minimize this problem. They are based on the suggestion of Almon (1999), who considers an adjustment factor for the series, which is described as follows:

Adj:

$$Adj_t = (1-\delta)^* Adj_{t-1} + 1 \qquad (22)$$

For the initial observation, it is assumed that $Adj_t = 1$ and it grows until it reaches the equilibrium value of the average depreciation rate $1/\delta$. From this adjustment factor, and from the estimate of *KS* in Equation 23, an adjusted series is calculated:

$$K_t = \frac{KS_t/Adj_t}{\delta} \qquad (23)$$

Concerning the depreciation rate, there is a lack of consensus. Shiau et al. (2002) assume a rate of 12%; Blázquez and Santiso (2004) suggest 8%; Santaella (1998) proposes 10%; and Bergoeing, Kehoe, Kehoe, and Soto (2002) opt for 5%. In order to determine our depreciation rates, we use the data from the Office for National Statistics (ONS) of the United Kingdom's PIM calculation (Martin, 2002) (refer to Table 1).

Table 1. Depreciation rates of assets.

Type of asset	Depreciation rate
Machinery and equipment	0.25
Buildings & plant	0.10
Transportation equipment	0.25

Source: Officer for international statistics (ONS) from United Kingdom, 2002.

According to the data in Table 1, the suggested depreciation value is a weighted average of $\delta = 0.11$. The use of 10% that Santaella (1998) mentions has, however, received approval in the majority of studies created for the manufacturing sector. In order to allow the possibility of comparing the values of the capital stock used in the corresponding series with investigations of the same line, it is necessary to highlight that for the present investigation, the value of $\delta = 0.10$ will be used.

4. RESULTS

Below are the results of the panel data econometric model proposed to identify the determinants of productivity in the wood industry for the economies that make up the Asia-Pacific Economic Cooperation Forum (APECF) in the period 1990-2019.

For the elaboration of the model, 8 APECF economies were considered: Canada, Chile, Korea, the United States, Japan, Malaysia, Mexico, and New Zealand. This is due to the same absence of historical records in some periods, without which it was not possible to complete a panel for a greater number of observations.

When performing the cross-section dependency test for each of the series, which establishes a Ho: no cross-section dependency and a Hi: cross section dependency. The results were verified with the Breusch-Pagan, Pesaran LM scale, and Pesaran CD tests. In all cases, Ho is rejected, thus accepting the existence of a cross section dependency (see Table 2).

Table 2. Cross section dependency test.

Test	Statistical	Prob. value
Breuch-Pagan LM	282.111	0.0000
Pesaran scaled LM	33.957	0.0000
Pesaran CD	12.503	0.0000

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By taking into account the tests carried out, it is possible to determine that there is a cross-section dependency in the series analyzed.

The outcomes of the preceding tests indicate the existence of cross-sectional dependence among panel units. Consequently, the estimation of first-generation unit root tests is precluded as they presume independence among individuals. In this framework, the estimates for this study rely on second-generation unit root tests. The Pesaran-CADF test (Pesaran, 2007) is used to find the integration order of each variable. The null hypothesis (Ho) says that there is a unit root, and the alternative hypothesis (Hi) says that there isn't one (refer to Table 3).

In the results, it can be seen that all the variables at levels presented unit roots, so in a second stage, the calculations proposed by Pesaran (2007) were performed again, where the first differences were applied to each of the variables.

Table 3. Results of the unit root test.

Serie	Test Pesaran- CADF	
	Level	First difference
	p-value	p-value
Sustainable productivity (Log SPI)	0.383	0.000
capital stock (Log CS)	0.123	0.019
Labor (Log L)	0.204	0.006
Innovation (Log Inn)	0.108	0.016
Log= Natural logarithm		

As can be seen in Table 3, once the variables were differentiated, the values obtained were significant at 1%, so in all cases the null hypothesis is rejected, thus accepting the alternative hypothesis that the series do not have a unit root or they are stationary and have the same order of integration, that is, the series are integrated of order one I(1).

Once it was determined that the series have the same degree of integration and share the same level, the second generation cointegration test was carried out for panels that present cross-sectional dependence, for which the test proposed by Westerlund and Edgerton (2008) is a test that allows us to know if there is cointegration in the study variables. This test poses a Ho: there is no cointegration between the series, and Hi: all the panels are cointegrated. The results are presented in Table 4.

Table 4. Results of the cointegration test.

Series: Log IPS, Log Sc, Log L, Log Inn	Westerlund	
	Statistical	p-value
Variance ratio	-2.402	0.008

Based on the findings from the preceding test, we can infer that the null hypothesis of no cointegration is rejected. Instead, we accept the alternative hypothesis, signifying the presence of cointegration in the model's panels.

4.1. Estimation of Panel Cointegration Coefficients

The augmented mean group (AMG) regression model estimation first presented in Eberhardt and Teal (2010) is used for models with cross-dependency.

Table 5. Results of the AMG augmented mean group regression model of the timber industry, APEC, 1990-2019.

Inips	Coef.	z	P > z
Δ log SC	0.037	0.004	0.007
Δ log L	0.297	0.045	0.000
Δ log Inn	0.133	0.019	0.001
Cons	0.46	0.026	0.006

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The AMG regression has been applied to the data set of the present investigation and was developed taking into account the first differences of the series in logarithms. The results of the model are observed in Table 5.

The values for the β obtained through this model are significant, and with a confidence level of 99%, it can be said that there is a relationship between the explanatory variables capital stock (CS), labor (L), and innovation (Inn) and the dependent variable sustainable productivity (SP).

The coefficients obtained are accompanied by positive signs, which were as expected, and based on this, it can be stated that the work variable (expressed through personnel employed in the industry) is the one with the greatest positive impact on the sustainable productivity of the wood industry, with a coefficient of 0.297. This coefficient tells us that a one percentage point increase in personnel employed in the wood industry generates a favorable increase in the sustainable productivity index of said industry of 0.30%.

Innovation (expressed as the number of technological patents registered in IP3), as an explanatory variable of the model, appears in second place of importance, with a positive coefficient equal to 0.133, which means that an increase of one percentage point in the number of technological patents registered in IP3 causes an increase of 0.13% in the sustainable productivity index of the wood industry in Mexico and the economies analyzed for Asia-Pacific.

There is a capital stock with an equally positive coefficient of 0.037. This means that a one percentage point increase in the capital stock in the wood industry generates a 0.04% increase in the sustainable productivity index for this industry.

5. DISCUSSION OF RESULTS

In the literature review section of this work, important contributions stand out in terms of productivity and the use of sustainable and sustained resources, such as the works of Padilla (2006); Lugones (2001), Fernández and Curado (2019); Coy and Chacón (2022), Puyana and Romero (2006), Economic Commission for Latin America and the Caribbean (ECLAC) (1996), Chudnovsky and Porta (1991), Vázquez-López (2021), Gurmendi (2023); Ziesemer (2020), Soete et al. (2020), Bianco (2007), García et al. (2021) and Purbowati et al. (2021). However, this research differs from that of these authors in the following aspects:

- First, the construction of the sustainable productivity index (SPI) to use it as a dependent variable. This index is made up of partial labor productivity and the Environmental Regeneration Index, which is obtained by taking into account the levels of forest use that are carried out in a sustainable manner.
- Second, the capital stock is used as one of the variables, which is estimated with the perpetual inventory method (PIM) and incorporating an adjustment factor.
- Third, the application of second-generation econometric models using the cross-section dependency test, the Pesaran-CADF unit root test, Westerlund's cointegration test, and a long-term regression model, Augmented Mean Group (AMG).

Carrying out this type of research is important since it shows the existence of productivity that is accompanied by a balance in the use of resources or public goods and not at their expense, such as land and water. The studies on the wood industry, from the perspective of sustainable productivity, are important not only for Mexico but also for the economies that continue to obtain significant sources of employment and income from this activity, since, as has been presented in this paper and research, this industry provides necessary and useful goods to the market.

In a world increasingly aware of environmental impact, sustainability has become a fundamental value in all industries, which implies a series of measures that guarantee the proper management of forests. Because of this, it is essential that wood comes from legal and sustainable sources, avoiding illegal logging and indiscriminate deforestation. Furthermore, as it could be observed in the analysis that was carried out, investment in innovation and technology is a factor that determines productivity in the industry, so the implementation of advanced technologies that minimize waste and reduce energy consumption is essential to being able to have a sustainable industry.

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Particularly for the APEC economies, based on the results on the determinants of sustainable productivity of this research, attention to the sustainable management of forest resources and the incorporation of new technologies or products is presented as a challenge and useful in the wood sector, as innovation has turned out to be a substantial element in achieving sustainable productivity in the wood industry.

6. CONCLUSIONS

In this research, the study of the determinants of sustainable productivity for the wood industry was carried out, considering Mexico and the Asia-Pacific economies in the period 1990-2019. The economies considered were Canada, Japan, Korea, Malaysia, Mexico, New Zealand, Singapore, and the United States.

The variables considered in the model were the sustainable productivity index, capital stock, total employment, and innovation. For the capital stock variable, the calculation was made using the Perpetual Inventory Method, where an adjustment factor was also applied to obtain more robust results.

The econometric methodology for panel data analysis was implemented, starting with the cross-section dependency test, where the Breusch-Pagan, Pesaran LM scale, and Pesaran CD tests were applied, and it was possible to determine that there is dependency in the series, a situation for which second-generation tests were used. Then, the unit root test of Pesaran (2007) was used to find the order of integration and make sure that no extra variables were used. It was seen that all the variables cointegrate in order I (1), so the next step was to do the cointegration test. The test suggested by Westerlund and Edgerton Westerlund and Edgerton (2008) was used, and the results showed that the variables cointegrate, which means they are in long-term equilibrium. Finally, a regression was performed for models with cross-sectional dependence, in this case the Augmented Mean Group (AMG) was used.

With the results of this model, it was possible to observe the influence of the labor factor, presented as the number of people employed in the wood industry for each economy. It is a relevant element for the generation of sustainable productivity in the wood industry since it directly influences. The coefficients obtained are accompanied by positive signs, which were as expected, and based on this, it can be affirmed that the work variable is the one with the greatest positive incidence on the sustainable productivity of the wood industry.

In second place, innovation was considered a relevant factor in the pursuit of higher levels of sustainable productivity, highlighting that in international marketing, innovation becomes an incentive that encourages the search for innovations in productive organization, commercial combinations, and a better use of the rest of the factors while guaranteeing the supply of renewable resources and better management of the resource. Finally, for the capital variable, it was also possible to observe its positive influence, in third place of importance, on the achievement of sustainable productivity.

With the results obtained in each of the tests and in the AMG model, it was possible to corroborate the proposed hypothesis, since the labor factor, capital, and innovation were the main factors that affected the sustainable productivity of the wood industry in Mexico and the member economies of the Asia-Pacific Economic Cooperation Forum during the period 1990-2019.

The main limitation of the research was to obtain a complete database of all the APEC economies. This would have made it possible to study these economies over a longer period of time, as well as incorporate a greater number of indicators. In this way, the research would have more robust results.

Based on the findings obtained on the determinants of sustainable productivity in APEC economies, there is a need to incorporate innovations and technology in the wood industry to make it more sustainable, as well as reinforce the training of workers to acquire better skills that can be applied to this industry.

Finally, the results of this research show the need to establish guidelines that lead to the development of public policies that promote sustainable productivity in the wood industry. Particularly in those APEC economies that presented serious problems with productivity.

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