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Labor Productivity Convergence among Eurozone Member Countries

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Abstract

This paper analyzes the evolution of labor productivity among the Eurozone's member countries between 1999 and 2019, using a dynamic panel estimate. The main findings indicate that, since the adoption of the single currency in 1999, both productivity per worker and productivity per hour followed different routes among Eurozone countries. Convergence among the founding countries stagnated after 2008, probably because of the Global Financial Crisis (GFC). But in the countries that joined the Eurozone several years after its creation, convergence did not slow down; indeed, towards the end of the period, the convergence of labor productivity among new entrants did not slow down. This paper focuses on measuring convergence in labor productivity and should be continued with a diagnosis of the likely causes of its stagnation. In this sense, it opens a line of research whose findings will contribute to the design of international integration policy between regions.

JEL Classification: C33, E24, F66, O47, J24, O3.

Keywords: Dynamic Panel Data, Labor Productivity, Convergence, Eurozone, R&D.

Convergencia de la Productividad Laboral entre los Países Miembros de la Eurozona

Resumen

Este trabajo analiza la evolución de la productividad laboral entre los países miembros de la Eurozona entre 1999 y 2019, utilizando una estimación de panel dinámico. Los principales hallazgos indican que, desde la adopción de la moneda única en 1999, tanto la productividad por trabajador como la productividad por hora, siguieron rutas diferentes entre los países de la Eurozona. La convergencia entre los países fundadores se estancó después de 2008, probablemente como consecuencia de la Crisis Financiera Global (GFC). Pero en los países que se unieron a la Eurozona varios años después de su creación, la convergencia no se desaceleró; en efecto, hacia el final del periodo, la convergencia de la productividad laboral entre los nuevos entrantes no se desaceleró. Este trabajo se enfoca a la medición de la convergencia en la productividad laboral, y debe ser continuado con un diagnóstico de las causas probables de su estancamiento. En este sentido, abre una línea de investigación cuyos hallazgos aportarán al diseño de la política de integración internacional entre regiones.

Clasificación JEL: C33, E24, F66, O47, J24, O3.

Palabras clave: Panel de Datos Dinámico, Productividad Laboral, Convergencia, Eurozona, I&D.

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1. Introduction

When the Eurozone members adopted the single currency, many expected to see a fast cross-country convergence in terms of income levels, productivity, and economic growth. By 2012, however, the Eurozone crisis raised questions on whether the problem could be explained by institutional factors such as inadequate regulations, the irresponsible execution of fiscal policy (e.g., the case of Greece), or whether it required a more fundamental economic explanation of conditions that underlie economic growth, income distribution, and international competitiveness.

For several decades before the introduction of the single currency, the member countries followed a clearly intended economic integration. The creation of the European Common Market (Treaty of Rome, 1957), and the formalization of the European Union (Maastricht Treaty, 1993), eliminated most institutional barriers to international trade among member and the flow of capital across member countries. The removal of cross border tariffs and quotas favored each country's specialization in those activities in which they enjoyed a comparative advantage, and this process induced a national migration of productive resources from the relatively less efficient towards the relatively more efficient industries. Greater specialization, in turn, attained economies of scale, increased investment, employment, and better standards of living for European citizens (Santillán, 2015).

The only non-explicit international trade barrier that remained in place was the use of different national currencies because it created exchange rate risk and represented bid-ask spread costs in each currency exchange transaction. However, with the adoption of the euro (1999), the uncertainty due to currency exchange rate risk was finally eliminated, and the conditions for a fully integrated economic area were consummated. In retrospective, one of the strongest arguments for monetary unification was the expectation that specialization would increase Eurozone members' international competitiveness (Santilllán and Ortega, 2017). However, according to Gräbner et al. (2020) two decades after the adoption of the single currency and one decade after the Subprime Mortgages crisis of 2008, the economic development of the Eurozone member countries remained "remarkably uneven".

From the point of view of economic integration and growth, the main consequence of not having achieved an efficient productivity convergence in the Eurozone was the limited specialization achieved by member countries, and the suboptimal utilization of their potential productive capacity, hindering their ability to innovate. This, in turn, is associated with the generation of new well-paid employments and with the creation of economic value, as pointed out by Krugman (1993).

In recognition that one of the most influential determinants of aggregate economic productivity in any country is labor productivity, because productive chains heavily depend on labor to deliver their products and services, this work analyzes labor-productivity convergence in the Eurozone from 1992 through 2019. This is a subject that has been consciously studied by Filippeti and Peyrache (2013), Sonderman (2014), and Ahmad Naveed, and Naz (2019), as it represents a necessary condition for long-term competitiveness and sustainable growth.

Filippetti and Peyrache (2013), suggest that labor productivity growth is closely related to technological progress and that to reduce the technology gap among Eurozone member states, labor productivity should converge. However, they explored the sources of labor productivity growth in

Europe between 1993 and 2007 and found that, although labor productivity differences diminished, disparities among countries were still substantial. Sonderman (2014), studied labor productivity among Eurozone countries and reported that, while capital and technology free movement should have contributed to convergence in manufacturing, telecommunications, and other information technologies, no evidence could be found at an aggregate level. Although, some indications of labor productivity convergence in agriculture, transport, and communications, as well as in non-market services were detected for the period 1970-1998, from 1999 to 2007 only non-market services converged and two another industries, construction and distributive trade, showed some signals of convergence. More recently, Ahmad, Naveed, and Naz (2019) explored the effect of structural change (for instance, differing share of employment in different industries, changes in demand, trade patterns and technological progress) on labor productivity convergence in the EU from 1991 to 2009. Looking at different levels of aggregation, i.e., regions, industries, and countries (hierarchical convergence analysis), these authors found that convergence was observed at a regional level. At an industry level, convergence was strongly confirmed in some sectors (agriculture, construction and market services), but it was not present in some other sectors (manufacturing, financial services and non-market services), concluding that labor productivity convergence is heterogeneous at different levels of aggregation.

Because of the elimination of frictions to the free movement of goods, capital, and labor, and the adoption of a single currency that removed exchange rate risk, economic convergence in a broad sense should have happened among Eurozone members. As expressed by Bertola et al. (2001), the abolition of "economic borders" among the EU member countries should result in welfare improvements at an aggregate level since most productive activities benefit from economies of scale and scope that could not be captured before the integration process. However, in view of the available evidence that this is not the case and, for that reason, a more detailed diagnosis is required.

This paper's contribution to the understanding of what is the state of convergence in labor productivity among Eurozone member countries is based on the results of a dynamic panel data analysis. The main findings indicate that labor productivity of Eurozone countries, measured both in per-worker terms and in per-hour terms, slowed down significantly after 2008 for the founding members (incumbents), likely as a consequence of the Global Financial Crisis (GFC). For those countries that joined the Eurozone some years after its creation (late comers), labor productivity has continued its convergence towards that of the Eurozone incumbents. However, two decades after the adoption of the euro, the gap between these two groups of countries is still economically significant.

The rest of the paper is organized as follows, the second section presents a brief literature review on labor productivity and its determinants. The third section introduces the methodological framework used in the analysis. The fourth section reports the main results of the study. The final section presents the conclusions of the study and suggests some ideas for future research.

2. Labor Productivity and its determinants

In the spirit of the neoclassical view of Solow (1956), as countries achieve more advanced levels of industrialization, there are decreasing returns on investment and, under the assumption of free factor mobility, there will be increasing capital flows invested in lower-income countries, producing a gradual economic convergence over time. A totally different view was proposed by Romer (1986) and Lucas (1988) who emphasized that physical and human capital accumulation represent the main drivers of growth and believe that, under certain conditions, divergence prevails (Kumar and Russel, 2002). These authors suggest that technological change is endogenous in the sense that it results from the accumulation of human capital and investments in research and development, which produces knowledge with an increasing marginal productivity. In this case there are no diminishing returns to human capital accumulation in the more advanced countries, so there are less incentives to invest overseas, reducing the chances of convergence and, in that sense, the uneven technological levels observed across countries and over time, may be explained by the prevailing differences in human capital accumulation.

The endogenous vs. exogenous perspectives dichotomy is too rigid to capture the complexity of economic integration and labor productivity convergence. However, it delineates the field's boundaries and frames research on the subject. Studies have followed a wide variety of approaches, each of them confirming that the complex modeling of economic integration, and labor productivity convergence among Eurozone members cannot be captured with a single lens. In what follows, we briefly discuss several reported findings that provided the necessary support for our own research design.

Rivera-Batiz and Romer (1991) proposed that the role that corresponds to increasing returns to scale is of paramount importance for regional economic integration. Productivity is associated with economies of scale in general, but with different implications depending on the characteristics of each country. However, in the case of the less developed countries of the Eurozone (e.g., Spain, Portugal and Greece), the potential benefits of eliminating economic barriers are probably less promising given the significant gap in productivity and per-capita income that prevail in those countries, relative to the more advanced economies (e.g., Germany, Netherlands). Syverson (2011) found that different studies in labor economics have focused on the relevance of human capital as a determinant of productivity, the productivity consequences of incentive schemes, and the influence of managerial talent and practices, among other relevant subjects. Villaverde and Maza (2008) examined aggregate productivity in Europe, considering it to be the outcome of the combined evolution of sectoral productivities and the sectoral distribution of economic activity, they concluded that: a) there is "a high degree of dispersion in productivity" across regions and across industries; b) the improvement in aggregate productivity is explained by productivity gains at a sectoral level; c) the sectors that have contributed the most to reduce productivity gaps are 'Food, beverages and tobacco' and 'Fuel and power products'; d) there is a declining relationship between the "aggregate productivity of each region and its geographic location", meaning that similar (more or less efficient) regions agglomerate in space. Vechiu and Makhlouf (2010) analyze productive specialization among an enlarged sample of all 27 EU countries by sector. These authors focus on individual manufacturing activities and report the presence of diminishing productive specialization across all economic

sectors but increasing specialization across manufacturing industries. One of the main consequences that the productive specialization of EU countries should bring about is the improvement of productivity as it favors the learning-curve and the creation of economies of scale, and would lead to convergence.

Most empirical studies interested in the country group convergence hypothesis have used gross domestic product per capita as the dependent variable (Barro & Sala-i-Martin, 1991; Friederich-Eckey & Türk, 2007); however, other indicators have been used more recently to study convergence at different levels of aggregation (regions, countries, and industries).

However, labor productivity is likely the most interesting variable to study regional and country convergence in the EU (and more specifically, in the Eurozone, which is the focus of this research) because of its theoretical implications as it is closely related to income distribution effects, international competitiveness, technological modernization, and political consequences (for example, in terms of the economic resources allocated by the European Commission to its members, in order to promote economic integration across the region).

Studies in labor productivity convergence include O'Leary (1999), who reports evidence of aggregate and sectoral labor productivity convergence for 11 EU countries, showing a greater degree of aggregate convergence than sectoral convergence, in between 1970 and 1990. O'Leary suggests that the existence of comparatively low productivity levels in traditional activities among the less developed EU countries can potentially contribute to a more expedite labor productivity growth in those activities that are more technologically advanced, directly contributing to a faster convergence. A concrete policy implication that derives from these findings is that poorer countries' policies which accelerate the reallocation of labor towards higher productivity activities promote convergence.

Martino (2015) studies labor productivity dynamics for many EU regions for the period from 1991 to 2007 and his results confirm a clear process of unconditional convergence in financial- and business-related services. According to the author, financial liberalization detonated in 1992 by the Maastricht Treaty probably influenced the convergence process of the financial industry, as financial institutions doing business across borders in the EU would transplant their best practices to their new operations. A similar reasoning would also apply to business-related services. However, the reported results confirm that labor productivity does not converge in manufacturing.

According to economic theory, the main determinants of productivity include the free movement of capital and labor, technological innovation based on research and development (R&D) investments, and the continuous modernization of productive plants. The literature focused on the determinants of labor productivity convergence in the Eurozone has included most of them (and some others). Table 1 summarizes eight studies that aim to explain labor productivity convergence in the region, listing their driving factors, analytical method and findings.

Table 1. Factors related to labor productivity convergence (divergence) in the Eurozone, according to the literature.

Study	Factor	Method	Finding
Naveed & Cong (2023)	Innovation	Panel data analysis with treatments for endogeneity (2SLS and system GMM)	Innovation as a factor of productivity growth moderated by structural change.

Study	Factor	Method	Finding
Vittori, Ricci & Ferri (2023)	Migration	Pool model, controlling for heteroskedasticity.	A larger participation of extra-EU workers results in declining labor productivity in Italy. The relationship is different between firms located in center-north and those in southern regions.
Del Río Casasola & Paz (2022)	Wages	Cluster analysis and productivity and wage ratios	Convergence has been higher in productivity than in wages, given that productivity gains of more advanced economies have been transferred to a wages in greater measure.
Jankowska (2021)	Increases in gross value added and reduction in employment in the agricultural sector.	Convergence indicator, time and spatial analysis	Changes in labor productivity in the agricultural sector were explained by structural change.
Ahmad et al. (2019)	Structural change	Hierarchical Convergence Analysis	There is convergence at a regional, but not at a country level
Filippetti and Peyrache (2013)	Fixed capital investment, technical change, and efficiency	Data Envelopment Analysis	53% of productivity growth is explained by FCI, 32% by efficiency and 15% by technical change. There is a lack of convergence.
Martino (2015)	Labor productivity growth	The average growth rate of labor productivity is regressed on its initial level	There is convergence in financial- and business-related services, but not in manufacturing
O'Leary (1999)	Structural change	Comparison of trends in aggregate and sectorial coefficients of variation	Aggregate labor productivity converges at a 0.9 per cent annual rate in the EU
Rivera-Batiz and Romer (1991)	Research and Development	Two theoretical models with different specifications of the R&D sector	Integration can increase the long-run rate of growth through the exploitation of economies of scale in the R&D sector
Sondermann (2014)	Innovation capacity, human resources, and regulations	Panel data unit root tests	No convergence: costs of structural heterogeneity tend to rise "when economic disparities are firmly entrenched

Study	Factor	Method	Finding
Vechiu and Makhlouf (2010)	Foreign Direct Investment	Entropy-based indices to measure relative specialization by sector; vector auto-regression	FDI positively influences specialization, although other variables, such as market potential and relative endowment, seem to be more relevant
Villaverde and Maza (2008)	Productivity gains at sectorial level	Cross-section, non-parametric and spatial econometric approaches	Aggregate productivity gains are due entirely to productivity gains across sectors

Source: Authors' own elaboration.

The studies discussed in this brief literature review suggest that the most likely determinants of labor productivity include investments in research and development, innovation, human capital skills, economies of scale, free movement of capital and labor, national and foreign direct investment. While the diversity of specific variables and empirical techniques is not conclusive, the literature provides the required framework to develop and estimate our own model of labor productivity convergence. Its results seem to support some relevant conclusions.

3. Methodology

The choice of time series methods to assess convergence has been questioned because they lack the ability to account for non-observable heterogeneity across countries. Once heterogeneity is accounted for, panel data is more suitable to test the robustness of any hypothesis (Pesaran, Smith & Yamagata, 2013).

Following (Brooks, 2002) notation, for a set of g variables $\sim I(1)$ and a VAR with k lags expressed as:

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \ldots + \beta_k y_{t-k} + u_t,$$

to test for cointegration, the model needs to be converted into a Vector Error Correction Model (VECM), as follows:

$$\Delta y_t = \Pi y_{t-k} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \ldots + \Gamma_{k-1} \Delta y_{t-(k-1)} + u_t,$$

where $\Pi = \left(\sum_{i=1}^{k} \beta_i\right) - I_g$, and $\Gamma_i = \left(\sum_{j=1}^{i} \beta_j\right) - I_g$, so that Π represents the long-term coefficient matrix. Since $\Delta y_{t-i} = 0$ and $E(u)=0$, the equilibrium is expressed as follows:

$$0 = \Pi y_{t-k} + 0 + \ldots + 0 + 0$$

These types of models are often used to test for convergence in a series but, as the information is pooled, the richness of heterogeneity is swept away. Therefore, it is preferable to use panel data to

account for the dynamics across countries and time (Baltagi, Griffin, & Xiong, 2000). To model labor productivity one can estimate a one-way error Panel Data Analysis model, which can be contemporaneous as in equation (1), with a lagged impact, as in equation (2), or a two-way error model with lagged impact as in equation (3):[2]

$$ln(productivity_{it}) = \alpha_i + \beta\, ln(X_{it}) + u_{it}, \quad (1)$$

$$ln(productivity_{it}) = \alpha_i + \beta\, ln(X_{it-1}) + u_{it}, \quad (2)$$

$$ln(productivity_{it}) = \alpha_i + \lambda_t + \beta\, ln(X_{it-1}) + u_{it}, \quad (3)$$

where i = 1-19 countries, and t=1992 to 2017, α_i represents the time invariant effect, λ_t the country invariant effect across time, and u_{it} the stochastic term, where $E(u_{it}) = 0$.

In the convergence approach, the panel data model used to represent the classical growth equation, rewritten for labor productivity to determine whether there is convergence in labor productivity, is modified following Ortega-Diaz (2006):

$$growth_{it,t-1} = \alpha_i + \lambda_t + \beta\, ln(productivity_{it-1}) + u_{it} \quad (4)$$

The estimation of equation (4) with a static Fixed Effects (*FE*) or Random Effects (*RE*) model that does not account for endogeneity would result in biased estimated coefficients, but the use of instrumental variables with the Generalized Method of Moments (*GMM*) of (Arellano & Bond, 1991) does account for endogeneity, as in equation (5):

$$ln(productivity_{it}) - ln(productivity_{it-1}) = \alpha_i + \lambda_t + \beta\, ln(productivity_{it-1}) + u_{it},$$

and

$$ln(productivity_{it}) = \alpha_i + \lambda_t + \gamma\, ln(productivity_{it-1}) + u_{it}, \quad (5)$$

where $\gamma = \beta + 1$, and $|\gamma| < 1$.

The model relies on the assumptions that T is small and N is large; u_{it} has finite moments, $E(u_{it}) = E(u_{it}, u_{is}) = 0$ for $s \neq t$; and the residuals u_{it} are not serially correlated (although not necessarily independent in time) (Arellano & Bond, 1991). The model may be extended to its multivariate form with *k-1* variables, as follows:

$$ln(productivity_{it}) = \alpha_i + \lambda_t + \gamma\, ln(productivity_{it-1}) + D'X_{it}^{*} + u_{it}$$

[2] Variables are expressed in natural logarithms, which is a monotonic transformation, that allows a straight interpretation of the model in terms of elasticities, $\left(\frac{\partial\, ln\, y}{\partial\, ln\, x}\right) = \beta$, see Chapter 2, Greene (2018).

and

$$ln(productivity_{it}) = \alpha_i + \lambda_t + \delta' X_{it} + u_{it}, \quad (6)$$

where X is a vector of dimensions $k \times 1$, and X_{it}^* is not correlated with α_i. The optimal instruments matrix will depend on whether the variables in vectorX_{it}^* are predetermined or completely exogenous. If they are predetermined in the sense that $E(X_{it}^* u_{is}) \neq 0$ for $t < s$ and zero otherwise, then the valid instruments are $X_{i1}^*, \ldots, X_{is-1}^*$. If the variables in vector X_{it}^* are completely exogenous, such that $E(X_{it}^* u_{is}) = 0$ for all t and s, then all $x's$ in $X_{it}^*$are valid instruments for all the equations. Therefore, this last estimation method is selected as the most suitable for our analysis.

4. Data

Productivity growth can be assessed in various ways. In the endogenous growth literature, the engine of economic growth is explained as a consequence of the "accumulation of human capital and knowledge generation following investments in research and development (*R&D*) or learning by doing" (Klenow & Rodríguez-Clare, 1997).

In this research we account for several determinants of labor productivity that can be related to either private or public R&D investment, and for different types of capital investments in the economy. The literature defines two measures of labor productivity that are used for this analysis: labor productivity per hour worked (*lphw*), available for most Eurozone countries from 1992 through the first quarter of 2019, and labor productivity per person employed (*lppe*), for a similar period, both expressed in constant US dollars of 2018. The series were obtained from The Eurostat database and The Conference Board Total Economy Database™ (CBTED).

Several independent variables identified from the literature as determinants of labor productivity were used in the estimations. They were grouped into three categories:

- The first category contains an aggregation of economic variables known as the Global Competitive Index (*Global*)[3], and calculated with: "*an aggregation of 103 individual indicators, (which are) derived from a combination of data from international organizations as well as from the World Economic Forum's Executive Opinion Survey.*" The indicators are assigned to twelve categories called *'pillars'*: *Institutions; Infrastructure; ICT adoption; Macroeconomic stability; Health; Skills; Product market; Labor market; Financial system; Market size; Business dynamism; and Innovation capability".* The index is available from 2006 (Schwab, 2019), takes values from 0 to 100, and each pillar weighs 8.3 per cent. The eighth pillar, referred to the labor market, has twelve dimensions which are frequently found in the business literature (i.e., IT investment, human capital and skills, sunk costs, economies of scale, free movements of capital and labor, national and foreign direct investment).

[3] The Global Competitive Index data was retrieved from the World Economic Forum website: http://gcr.weforum.org

- The second category of explanatory variables refers to debt, because of its effect on productivity growth (Panizza & Presbitero, 2014) and includes the countries' external debt as a percentage of GDP (*ExtD2*)[4], and public debt as a percentage of GDP (*PubD*).
- The third category includes several measures of R&D expenditure, as this construct is widely recognized an important determinant of productivity among EU countries' economic development.

Summarizing, the list of explanatory variables used to model labor productivity were the following:

1st category: Globalci: Global Competitiveness Index (2006-2017);
2nd category: *ExtD2*: External debt as % of GDP (2003-2014) ; and PubD: Public debt as % of GDP (1992-2014).
3rd category: R&D*: Busexprd:* Business Enterprise Funds Expenditure on R&D as % of Total Expenditure on R&D*; Ffaexprd*: Funds from Abroad Expenditure on R&D as % of Total Expenditure on R&D; *Gvtexprd*: Government Funds Expenditure on R&D as % of Total Expenditure on R&D; *Priexprd:* Private Non-Profit Funds Expenditure on R&D as % of Total Expenditure on R&D; and *Totpatnatoff*: Total Patent Grants at National Patent Office.

The summary statistics of the database are included in the Appendix. (our summary statistics are presented in the Appendix)

5. Estimation results

5.1 Global competitive index as the explanatory variable (2006-2017)

As explained in the methodological section, the estimation of the model using FE and RE produces biased results, as it does not account for endogeneity. The model is estimated using dynamic panel data technique, in this case the Arellano-Bond GMM methodology that corrects for the presence of an endogenous lagged variable. Tables 1 shows the estimation results of labor productivity per hour worked (columns 1 to 4), and labor productivity per person employed (columns 5 to 8). The Global Competitive Index (GCI) is used with both dependent variables as an explanatory variable for the two-way error model (equations 6), indicated using period dummies. The results in Table 2 show that either type of productivity estimation (in per worker terms or per hour terms), as labor productivity per worker increases in *t-1*, it keeps increasing in *t* so that $\hat{\gamma}$=0.8801, and $\widehat{\beta}$=-0.1199, indicating convergence (see Table 2 column 5). The same applies to labor productivity per hour where $\hat{\gamma}$=0.8613. The estimation presented in column 1 is preferred given that column 2 results are estimated using the two-step estimator, but the test suggests that the standard errors are biased, and in columns 3 and 4 the estimations used the GCI as predetermined variables under the assumption

[4] Luxemburg is an outlier among the EU countries. A similar case regarding public debt occurs with Luxemburg and Malta, with the highest and lowest levels in the sample.

of a feedback effect through time, but this assumption makes the GCI non-statistically significant. The best estimations are in columns 1 and 5 in Tables 2. In all static estimations, when using period dummies (2006-16), the coefficients are negative and statistically significant suggesting decreasing productivity over time. In addition, when the lagged dependent variable is introduced, using equation 5 estimated with GMM, the period dummies cover the years 2007 to 2017, and the estimated coefficients are negative and statistically significant only for 2008, 2009 and 2012. These inflexion points coincide with the observed trends after the financial crisis in 2008.

To compare $\widehat{\beta}$ estimates for the whole sample of countries ($\widehat{\beta}$=-0.1199), with the sample for 14 countries (the incumbents) and the sample with 5 countries (the entrants) we computed the coefficient of beta convergence shown in Table A2 of the Appendix, to find that incumbents have a lower convergence coefficient $\widehat{\beta}$=-0.0732 and entrants a higher convergence coefficient, $\widehat{\beta}$=-0.3442 for labor productivity per person employed. Something analogous happens with labor productivity per hour, where $\widehat{\beta}$=-0.1387, -0.1024, and -0.5195, respectively.

Table 2.

	Labor productivity per hour worked (*ln_lphw*)				Labor productivity per person employed (*ln_lppe*)			
Variable	**AB1**	**AB2**	**AB3**	**AB4**	**AB1**	**AB2**	**AB3**	**AB4**
	1	2	3	4	5	6	7	8
Constant	0.4748**	1.7241	0.5029*	0.4868	1.2976***	1.1489	1.6471***	3.4835
lnglobalci (t)			-0.054	-0.1055			0.052	-0.351
lnglobalci (t-1)	0.0546	1.1949	0.0957	0.8342	0.0499	0.4090*	0.0194	0.3319
ln_lphw (t-1)	0.8613***	0.0911	0.8608***	0.5946*	0.8801***	0.8435***	0.8465***	0.6984*
Period dummies	yes	yes	yes	yes	yes	yes	yes	yes
N*	209	209	190	190	209	209	190	190
Sargan Tests (Prob>chi2)	0.329	1	0.3229	1	0.5199	1	0.5042	1
Autocorrelation Tests order 1 & 2		1) p= 0.0502 2) p=0.0082		1) p=0.1685 2) p= 0.0240		1) p= 0.7608 2) p=0.0080		1) p= 0.0104 2) p=0.0844

Source: Authors' own estimations.
Legend: * p<0.05; ** p<0.01; *** p<0.001.

5.2 Debt as an explanatory variable (2003-2017)

The effects of external debt (l*nExtD2*) and public debt (*lnPubD*) as explanatory variables of labor productivity is positive. A 1 per cent increase in the use of external debt results in a positive change in labor productivity, regardless of the way it is measured, in columns 1-4 of Table 3. There is evidence of convergence in both types of labor productivity. In the case of labor productivity per hour, $\hat{\gamma}$=0.8019, and equivalent to $\hat{\beta}$=-0.1981; and when labor productivity per person employed is used, $\hat{\gamma}$=0.8669, which is equivalent to $\hat{\beta}$=-0.1331.

The period dummies are positive and significant, but again negative for 2008 in the convergence equation. When considering the two sets of countries (incumbents and entrants), the

convergence is lower for labor productivity per person employed for the incumbents, than for entrants, -0.1481 and -0.1795, respectively, as reported in Table A3. And there is a higher rate of convergence for entrants, equal to $\hat{\beta} = -0.5025$, and for incumbents $\hat{\beta} = -0.3122$ when labor productivity per hour worked is used.

5.3 R&D as the explanatory variable (1992-2017)

Following Klenow & Rodríguez-Clare (1997), several measures of R&D expenditure are introduced in the model to account for changes in labor productivity among EU countries. The estimations make it possible to infer that labor productivity increases with all types of R&D, except with private non-profit fund expenditures, which in some cases is not statistically significant and in others reduces labor productivity when a static model is considered (i.e., FE or RE). With respect to convergence in Table 4, when an endogenous lagged variable is introduced, the rest of the R&D expenditure becomes irrelevant, and it seems that convergence is induced by the rate at which labor increases across countries.

Using different samples, the rate of convergence for the late incomers is higher using the labor productivity per person employed with $\hat{\beta}$=-0.1625 for the complete sample, $\hat{\beta}$=-0.1054 for incumbents and $\hat{\beta}$=-0.5091 for entrants.

In the case of labor productivity per hour worked $\hat{\beta}$=-0.1551 for the whole sample, $\hat{\beta}$=-0.1336 for incumbents and $\hat{\beta}$=-1.0254 for entrants; however, the latter coefficient is not statistically significant. The estimation for the last subsample with only five countries is not reliable since the sample was reduced from 319 observations to only 43 due to limited data availability (see Table A4).

Table 3. Labor productivity and debt

Variable	A_B1	A_B1
	ln_lphw	***ln_lppe***
Constant	0.8064***	1.5634***
lnExtD2 (t-1)	-0.0202	-0.0205*
lnPubD (t-1)	0.0033	0.0023
ln_lphw (t-1)	0.8019***	0.8669***
Period dummies	yes	yes
N	219	219
Sargan Tests (Prob>chi2)	0.0234	0.4117

Table 4. Labor Productivity and R&D

Variable	ABO1	ABO1
	ln_lphw	***ln_lppe***
Constant	0.5686***	1.8211***
lnbusexprd (t-1)	0.0149	0.0089
lnffaexprd (t-1)	0.0022	0.0047
lngvtexprd (t-1)	-0.0018	-0.0038
lnpriexprd (t-1)	-0.0018	-0.0021
lntotpatnaoff (t-1)	0.0003	0.0014
ln_lphw (t-1)	0.8449***	0.8375***
Period dummies	yes	yes
N	317	319
Sargan Tests (Prob>chi2)	0.0002	0.0788

Source: Authors' own estimations.
Legend: * p<0.05; ** p<0.01; *** p<0.001.

5.4 Findings of convergence

This study tests whether labor productivity has converged or diverged among Eurozone member countries, considering that previous findings suggest that different types of economic convergence change through time and depend on the subsector or industry analyzed (Santillán-Salgado and Ortega-Díaz, 2017). The findings reveal there was a tendency to converge, as seen by the consistent negative coefficient of beta in all estimations. The coefficients of the years' variables show that after 2008, the convergence trend stopped, there is a stronger convergence among entrants relative to the incumbents. This might suggest that at the beginning of the period, labor productivity convergence was taking place, but the Financial Crisis of 2008 slowed that trend. A parallel analysis was performed for Productivity per Person per Hour Worked in 2018 USD, and the findings were analogous, it may be worth to explore in the future if a relationship of leader (incumbent) and follower (entrant) exists in the EU.

This phenomenon, of seeing the entrants converging is referred to as the "catching-up" rate, and intends to describe that when a country begins to converge with other countries from a lower level in any economic indicator, it needs a higher rate of growth to catch up, as in between 2000 and 2008; however, if countries at lower levels of the given economic indicator begin growing at the same pace, convergence will not be achieved. Some possible breaks to catching up are the types of productivity growth of the funds than banks provide, as (Huljak, Martin, & Moccero, 2022), from 2006 to 2017 , some banks or these countries were persistently inefficient, and their regulations should be revised. Another determinant of not seeing a higher convergence is the inefficiency of R&D when the providers of funding are persistent institutions that have contracts with the government and do not allow for a better allocation and competition (Añón Higón, 2022).

6. Conclusions

The results of our Dynamic Panel Data Analysis assessed whether there is convergence or divergence in labor productivity among Eurozone countries. They suggest the existence of gradual convergence among all eurozone countries, with a lower rate of convergence for incumbent countries, and with a higher convergence rate for late-entrant countries. Labor productivity growth converged for all countries up to 2008, suggesting that the GFC may have deterred the economic processes that leads labor productivity growth to reach a similar level across countries, after 2008 the gap among all has not diminished. Different authors have documented that the EU (as well as the United States) economy experienced a significant decline in labor productivity growth rates since the outburst of the GFC. For example, Roth (2022) reported that labor productivity growth rates were more than halved relative to the years before the GFC (1995-2007), and recognized that the decline was puzzling considering that real interest rates were either zero or below zero, as well as the fact that it happened at the same time a revolution in information and communications technology, as well as in Artificial Intelligence. His thoroughly comprehensive work documents the attempts to explain this contradiction, and critically discusses the key role of intangibles in labor productivity growth, furthering the understanding of the puzzle.

Based on our results, productivity per hour worked and productivity per worker, convergence stopped around 2008 for the 14 original members of the Eurozone. After 2012, only the late entrants catch-up towards the average growth rate of the rest, maybe since new members were characterized by lower levels of labor productivity and technological capabilities, so a rapid improvement relative to the countries with an already advanced industrialization would be expected. Our study reinforces Filippetti and Peyrache's (2013) findings that the lack of convergence among all countries may be attributed to the insufficient development of technological abilities in the most backward countries, as well as to the incapacity of countries to convert their technological capabilities into labor productivity.

While the findings reported in this study reveal interesting features of the evolution of labor productivity among Eurozone countries, further research is necessary to improve the understanding of the economic forces that have determined the convergence of labor productivity growth rates. A better understanding of the dynamics of R&D, the sources of Debt and the evolution of the GCI, as well as their relationship with the labor productivity gap, is fundamental for future EU expansion plans and policies.

Although this analysis is focused on national labor productivity convergence, we hope that our findings may give support to future studies at the sub-national and industry levels. New findings may also contribute to a better understanding of why labor productivity convergence stagnated among the founding member countries of the Eurozone during the past decade, and why labor productivity growth converged for all members toward the end of our sample period.

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Appendix

Table A1-Summary Statistics of Variables

Variable		Mean	Std. Dev.	Min	Max	Observations
lppe	overall	82135.74	26871.77	23110	158260	N = 532
	between		25262.92	43590.64	145098.8	n = 19
	within		10785.57	45520.38	124625.4	T = 28
lphw	overall	49.09903	18.61979	13	101	N = 515
	between		17.8491	23.92	93.46429	n = 19
	within		6.674585	25.24189	74.24189	Tbar = 27.1053
globalci	overall	4.767168	0.468802	3.9	5.8	N = 228
	between		0.467136	4.020425	5.507107	n = 19
	within		0.110155	4.463904	5.144701	T = 12
ExtD2	overall	386.4015	855.1885	20.6	5732	N = 274
	between		890.459	47.60455	4010.4	n = 19
	within		195.3393	-629.499	2108.001	T = 14.4211
pubdebt	overall	5.68829	16.54726	-101.3	161.8	N = 427
	between		8.253994	0.8	32.82308	n = 19
	within		14.98303	-118.368	144.7318	T = 22.4737
busexprd	overall	45.95516	15.56423	10.2	90.7	N = 455
	between		13.75143	18.84615	64.83462	n = 19
	within		7.828937	18.1885	79.10901	T = 23.9474
ffaexprd	overall	11.813	8.606016	1.3	53.4	N = 454
	between		6.604512	3.361538	30.96087	n = 19
	within		5.869409	-11.6479	42.96716	T = 23.8947
gvtexprd	overall	40.14308	12.87812	7.7	82.5	N = 455
	between		10.74487	23.41923	65.59231	n = 19
	within		7.359157	5.550769	67.22879	T = 23.9474
priexprd	overall	0.94199	1.043697	0	4.7	N = 412
	between		0.961735	0.08	2.830769	n = 19
	within		0.577734	-0.74263	4.92699	T = 21.6842
totpatoff	overall	2551.815	4501.933	1	21034	N = 475
	between		4421.149	35.25	15610.58	n = 19
	within		1094.522	-1726.76	13095.78	T = 25

Source: Author´s own elaboration.

Table A2-Two-group comparison: incumbents vs entrants (2007-2017)

	Labor productivity per person employed			**Labor productivity per hour worked**		
Variable	**All**	**AB1 Incumbent**	**AB1 Entrant**	**All**	**AB1 Incumbent**	**AB1 Entrant**
	1	2	3	1	2	3
Constant	1.2976***	0.7894*	3.6624***	0.4748**	0.238	1.6994***
lnglobalci	0.0499	0.0347	0.1321	0.0546	0.113	0.1585
ln_lppe	0.8801***	0.9268***	0.6558***			
ln_lphw				0.8613***	0.8976***	0.4805***
Period dummies	yes	yes	yes	yes	yes	yes
N	209	154	55	209	154	55
beta_convergence	-0.1199	-0.0732	-0.3442	-0.1387	-0.1024	-0.5195

legend: * p<0.05; ** p<0.01; *** p<0.001

Table A3. Labor productivity and Debt for two sets of countries (1994-2015)

	Labor productivity per person employed			**Labor productivity per hour worked**		
Variable	**All**	**AB1_Incumbent**	**AB1_entrant**	**All**	**AB1_Incumbent**	**AB1_entrant**
	1	2	3	1	2	3
Constant	1.5634***	1.8157**	2.0890**	0.8064***	1.3715***	1.5007***
lnExtD2	-0.0205*	-0.0250*	-0.0153	-0.0202	-0.0325*	-0.0063
lnpubdebt	0.0023	0.0046**	-0.0048	0.0033	0.0045*	-0.007
ln_lppe	0.8669***	0.8519***	0.8205***			
ln_lphw				0.8019***	0.6878***	0.4975***
period dummies	yes	yes	yes	yes	yes	yes
N	219	143	76	219	143	76
beta_convergence	-0.1331	-0.1481	-0.1935	-0.1981	-0.3122	-0.5025
				legend: * p<0.05; ** p<0.01; *** p<0.001		

Table A4. Labor productivity and R&Dt for two sets of countries (1993-2018)

	Labor productivity per person employed			**Labor productivity per hour worked**		
Variable	**All**	**AB1_Incumbent**	**AB1_entrant**	**All**	**AB1_Incumbent**	**AB1_entrant**
	1	2	3	1	2	3
Constant	1.8211***	1.1953***	5.0492**	0.5686***	0.5639**	2.0854*
lnbusexprd	0.0089	0.0021	0.0688	0.0149	0.0019	0.1323
lnffaexprd	0.0047	0.0003	0.0277	0.0022	0.0008	0.0371
lngvtexprd	-0.0038	0.0026	-0.0015	-0.0018	-0.0026	0.0731
lnpriexprd	-0.0021	-0.0001	0.0015	-0.0018	0.0018	0.0065
lntotpatnaoff	0.0014	0.0006	0.0051	0.0003	-0.0018	0.0188
ln_lppe	0.8375***	0.8946***	0.4909**			
ln_lphw				0.8449***	0.8664***	-0.0254
period dummies	yes	yes	yes	yes	yes	yes
N	319	274	45	317	274	43
beta_convergence	-0.1625	-0.1054	-0.5091	-0.1551	-0.1336	-1.0254
				legend: * p<0.05; ** p<0.01; *** p<0.001		

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