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Does innovative capacity affect the deindustrialization process? A panel data analysis

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Abstract

The objective of the article is to analyze the relation between the innovative capacity and the deindustrialization process. We use data from 80 countries from 1995 to 2016. In addition, we use a new dependent variable to measure the deindustrialization process, related to the quality of exports and industrial competitiveness. The results suggest that there is a direct relationship between the innovative capacity and the share of industry in GDP, the relative share of industrial employment, and the quality of industrial exports. In the estimates considering the income level, we found that the impact of the innovative process on the dependent variables decreases as the income level rises. Although the effects of innovative capacity on industrial muscle remain positive. The results suggest that low innovative capacity may affect the deindustrialization process of a given country. The estimated result for the dependent variable related to the quality of exports presented the same behavior as the variables reported in the literature. As a public policy implication, the results suggest that policymakers should adopt incentive policies to build innovative capacity according to their income level, so that industrial development can provide special and favorable conditions for sustained growth.

Keywords: Deindustrialization, Innovative capacity, Industry, Development, Public policy

1 Introduction

The importance of the industrial sector for development is widely reported [e.g., Rostow (1958), Gerschenkron (1962), Schumpeter (1985), Prebisch (1949), and Kaldor (1966)]. According to Szirmai and Verspagen (2015), the main characteristics of the industrial sector that qualify it as the vector for sustained growth of the economy are: (i) empirical correlation between GDP per capita and the share of industry in GDP; (i) high productivity compared to the other sectors of the economy; (iii) existence of static and dynamic economies of scale [e.g., Kaldor (1966)]; (iv) existence of chaining effect of the industrial sector and spillover of technological content from the industrial sector to the other sectors of the economy [e.g., Perroux (1955), Hirschman (1958)]; (v) special opportunities for technological development, given that the locus of the innovative process is industry [e.g., Lazonick (2005)],; (vi) relevant impact of technological development in the industrial sector on extractive and capital-intensive services segments, such as mining, utilities, construction, transportation and urban mobility.

The key process for the dynamism of the industry is associated with the innovative process [e.g., Cohen and Levinthal (1990), Teece et al. (1997), and Bell and Pavitt (1995)]. The learning capacity of organizations is an important element of business survival conditions [e.g., Teece (2009)], to provide opportunities for differentiation from competitors, given the hostile environment of international competition. This process is related to routine and interactive economic activities between internal and external agents of the firm, highlighting the expensive, social and collective nature of learning, making endogenous the technological and organizational changes of firms in the development process [e.g., Nelson and Winter (1982), Edquist and Lundvall (1993), Malerba (2002), Edquist (2005), Lazonick (2005), Lundvall et al. (2009) and Fagerberg (2017)].

Industrial development assumes evolutionary and disruptive attributes for the alteration and conformation of new productive structures. In this sense, a weakened country's innovative process results in a low innovative capacity of organizations and countries. It may imply the reduction of the degree of industrial densification. Moreover, low innovative capacity, stemming from low learning capacity, resulting in adverse conditions for absorptive capacity, dynamic capacity, and adverse conditions for accumulation of technological competencies, may influence the industrial competitiveness in international trade, given that technological skills shape the competitive environment of industrial companies [e.g., Cantwell (2005), Fagerberg et al. (2007), Melo et al. (2015) and UNIDO (2019)]. Thus, the low innovative capacity may reduce the industry capacity, reducing the observed impact of the industry on society.

In the last decades, the debate on the deindustrialization process has grown. Some countries have shown a reduction in the participation of industry in GDP and loss of industrial competitiveness, which has motivated countries such as the United States and Germany to adopt policies of incentives and protection for industrial sectors in response to the industrial development of East Asia, especially China [see, e.g., Oliveira et al. (2021)].

The literature has developed based on the study of the deindustrialization process in advanced or developed countries. The work of Rowthorn and Ramaswamy (1999) analyses the process of deindustrialization for developed countries, treated in terms of the reduction of the relative share of industrial employment over time. Tregenna (2008) associates the process of deindustrialization to the joint occurrence in the reduction of the relative participation of industrial employment, as well as the participation of industry in GDP, over time. The deindustrialization process can occur naturally because of the development process. When countries reach economic maturity, associated with high per capita income levels, it reduces the participation of industrial jobs and products [e.g., Rowthorn and Ramaswamy (1999)]. However, deindustrialization can be premature or early when the relative participation of industry and industrial employment peaks at relatively low levels of per capita income [e.g., Felipe et al. (2019) and Rodrik (2015)], especially for countries in the middle-income trap [see, e.g., Atolia et al. (2018)].

The literature lists the effect of relative prices as a determinant for the deindustrialization process [e.g., Rowthorn and Ramaswamy (1999)] due to the change in productivity levels between the service and industrial sectors [e.g., Rowthorn and Coutts (2004) and Palma (2005)], causing the productivity to unbalance [e.g., Kollmeyer (2009)]. Another determinant reported concerns the effects of international trade on the productive structure and industrial jobs, translated in terms of the degree of openness of the economy, trade balance and North–South trade structure [e.g., Alderson (1999), Rowthorn and Ramaswamy (1999), Rowthorn and Coutts (2004), Kollmeyer (2009), Kang and Lee (2011) and Van Neuss (2018)]. In addition, Dutch disease is reported as a determinant of deindustrialization [e.g., Palma (2005), Bresser-Pereira (2008) and Bacha (2013)], exchange rate [e.g., Marconi and Rocha (2012) and Cruz (2014)], low investment rates of the economy [e.g., Rowthorn and Coutts (2004) and Kang and Lee (2011)], income distribution [e.g., Cruz (2014)], liberalizing policies, especially in Latin America [e.g., Daspugta and Singh (2006) and Bogliaccini (2013)], and foreign direct investment flows [e.g., Alderson (1999) and Kang and Lee (2011)].

Based on these, the main objective of the article is to test whether the innovative capacity represents a determinant of the deindustrialization process of countries. The specific objectives of the study are: (i) to verify if there is a difference in magnitude of the impact of the innovation process on production, industrial employment, and export quality in the industrial sector; and (ii) to verify if there are differences in the impact of the indicators related to the innovation process on the variables related to industrial densification by income level.

The novel in the present work is the analysis of the possible effects of innovative activity on the deindustrialization process. The article tests the hypothesis that the low innovative capacity of a country may affect the degree of productive densification of industry. It derives from low learning capacity, resulting in adverse conditions of absorptive capacity, dynamic capability, and adverse conditions for the accumulation of technological skills. In addition, the results presented to assist in the formulation of public policies more in line with the reality of the countries. In addition to this section, the present study will include a methodological section, followed by the analysis of the results found and the final considerations.

2 Methodology and data

The database contains data from 80 countries from 1995 to 2016 organized in an unbalanced panel. We present the list of countries in Table 11 in the Appendix. We collect the data from World Bank data, National Accounts–Analysis of Main Aggregates (UN–AMA), and Eurostat. We select the sample based on the data availability. The variables and data of this study are summarized in the list of Table 12 in the Appendix.

The econometric specification follows Rowthorn and Ramaswamy (1999). We use the logarithm of the industrial sector to GDP ratio (*LN OUTSHARE*) and the logarithm of the industrial employment to a total of employments ratio (*LN EMPSHARE)* to measure the deindustrialization process. Moreover, the present work proposes the use of a new variable to measure deindustrialization. We also use the high-tech exports to total exports ratio (*H_TECH_EXP)*. According to Hausmann et al. (2007), Archibugi et al. (2009) and UNIDO (2019), the type of products the country exports indicates a level of productive specialization and the competitiveness of the industrial sector in the international market. Edquist and Lundvall (1993) indicate that this measure can indicate the capacity of a country to diffuse new technology. Furthermore, one can relate *H_TECH_EXP* with the complexity grade of the productive structure [e.g., Hausmann et al. (2014), Hartmann et al. (2017) and Ferraz et al. (2018)].

To measure the innovation process, the variables selected are grouped into three groups: (i) innovative effort; (ii) scientific and technological base; (iii) educational system. We choose the variables according to the literature about innovation [e.g., Nelson (1993), Freeman (1995), Grupp and Mogee (2004), Fagerberg and Srholec (2008), Archibugi et al. (2009), Cirillo et al. (2019), Fagerberg and Srholec (2009) and Ribeiro (2019)].

In the group of variables related to the innovative effort, we use the total expend in research and development to GDP ratio (*R&D*) to measure the level of effort a country realizes in search of new forms of production and technology. We also use the number of researchers and technicians involved in activates of R&D, in millions per capita (*RESEARCHERS* and *TECHNICIANS*).

Concerning the scientific and technological base, the number of scientific articles published in technical and scientific journals covered by SCI and SSCI (*ARTICLE*) and the requirement of patents by residents and non-residents (*PATENTS*) is relevant indicators to measure the production of knowledge of a given country. Moreover, the number of requirements of trademarks by resident and non-resident (*TRADEMARK*) relates with the competencies not computed as R&D activities or patents.

We measure the scientific structure related to the educational system using three variables. Students in science, engineering, and industrial production, expressed as a percentage of the population of higher education age (*INCENG*); PhD students, expressed as a percentage of the population of higher education age (*INDOUT*); and number of gross enrollments in Higher Education, as a proportion of the population of higher education age (*INES*). We use these variables to measure the scientific and technological policy of a given country. They are associated with the construction of an absorptive capacity and quality of the innovative national system [see, e.g., Fagerberg and Srholec (2009)].

Besides the variables related to the innovative system, we also include control variables in the estimates. The logarithm of the GDP per capita in power purchase parity (*LN Y*) relates with incentives of an increase in the country's yield over the industry. Moreover, we also include the square of the *LN Y* to verify if the level of yield matters in this relation.

The manufacturing relative prices indicator about the general price level (*LN RELPRICE)* follows Rowthorn and Ramaswamy (1999). The indicator is calculated using the ratio between the manufacturing deflator and the GDP implicitly deflator. We use this variable only in the estimates to the *LN OUTSHARE*.

We also include as control variables the Gross Fixed Capital Formation to GDP ratio (*FIXCAP*) and the overall trade balance in manufactured goods to GDP ratio (*TRADEBAL*) to show the effect of the investment and the balance of trade over the industrial density (Rowthorn and Ramaswamy (1999). Furthermore, we use the real interest rate (RIR) and the real exchange rate (RER) as control variables following Marconi and Rocha (2012) and Sonaglio et al. (2010). It is important to highlight that we do not use the imports of manufactured goods from developing countries to GDP ratio because use available data from all countries and not only for European countries.

We present the data described in Table 12 in the Appendix. Tables 13 and 14 in the Appendix present the descriptive analysis. We present the correlation between the dependent variables and the other variables in the model in Table 15 in the Appendix.

2.1 Econometric specification

To measure the effect of the innovative effort over the deindustrialization process, we estimate the following specifications:

$$LNOUTSHARE_{it} = \theta LNOUTSHARE_{i(t-1)} + \gamma INNOV_{it} + \delta Z_{it} + \alpha_i + \varepsilon_{it} \quad (1)$$

$$LNEMPSHARE_{it} = \theta LNEMPSHARE_{i(t-1)} + \gamma INNOV_{it} + \delta Z_{it} + \alpha_i + \varepsilon_{it} \quad (2)$$

$$H\_TECH\_EXP_{it} = \theta H\_TECH\_EXP_{i(t-1)} + \gamma INNOV_{it} + \delta Z_{it} + \alpha_i + \varepsilon_{it}, \quad (3)$$

where i indicates the country, t indicates the period, α_i is the unobserved effect of the country i, ε_{it} is the error term and $LNOUTSHARE_{i(t-1)}$, $LNEMPSHARE_{i(t-1)}$, and $H\_TECH\_EXP_{i(t-1)}$ indicate the dynamic term of the regression. The Z_{it} matrix contains the control variables and the $INNOV_{it}$ matrix contains the innovative process variables.

The dynamic variables represent the path dependence of the dependent variables. According to De Carvalho and Ruiz (2018), variables related to the share of industrial products and industrial employment present a path dependence. Hence, we follow the authors and use a dynamic panel to estimate the econometric specification.

Besides the models (1), (2), and (3), we include dummies related to the countries' income levels. We classify the countries following the World Bank criteria. The countries are classified as low-income countries, middle-income countries (which groups upper-middle-income countries and lower-middle-income countries), and high-income countries. Hence, we have the following econometric specifications:

$$LNOUTSHARE_{it} = \theta LNOUTSHARE_{i(t-1)} + \gamma (INNOV * INCOME)_{it} + \delta Z_{it} + \alpha_i + \varepsilon_{it} \quad (4)$$

$$LNEMPSHARE_{it} = \theta LNEMPSHARE_{i(t-1)} + \gamma (INNOV * INCOME)_{it} + \delta Z_{it} + \alpha_i + \varepsilon_{it} \quad (5)$$

$$H\_TECH\_EXP_{it} = \theta H\_TECH\_EXP_{i(t-1)} + \gamma (INNOV * INCOME)_{it} + \delta Z_{it} + \alpha_i + \varepsilon_{it}, \quad (6)$$

where *INCOME* is the matrix of dummies related to the three income classifications.

To estimate the models, we use the System Generalized Method of Moments (S-GMM). To estimate dynamic panels, the Ordinary Least Squares estimates present bias and problems of endogeneity, considering that the studies used for the selection of variables related to innovative capacity show their relationship with GDP per capita, which is used as a control variable in the model to be estimated. According to Ullah et al. (2018), the endogeneity problem may lead to inconsistent and inefficient estimates. In this way, we make use of instrumental variables estimators.

Arellano and Bond (1991) indicate that the first difference GMM (D-GMM) can withdraw the non-observable effects constant in time. However, Arellano and Bover (1995) and Blundell and Bond (1998) show that the D-GMM are weak in the presence of dependent and explanatory variables with strong resilience and, its sense, purpose the use of a combination of the model in level and first difference, using a system of equation, which is the System Generalized Method of Moments (S-GMM). We consider the possibility of a simultaneity problem in the analysis because the innovative effort may be influenced by the industrialization level, which suggests an endogeneity problem in the regressions. The use of instrumental variables allows the estimation of parameters more consistently, even in the case of endogeneity in explanatory variables (Bond et al. 2001).

In S-GMM, the estimators deal with unobservable temporal effects by including period-specific interceptors containing endogenous regressors, controlled by the use of instruments of the lagged variables at the level and in differences of the predetermined endogenous variables.

For Roodman (2009), although estimates by D-GMM and S-GMM are adherent for samples with short periods and high number of individuals, the diversity of instruments may generate the overlap of instruments on the variables used, generating bias in the results. Thus, in the empirical analysis, the ratio number of instruments/number of cross-sections less than 1 is observed for each regression, so that the use of instruments in an excessive way does not occur (Roodman 2009).

The Sargan–Hansen test will be performed to verify the hypothesis of overidentification (prob J-statistic). In this case, the validity condition of the instruments is met when the *p*-value of the prob J-statistic is higher than 0.1. In addition, the serial autocorrelation test of errors in first-order (AR1) and second-order (AR2) differences is performed, as proposed by Arellano and Bond (1991) to check the consistency of the estimation, where the value for AR1 must be negative and significant and AR2 must be only non-significant.

3 Results

3.1 Empirical analysis

Regarding the estimates, Tables 1, 2, 3 present the results. The Sargan–Hansen test indicates that the instruments used in the model are valid and the serial autocorrelation test presents the expected behavior according to Tables 1, 2, 3. The list of instruments used to estimate the models in Tables 1, 2 and 3 is presented in Table 16 in the Appendix.

Regarding the proposed estimates in terms of LN OUTSHARE and LN EMPSHARE, the control variables presented the results expected by the literature. The models estimated with the dependent variable H_TECH_EXP, according to Table 3, the control variables presented similar results of LN OUTSHARE and LN EMPSHARE. The variables used to size the effect of the innovative activity on industrial production, industrial employment, and on the export of high-tech products present statistical significance, with a positive impact regarding the dependent variables listed, which indicates that factors related to the innovation process of the countries can be considered as one of the causes of the deindustrialization process.

It should also be noted that the dynamic coefficient of the estimated models considering the three dependent variables used in this study is statistically significant and presents a relevant impact on the estimated dependent variable, which validates the hypothesis of cumulatively of the industrial sector.

Table 1 S-GMM estimation—dependent variable: LN OUTSHARE

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
LN OUTSHARE(-1)	0.855405***	0.624268***	0.770473***	0.626377***	0.469256***	0.565939***	0.701665***	0.604291***	0.585251***	0.610188***
	(0.008559)	(0.017541)	(0.026241)	(0.038554)	(0.078385)	(0.025998)	(0.019422)	(0.039854)	(0.044090)	(0.012790)
LN Y	0.290860***	1.150675***	1.450406**	0.681888**	3.126427*	0.728305***	0.297857*	1.787952***	0.974405***	0.752495***
	(0.042533)	(0.238470)	(0.670192)	(0.325015)	− 1,619,443	(0.138941)	(0.164530)	(0.582881)	(0.326356)	(0.189320)
$(LN\ Y)^2$	− 0.019428***	− 0.069696***	− 0.092534**	− 0.045808***	− 0.175123*	− 0.051235***	− 0.024000***	− 0.096139***	− 0.063117***	− 0.044139***
	(0.002538)	(0.013202)	(0.035809)	(0.016596)	(0.089952)	(0.007930)	(0.009081)	(0.031806)	(0.018059)	(0.010725)
LN RELPRICE	0.151979***	0.141222***	0.077309	0.191591***	1.031461***	0.112148***	0.117706***	0.292029***	0.211497***	0.507475***
	(0.011588)	(0.015451)	(0.054712)	(0.067241)	(0.287530)	(0.022550)	(0.036492)	(0.111148)	(0.065909)	(0.016915)
FIXCAP	0.001440***	0.003483***	0.005214***	0.006046***	0.009748**	0.004217**	0.001884***	0.007024***	0.004898***	0.005720***
	(0.000399)	(0.001025)	(0.001870)	(0.001984)	(0.004776)	(0.001750)	(0.000608)	(0.002314)	(0.001796)	(0.000940)
TRADEBAL	0.002210***	0.001184*	0.003955***	0.010270***	0.006753**	0.004840***	0.001537***	0.007305***	0.005780***	0.003643***
	(0.000320)	(0.000620)	(0.000951)	(0.001580)	(0.003324)	(0.000961)	(0.000526)	(0.001484)	(0.000960)	(0.000412)
RIR	− 0.001655***	− 0.004519***	− 0.010197***	− 0.003794***	− 0.011288***	− 0.004269***	− 0.001881***	− 0.002621***	− 0.007023***	− 0.002751***
	(0.000244)	(0.000666)	(0.001234)	(0.001142)	(0.002708)	(0.000551)	(0.000352)	(0.000859)	(0.000976)	(0.000185)
RER	0.000756***	0.000701***	0.002102***	0.001135**	0.001493**	0.001016***	0.000615***	0.001434***	0.001148**	0.000465**
	(0.000101)	(0.000130)	(0.000369)	(0.000528)	(0.000646)	(0.000194)	(0.000158)	(0.000318)	(0.000558)	(0.000182)
INNOVATION		0.055828***	2.92E−05***	9.61E−05***	7.51E−07**	9.16E−08***	2.87E−08***	0.008698***	0.024898***	0.001277***
		(0.007367)	(1.11E−05)	(2.28E−05)	(3.38E−07)	(1.08E−08)	(7.67E−09)	(0.001639)	(0.008555)	(0.000230)
Obs	990	495	452	294	575	696	732	397	459	644
Countries	78	53	47	42	67	63	66	52	50	67

Table 1 (contined)

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
Number instruments/number cross-section ratio	0.859	0.849	0.83	0.881	0.448	0.778	0.742	0.827	0.84	0.851
Prob J	0.264783	0.166808	0.408991	0.226811	0.641532	0.296433	0.185479	0.354973	0.321484	0.387103
AR(1)	−0.508060	−0.457165	−0.455419	−0.481332	−0.357658	−0.446859	−0.445705	−0.439178	−0.459184	−0.423271
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2)	0.056039	−0.038469	−0.013386	0.009455	0.025117	0.012329	0.027153	0.027043	−0.031441	−0.015865
P-value	0.1315	0.3561	0.7944	0.9029	0.6008	0.7538	0.4486	0.6068	0.5550	0.7023

i) Information in brackets is the standard error associated with the coefficient

(ii) Level of statistical significance: (***) denotes 1%, (**) denotes 5% and (*) denotes 10%

(iii) S-GMM: based on Arellano and Bover (1995), two stages and no time dummy. AR (1) and AR (2) tests to verify the presence of first-order and second-order serial correlation in the waste in difference

iv) The number of instruments to the number of cross-section ratio needs to be higher than 1. Although the S-GMM estimates are adherent for samples with short periods and a high number of individuals, the diversity of instruments may generate the overlapping of instruments on the variables used, generating bias in the result (Roodman 2009)

Table 2 S-GMM estimation—dependent variable: LN EMPSHARE

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
LN EMPSHARE(-1)	0.869828***	0.753016***	0.852285***	0.688778***	0.854859***	0.785399***	0.808471***	0.749371***	0.836689***	0.761309***
	(0.013829)	(0.017692)	(0.052975)	(0.020220)	(0.030045)	(0.029720)	(0.025146)	(0.012561)	(0.026999)	(0.014860)
LN Y	0.117183**	0.424773***	0.643524***	0.882435***	0.525804**	0.297549***	0.104825*	0.321009***	0.254681**	0.357068***
	(0.055889)	(0.119993)	(0.233292)	(0.187160)	(0.255377)	(0.109358)	(0.054473)	(0.090549)	(0.121120)	(0.109936)
$(\text{LN Y})^2$	−0.008562***	−0.026684***	−0.039090***	−0.053816***	−0.031506**	−0.020719***	−0.009937***	−0.021876***	−0.017556***	−0.023867***
	(0.003056)	(0.006423)	(0.012662)	(0.009733)	(0.014096)	(0.005743)	(0.003217)	(0.004801)	(0.006654)	(0.005900)
FIXCAP	0.001076***	0.008070***	0.008560***	0.004329***	0.002517***	0.003945***	0.003080***	0.005462***	0.004552***	0.004869***
	(0.000399)	(0.000410)	(0.000945)	(0.000602)	(0.000963)	(0.000622)	(0.000703)	(0.000804)	(0.000652)	(0.000416)
TRADEBAL	0.000334**	0.001860***	0.002393***	0.000813**	0.002678***	0.000826***	0.001388***	0.001156**	0.000599*	0.001752***
	(0.000151)	(0.000226)	(0.000398)	(0.000411)	(0.001026)	(0.000318)	(0.000503)	(0.000493)	(0.000313)	(0.000215)
RIR	−0.001737***	−0.000308*	−0.003644***	−0.002852***	−0.002534***	−0.002195***	−0.001252***	−0.000516***	−0.001165***	−0.000392***
	(0.000148)	(0.000165)	(0.000756)	(0.000366)	(0.000517)	(0.000463)	(0.000166)	(0.000142)	(0.000387)	(0.000107)
RER	0.000300***	0.000169**	0.000289**	0.000668***	0.000438**	0.000369***	0.000322***	0.000392***	0.000243***	0.000590***
	(5.84E−05)	(7.99E−05)	(0.000130)	(0.000150)	(0.000209)	(8.89E-05)	(8.19E−05)	(5.83E−05)	(9.27E−05)	(5.60E−05)
INNOVATION		0.008713***	6.93E−06***	4.68E−05***	1.39E−07*	7.82E−08***	5.82E−08***	0.000591*	0.019317***	0.000145*
		(0.003082)	(1.62E−06)	(9.93E−06)	(7.16E−08)	(1.43E−08)	(4.71E−09)	(0.000341)	(0.004156)	(8.41E−05)
Obs	1016	522	393	313	574	739	764	365	561	552
Countries	78	52	44	41	65	63	66	53	58	63

Table 2 (contined)

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
Number instruments/ Number cross section ratio	0.782	0.942	0.977	0.951	0.554	.	0.788	0.849	0.776	0.952
Prob J	0.160384	0.243426	0.464088	0.395213	0.775799	0.295057	0.250042	0.384297	0.131712	0.557639
AR(1)	−0.420420	−0.385865	−0.408203	−0.342694	−0.382980	−0.436203	−0.431961	−0.472342	−0.419081	−0.387167
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2)	−0.052266	−0.087823	−0.070758	0.011518	−0.050546	−0.040913	−0.063828	−0.063828	−0.006831	−0.057561
P-value	0.1607	0.1020	0.2742	0.8676	0.3325	0.3331	0.1354	0.5872	0.8925	0.2476

i) Information in brackets is the standard error associated with the coefficient

(ii) Level of statistical significance: (***) denotes 1%, (**) denotes 5% and (*) denotes 10%

(iii) S-GMM: based on Arellano and Bover (1995), two stages and no time dummy. AR (1) and AR (2) tests to verify the presence of first-order and second-order serial correlation in the waste in difference

iv) The number of instruments to the number of cross-section ratio needs to be higher than 1. Although the S-GMM estimates are adherent for samples with short periods and a high number of individuals, the diversity of instruments may generate the overlapping of instruments on the variables used, generating bias in the result (Roodman 2009)

Table 3 S-GMM estimation—dependent variable: H_TECH_EXP

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
H_TECH_EXPORT(-1)	0.236789***	0.637376***	0.866711***	0.815331***	0.534881***	0.681528***	0.501507***	0.652418***	0.686687***	0.728189***
	(0.005227)	(0.036398)	(0.013993)	(0.008791)	(0.005597)	(0.016524)	(0.025004)	(0.008388)	(0.011115)	(0.005813)
LN Y	57.62584***	123.0758***	73.28574***	71.18630***	141.4240***	71.47007***	42.04625***	32.56416***	63.07160***	59.06819***
	(7.304258)	(36.28240)	(13.99600)	(13.22959)	(7.172046)	(6.352812)	(10.55410)	(10.98463)	(5.737070)	(4.350452)
$(LN\ Y)^2$	− 4.591437***	− 7.068219***	− 3.969270***	− 4.093837***	− 8.058674***	− 4.585833***	− 3.296316***	− 1.953200***	− 3.959310***	− 3.682506***
	(0.396822)	(1.914156)	(0.713901)	(0.678123)	(0.392043)	(0.352939)	(0.538337)	(0.546943)	(0.299825)	(0.248012)
FIXCAP	1.304169***	0.401613***	0.113691*	0.124897*	0.307468***	0.203506***	0.958559***	0.706857***	0.261594***	0.284430***
	(0.036813)	(0.151802)	(0.059633)	(0.072001)	(0.016720)	(0.065059)	(0.056140)	(0.059532)	(0.025747)	(0.033372)
TRADEBAL	0.283799***	0.162523*	− 0.056649	− 0.043252	0.106606***	0.093091**	0.731358***	0.095067**	0.068627**	0.061456***
	(0.041314)	(0.096389)	(0.051108)	(0.046071)	(0.021848)	(0.045886)	(0.053885)	(0.040727)	(0.028192)	(0.023221)
RIR	− 0.068959***	− 0.031818	− 0.044415**	− 0.230746***	− 0.062411***	− 0.209459***	− 0.089647**	− 0.127239**	− 0.047110**	− 0.021734**
	(0.020840)	(0.068555)	(0.020431)	(0.050033)	(0.014828)	(0.027904)	(0.037412)	(0.049800)	(0.018295)	(0.009533)
RER	0.232459***	0.107816***	0.010930**	0.057487***	0.056323***	0.079752***	0.157960***	0.059802***	0.092677***	0.065064***
	(0.009322)	(0.031299)	(0.005392)	(0.007718)	(0.007124)	(0.021110)	(0.016781)	(0.009649)	(0.004882)	(0.002787)
INNOVATION		4.590632**	0.000531***	0.001694**	2.81E−05***	3.53E−05**	3.07E−06***	0.505997***	0.778590***	0.085216***
		(2.116659)	(0.000122)	(0.000753)	(7.28E−06)	(1.49E−05)	(7.12E−07)	(0.036089)	(0.151254)	(0.006325)
Obs	822	267	298	249	412	679	687	390	489	584
Countries	73	44	40	38	61	65	63	49	55	66

Table 3 (contined)

Regressors	Model 1 **BASELINE**	Model 2 **R&D**	Model 3 **RESEARCHERS**	Model 4 **TECHNICIANS**	Model 5 **ARTICLE**	Model 6 **PATENTS**	Model 7 **TRADEMARK**	Model 8 **INCENG**	Model 9 **INDOUT**	Model 10 **INES**
Number instruments/ number cross-section ratio	0.781	0.659	0.875	0.842	0.754	0.631	0.73	0.857	0.818	0.894
Prob J	0.438822	0.356827	0.398423	0.346422	0.438620	0.278122	0.331336	0.423937	0.301871	0.453112
AR(1)	−0.378769	−0.326715	−0.610460	−0.483374	−0.294903	−0.401180	−0.455426	−0.490436	−0.438758	−0.388040
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2)	−0.039303	−0.009095	−0.066793	−0.073292	−0.082484	−0.075214	−0.004522	0.111041	0.055437	0.056261
P-value	0.2283	0.8834	0.2991	0.3178	0.1055	0.1071	0.8892	0.1057	0.2982	0.1931

Information in brackets is the standard error associated with the coefficient

Level of statistical significance: (***) denotes 1%, (**) denotes 5% and (*) denotes 10%

S-GMM: based on Arellano and Bover (1995), two stages and no time dummy. AR (1) and AR (2) tests to verify the presence of first-order and second-order serial correlation in the waste in difference

The number of instruments to the number of cross-section ratio needs to be higher than 1. Although the S-GMM estimates are adherent for samples with short periods and a high number of individuals, the diversity of instruments may generate the overlapping of instruments on the variables used, generating bias in the result (Roodman 2009)

The empirical results of the effects of the countries' innovative activity on the industrial structure by type of income are shown in Tables 4, 5, 6. The list of instruments used to estimate the models in Tables 4, 5 and 6 is presented in Table 16 in the Appendix. LN OUTSHARE, the coefficients of the variables related to the innovative effort are decreasing on average as a given country raises its income level. For RESEARCHERS and TECHNICIANS, the variables for high income are slightly higher than for average income, however, these variables are lower than those for low income. As for the variables used to describe the scientific and technological basis of the countries, a movement similar to that described for RESEARCHERS and TECHNICIANS is observed. As for the variables used to measure the scientific structure related to the educational system, a heterogeneous behavior in terms of LN OUTSHARE is observed. For the INCENG and INDOUT variables, we observe an increasing evolution of the coefficients as income levels advance. For the INES variable, the verified behavior is the decreasing evolution per income level. one hypothesis for this behavior is that as the income level of the economies grows over time, the benefit of higher education continues to be positive, but with decreasing effects.

In terms of LN EMPSHARE, we observe a behavior analogous to the LN OUTSHARE, considering the variables related to the innovative effort and related to the scientific and technological base. In the variables related to the educational system, the variables present decreasing coefficients to the advance in the income level.

The results of innovative effort variables on H_TECH_EXP by income classification are similar to the LN OUTSHARE and LN EMPSHARE results, but with some exceptions. RESEARCHERS and TECHNICIANS show the same R&D behavior, with the coefficient decreasing as income increases, however, without statistical significance for low-income countries. For the variables related to the scientific and technological basis, we observe a convergent movement for ARTICLE and TRADEMARK, presenting a decreasing behavior by income level, with coefficients for low and middle-income countries without statistical significance. A negative coefficient for PATENTS was verified for high-income countries with statistical significance. This result must be verified with caution because, of all the estimations made, it was the only result found with a sign different from the others. As for the variables used to measure the scientific structure related to the educational system, a similar behavior was observed for INDOUT and INES, in decreasing terms on H_TECH_EXP. For the INCENG variable, the average income coefficient is lower than for low income, but the coefficient for high income is higher than the average income but lower than the low-income coefficient.

With the estimates to the income classification in terms of LN OUTSHARE, LN EMPSHARE, and H_TECH_EXP, the control variables present the expected results by the literature. It is important to observe that the dynamic coefficient is statistically significant and presents a relevant impact on the dependent variable, reinforcing the results presented in Tables 3, 4, and 5.

3.2 Discussion of economic impacts

In this section, we discuss the economic impacts of the countries' innovative structures on their respective industrial densification indicators. The methodology for measuring

Table 4 System-GMM estimation, with income level dummy—dependent variable: LN OUTSHARE

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
LN_OUTSHARE(-1)	0.855405***	0.566266***	0.634217***	0.467733***	0.471676***	0.649066***	0.696242***	0.590670***	0.594404***	0.682809***
	(0.008559)	(0.034082)	(0.022840)	(0.070501)	(0.034056)	(0.014487)	(0.008262)	(0.047051)	0.037235	(0.020353)
LN Y	0.290860***	1.740323***	1.954791***	2.670687***	1.676604***	1.240666***	0.201220**	2.114770***	1.422408**	0.783845***
	(0.042533)	(0.382062)	(0.418238)	(0.744080)	(0.519989)	(0.206066)	(0.078359)	(0.422189)	0.644003	(0.282609)
$(LN\_Y)^2$	− 0.019428***	− 0.104182***	− 0.109272***	− 0.148958***	− 0.096779***	− 0.071371***	− 0.014149***	− 0.116315***	− 0.089770***	− 0.047731***
	(0.002538)	(0.020447)	(0.022740)	(0.039650)	(0.028890)	(0.0105920	(0.004430)	(0.022812)	0.034681	(0.015420)
LN RELPRICE	0.151979***	0.136632**	0.373361***	0.428845***	0.788973***	0.269373***	0.397079***	0.312171**	0.349521***	0.348164***
	(0.011588)	(0.066273)	(0.042380)	(0.141016)	(0.059785)	(0.034264)	(0.011528)	(0.121480)	0.053110	(0.023467)
FIXCAP	0.001440***	0.005626***	0.006935***	0.008805**	0.005227***	0.001362*	0.001443***	0.007417***	0.006139***	0.007082***
	(0.000399)	(0.002013)	(0.001532)	(0.004064)	(0.001208)	(0.000825)	(0.000429)	(0.002284)	0.001555	(0.000881)
TRADEBAL	0.002210***	0.005980***	0.006714***	0.006725**	0.002823***	0.004032***	0.001600***	0.007259***	0.003407**	0.006424***
	(0.000320)	(0.001010)	(0.001249)	(0.002600)	(0.000627)	(0.000611)	(0.000162)	(0.001144)	0.001465	(0.000366)
RIR	− 0.001655***	− 0.004311***	− 0.001809**	− 0.008437***	− 0.006358***	− 0.003740***	− 0.003774***	− 0.002895**	− 0.004264***	− 0.001664***
	(0.000244)	(0.001185)	(0.000724)	(0.002305)	(0.000817)	(0.000430)	(0.000187)	(0.001156)	0.001152	(0.000446)
RER	0.000756***	0.000901**	0.000640*	0.001878***	0.001073***	0.000247**	0.000447***	0.001424***	0.000805***	0.000639**
	(0.000101)	(0.000449)	(0.000330)	(0.000598)	(0.000288)	(0.000125)	(6.99E−05)	(0.000402)	0.000205	(0.000252)
INNOV*L_INCOME		0.100067**	0.003598*	0.012357***	0.000135***	2.27E−05**	4.30E−06**	0.006854***	0.053362*	0.002109**
		(0.050083)	(0.002022)	(0.003719)	(4.35E−05)	(1.14E−05)	(2.03E−06)	(0.002312)	0.029373	(0.001023)
INNOV*M_INCOME		0.077496**	2.43E−05*	0.000136*	5.23E−07***	4.58E−08*	1.01E−07***	0.007898***	0.059341***	0.001926***
		(0.038417)	(1.26E−05)	(7.89E−05)	(1.04E−07)	(2.67E−08)	(7.74E−09)	(0.001687)	0.009435	(0.000339)
INNOV*H_INCOME		0.047605**	3.42E−05***	0.000172***	1.33E−06**	3.74E−07*	1.66E−07	0.010468***	0.090811***	0.001436***
		(0.021706)	(1.23E−05)	(5.44E−05)	(5.31E−07)	(2.04E−07)	(2.28E−07)	(0.001639)	0.011944	(0.000347)
Obs	990	462	432	319	468	587	794	403	508	643
Countries	78	52	54	42	64	59	69	52	57	67

Table 4 (continued)

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
Number instruments/number cross-section ratio	0.859	0.904	0.796	0.81	0.75	0.915	0.913	0.788	0.789	0.881
Prob J	0.264783	0.541220	0.248996	0.414820	0.198516	0.241809	0.384835	0.321058	0.254330	0.352379
AR(1)	−0.508060	−0.453834	−0.448195	−0.362385	−0.347655	−0.361133	−0.438543	−0.434008	−0.395548	−0.460671
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2)	0.056039	−0.069650	−0.040366	−0.085600	−0.005624	0.027233	0.013379	0.033342	−0.001910	0.014842
P-value	0.1315	0.2116	0.4956	0.2545	0.9120	0.5406	0.7059	0.5205	0.9713	0.7211

Information in brackets is the standard error associated with the coefficient

Level of statistical significance: (***) denotes 1%, (**) denotes 5% and (*) denotes 10%

S-GMM: based on Arellano and Bover (1995), two stages and no time dummy. AR (1) and AR (2) tests to verify the presence of first-order and second-order serial correlation in the waste in difference

The number of instruments to the number of cross-section ratio needs to be higher than 1. Although the S-GMM estimates are adherent for samples with short periods and a high number of individuals, the diversity of instruments may generate the overlapping of instruments on the variables used, generating bias in the result (Roodman 2009)

Table 5 System-GMM estimation, with income level dummy—dependent variable: LN EMPSHARE

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
LN EMPSHARE(-1)	0.869828***	0.678002***	0.856861***	0.721469***	0.778751***	0.810980***	0.844851***	0.804786***	0.705562***	0.633975***
	(0.013829)	(0.015378)	(0.033870)	(0.024906)	(0.016856)	(0.018288)	(0.030733)	(0.023125)	(0.039546)	(0.029644)
LN Y	0.117183**	1.168891***	0.518018*	1.427659***	0.473954***	0.376770***	0.169181***	0.689775***	0.601621***	1.049838***
	(0.055889)	(0.090563)	(0.269793)	(0.213328)	(0.083156)	(0.082948)	(0.064403)	(0.248777)	(0.150898)	(0.125336)
$(LN\ Y)^2$	−0.008562***	−0.066846***	−0.031274**	−0.078420***	−0.032316***	−0.024336***	−0.012537***	−0.039248***	−0.036843***	−0.063656***
	(0.003056)	(0.004929)	(0.014318)	(0.010656)	(0.004670)	(0.004394)	(0.003860)	(0.013111)	(0.008459)	(0.007124)
FIXCAP	0.001076***	0.007374***	0.005642***	0.005530***	0.001823***	0.004149***	0.001997**	0.007396***	0.006614***	0.004777***
	(0.000399)	(0.000855)	(0.000966)	(0.000740)	(0.0003390	(0.000296)	(0.000780)	(0.001123)	(0.000963)	(0.000969)
TRADEBAL	0.000334**	0.001822***	0.000585	0.001049***	0.001158***	0.000516**	0.000955*	0.002814***	0.001093**	0.001821***
	(0.000151)	(0.000490)	(0.000601)	(0.000297)	(0.000209)	(0.000239)	(0.000571)	(0.000717)	(0.000513)	(0.000651)
RIR	−0.001737***	−0.000529**	−0.003029***	−0.002873***	−0.001207***	−0.001734***	−0.001101***	−0.001625***	−0.000666*	−0.000431*
	(0.000148)	(0.000251)	(0.000606)	(0.000433)	(0.000155)	(0.000219)	(0.000194)	(0.000460)	(0.000363)	(0.000246)
RER	0.000300***	0.000219*	0.000424***	0.000588***	0.000861***	0.000344***	0.000248**	0.000451***	0.000299***	0.000752***
	(5.84E−05)	(0.000116)	(0.000100)	(0.000155)	(0.000127)	(5.35E−05)	(0.000110)	(8.51E−05)	(0.000110)	(0.000145)
INNOV*L_INCOME		0.055675**	9.18E−05**	0.025603**	9.29E−05**	9.22E−06**	4.51E−06*	0.008376***	0.020213**	0.001700***
		(0.021625)	(3.71E−05)	(0.011596)	(4.08E−05)	(4.45E−06)	(2.32E−06)	(0.001503)	(0.008988)	(0.000620)
INNOV*M_INCOME		0.015431**	2.36E−05***	0.000147***	6.35E−07***	1.80E−07**	4.65E−08***	0.004364***	0.010358**	0.001006**
		(0.006760)	(3.60E−06)	(4.02E−05)	(1.99E−07)	(8.43E−08)	(6.67E−09)	(0.000934)	(0.004720)	(0.000395)
INNOV*H_INCOME		0.012501***	7.48E−06***	3.64E−05***	1.12E−06***	4.01E−07***	3.11E−07*	0.002853***	0.011201*	0.000620**
		(0.004466)	(1.65E−06)	(1.19E−05)	(4.19E−07)	(1.51E−07)	(1.65E−07)	(0.000885)	(0.006021)	(0.000291)
Obs	1016	482	393	313	701	836	710	366	549	583
Countries	78	53	44	41	72	68	64	53	58	65

Table 5 (continued)

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
Number instruments/ number cross-section ratio	0.782	0.962	0.977	0.951	0.847	0.868	0.797	0.811	0.793	0.738
Prob J	0.160384	0.375879	0.332168	0.258393	0.384292	0.314723	0.301224	0.308133	0.174854	0.336980
AR(1)	−0.420420	−0.374270	−0.402709	−0.398945	−0.354249	−0.457684	−0.439731	−0.468025	−0.389239	−0.352414
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2)	−0.052266	−0.088957	−0.103738	−0.054130	−0.069411	−0.042501	−0.050278	0.019809	−0.043591	−0.044065
P-value	0.1607	0.1135	0.1146	0.4427	0.1386	0.1915	0.2290	0.7711	0.4141	0.3586

Information in brackets is the standard error associated with the coefficient

Level of statistical significance: (***) denotes 1%, (**) denotes 5% and (*) denotes 10%

S-GMM: based on Arellano and Bover (1995), two stages and no time dummy. AR (1) and AR (2) tests to verify the presence of first-order and second-order serial correlation in the waste in difference

The number of instruments to the number of cross-section ratio needs to be higher than 1. Although the S-GMM estimates are adherent for samples with short periods and a high number of individuals, the diversity of instruments may generate the overlapping of instruments on the variables used, generating bias in the result (Roodman 2009)

Table 6 System-GMM estimation, with income level dummy—dependent variable: H_TECH_EXP

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
H_TECH_EXPORT(-1)	0.236789***	0.741529***	0.854569***	0.703670***	0.780160***	0.587154***	0.765262***	0.809830***	0.671679***	0.720504***
	(0.005227)	(0.019844)	(0.058652)	(0.011090)	(0.028682)	(0.010479)	(0.035567)	(0.069993)	(0.020100)	(0.005511)
LN Y	57.62584***	48.04960**	223.0494**	53.12590***	81.63015***	49.74834***	28.45970*	90.20161**	132.3779***	90.58492***
	(7.304258)	(19.92995)	(90.79123)	(18.93544)	(14.67859)	(5.874587)	(15.94707)	(43.72893)	(11.15474)	(4.651450)
$(LN\ Y)^2$	−4.591437***	−2.893456***	−11.70970**	−3.777497***	−4.509308***	−3.326673***	−1.898104**	−4.767502**	−7.825082***	−5.389862***
	(0.396822)	(1.057637)	(4.576053)	(0.944178)	(0.832030)	(0.319518)	(0.827464)	−2,273,958	(0.556027)	(0.272625)
FIXCAP	1.304169***	0.231345***	0.816835***	− −0.009115	0.421406***	0.247221***	0.203645**	0.339544*	0.320666***	0.312091***
	(0.036813)	(0.079434)	(0.217823)	(0.093477)	(0.084836)	(0.042997)	(0.085012)	(0.202160)	(0.032643)	(0.028752)
TRADEBAL	0.283799***	0.089768**	0.464309**	0.134262**	0.145593***	0.132924***	0.132186*	0.102118	0.082905**	0.145065***
	(0.041314)	(0.043828)	(0.214121)	(0.057602)	(0.043122)	(0.040632)	(0.068508)	(0.114978)	(0.039377)	(0.018102)
RIR	-0.068959***	−0.252808***	0.084250	−0.337585***	−0.031565	− −0.280788***	−0.085206**	−0.381140**	−0.272525***	−0.036240***
	(0.020840)	(0.066148)	(0.109295)	(0.029050)	(0.065948)	(0.016423)	(0.034347)	(0.167445)	(0.019368)	(0.011189)
RER	0.232459***	0.068454***	0.003740	0.275325***	0.059429**	0.084079***	0.093170***	0.081635**	0.185173***	0.087675***
	(0.009322)	(0.013290)	(0.029717)	(0.031180)	(0.024724)	(0.007473)	(0.021427)	(0.038013)	(0.015196)	(0.004771)
INNOV*L_INCOME		11.44694**	0.034257	0.025689	0.002514	0.000900***	0.000334	1.191435***	9.559737***	0.354823***
		(4.904051)	(0.045220)	(0.325650)	(0.007118)	(0.000266)	(0.000349)	(0.397017)	(0.532337)	(0.021854)
INNOV*M_INCOME		2.480264*	0.005784***	0.007554***	2.41E−05	3.50E−05***	5.14E−06	0.903410***	2.568074***	0.203470***
		(1.266479)	(0.001513)	(0.001195)	(4.98E−05)	(1.30E−05)	(5.33E−06)	(0.301082)	(0.303696)	(0.011192)
INNOV*H_INCOME		2.211333***	0.002617***	0.001134***	3.37E−05***	−0.000115***	7.91E−05**	1.017846***	1.296513***	0.079976***
		(0.706753)	(0.000928)	(0.000377)	(1.18E−05)	(3.25E−05)	(3.96E−05)	(0.333024)	(0.414988)	(0.010572)
Obs	822	314	341	279	361	575	708	391	533	584
Countries	73	43	41	39	51	52	64	50	58	66

Table 6 (continued)

Regressors	Model 1 BASELINE	Model 2 R&D	Model 3 RESEARCHERS	Model 4 TECHNICIANS	Model 5 ARTICLE	Model 6 PATENTS	Model 7 TRADEMARK	Model 8 INCENG	Model 9 INDOUT	Model 10 INES
Number instruments/number cross-section ratio	0.781	0.767	0.61	0.974	0.725	0.846	0.516	0.52	0.897	0.879
Prob J	0.438822	0.531840	0.273664	0.456632	0.553086	0.212586	0.210725	0.852185	0.468131	0.374773
AR(1)	−0.378769	−0.503872	−0.378553	−0.398227	−0.440035	−0.375286	−0.530192	−0.489457	−0.346786	−0.359988
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR(2)	−0.039303	0.050483	−0.101763	−0.006809	0.073359	−0.072131	0.006581	0.100403	−0.002028	0.035577
P-value	0.2283	0.4902	0.1050	0.9271	0.2485	0.1375	0.8316	0.1391	0.9672	0.4148

Information in brackets is the standard error associated with the coefficient

Level of statistical significance: (***) denotes 1%, (**) denotes 5% and (*) denotes 10%

S-GMM: based on Arellano and Bover (1995), two stages and no time dummy. AR (1) and AR (2) tests to verify the presence of first-order and second-order serial correlation in the waste in difference

The number of instruments to the number of cross-section ratio needs to be higher than 1. Although the S-GMM estimates are adherent for samples with short periods and a high number of individuals, the diversity of instruments may generate the overlapping of instruments on the variables used, generating bias in the result (Roodman 2009)

Table 7 Measuring the impact of innovation on dependent variables

Variables	*LN OUTSAHRE*		*LN EMPSAHRE*		*H_TECH_EXP*	
	10%	**1 S.D**	**10%**	**1 S.D**	**10%**	**1 S.D**
R&D	0.29%	2.2%	0.04%	0.29%	4.44%	34.19%
RESEARCHERS	0.28%	2.14%	0.06%	0.43%	0.96%	7.38%
TECHNICIANS	0.28%	2.55%	0.11%	1.05%	0.92%	8.52%
ARTICLE	0.06%	1.71%	0.01%	0.27%	0.44%	12.13%
PATENTS	0.01%	0.36%	0.01%	0.26%	0.72%	25.91%
TRADEMARK	0.00%	0.13%	0.01%	0.22%	0.08%	2.62%
INCENG	0.54%	2.23%	0.03%	0.13%	5.96%	24.56%
INDOUT	0.24%	1.85%	0.16%	1.22%	1.43%	10.97%
INES	0.22%	1.24%	0.02%	0.12%	2.84%	15.62%

the economic impact of the explanatory variables on dependent variables follows that proposed by de Mendonça and Silva (2017) and Montes et al. (2019).

3.2.1 Aggregate economic impact

According to Table 7, in most of the results, the impact of the variables related to the innovative effort on the dependent variables is higher than the effect of the variables related to the educational system. In turn, both are higher than the effect of the variables related to the technological scientific base, considering a variation of 10% or 1 standard deviation, according to the methodology proposed by de Mendonça and Silva (2017) and Montes et al. (2019).

Concerning the economic impacts of the innovative activity, there is a hierarchical composition. The impact on H_TECH_EXP is higher than the impact on LN OUTSHARE, which, in turn, is higher than the impact on LN EMPSHARE. In the latter case, the results indicate that the impact of innovation on production is higher than the impact on employment. It corroborates the theoretical arguments set out in the literature (Tregenna 2008; Rodrik 2015).

By verifying the importance of total R&D spending as a proportion of GDP (R&D) for the industrial sector, and the importance of the capacity to absorb, process information, and build knowledge, improving the performance of organizations and countries [e.g., Castellaci and Natera (2013)], just as indicates the countries committed to the creation of knowledge and sources of differentiation of productivity rates of economies [e.g., Fagerberg (1987), Smith (2005), Fagerberg et al. (2007)]. The countries persistence in activities related to the innovative effort represents the sustainability of industrial activity over time, given that the dynamic coefficient of the estimated empirical model is statistically significant. This reinforces the importance of the innovative activity to the process of industrial cumulative [see, e.g., Dosi (2006)].

Nevertheless, efforts made through R&D activities allow countries to differentiate themselves in the international market by exporting sophisticated products with high added value. Thus, the quality of the export depends on the capacity of development and diffusion of new products and technology [e.g., Edquist and Lundvall (1993)]. The exports sophistication also implies an improvement in the countries industrial competitiveness, given the relevance of technological capacity for a more complex industry and its differentiation in the international market [see, e.g., Hausmann et al. (2007) and Fagerberg et al. (2007)].

According to the results presented in the empirical analysis, the variables RESEARCHERS and TECHNICIANS are relevant for the degree of industrial densification. Even if the estimated coefficients and impacts are low, one can observe the importance of human resources linked to research and development activities for technological qualification and productive sophistication.

The analysis of the scientific and technological base is important for measuring the innovation systems, given that the patterns of scientific and technological activities influence the strengthening of countries innovative capacity [e.g., Furman et al. (2002)], the creation of new technologies [e.g., Archibugi and Coco (2004)], and the shaping of the productive structure and competitiveness [e.g., Fagerberg et al. (2007)]. Thus, the empirical findings of the impacts of PATENTS, ARTICLE, and TRADEMARK on the industrial structure, industrial employment, and export of the high-tech sector highlights the importance of the innovative effort and the stock of codified knowledge on the elements that influence the trajectory and differentiation of the growth rate of national economies [e.g., Fagerberg (1987) and Fagerberg et al. (2007)].

The indicators used to measure the educational structure (INCENG, INDOUT, and INES), highlight the importance of generating human capital to expand the innovative capacity. The results related to the scientific structure related to the educational system reinforce the importance of human capital on industrial densification, considering that the qualification of human capital allocated in the industrial sector raises the capacity of information codification and increases the absorption capacity of firms.

The results found to measure the effects of countries' innovative capacity on the industrial fabric suggest a direct relationship and positive impact of the innovative process and activity for the dynamization of the countries' industrial sector. On the other hand, the results also suggest that the reduction of countries' efforts in terms of their innovative and technological capacity has a significant impact on the trajectory of industrial development, reducing their competitive advantages in the international market. The consequence of this effect is the increased vulnerability of the economies, given that technological innovation is one of the main drivers of economic growth [see, e.g., Grupp and Mogee (2004)].

In the absence of precariousness of the elements that form the basis for the construction of knowledge, learning, and technological training of countries, which is a certain way results in the low dynamism of NISs, the weakness of innovative activity can be considered as one of the elements that imply in the reduction of industrial competitiveness in the international market, the reduction of industrial jobs and the atrophy of industrial muscle, generating productive chains vulnerable to the intense and hostile environment of competition. This being said, based on the results, innovative capacity must be considered as one of the determinants of the deindustrialization process.

Table 8 Measuring the impact of innovation on LN OUTSHARE, by income level

Dependent variable: *LN OUTSHARE*

Variables	Low income		Middle income		High income	
	10%	1 S.D	10%	1 S.D	10%	1 S.D
R&D	0.13%	1.22%	0.18%	1.17%	0.34%	1.8%
RESEARCHERS	2.02%	32.91%	0.09%	0.76%	0.46%	2.25%
TECHNICIANS	2.74%	47.8%	0.16%	1.2%	0.71%	4.77%
ARTICLE	0.16%	3.66%	0.02%	0.97%	0.18%	3.59%
PATENTS	0.21%	7.12%	0.00%	0.17%	0.05%	1.47%
TRADEMARK	0.13%	4.71%	0.02%	0.62%	0.02%	0.37%
INCENG	0.39%	2.69%	0.53%	2.09%	0.61%	2.38%
INDOUT	0.32%	2.16%	0.35%	3.02%	1.12%	7.01%
INES	0.11%	1.28%	0.25%	1.37%	0.34%	1.07%

Considering the results listed for the dependent variable H_TECH_EXP, the concept of deindustrialization proposed by Tregenna (2008) can be expanded, also considering the reduction of this variable, which can be interpreted as an indicator of export quality, industrial competitiveness, degree of productive sophistication and capacity of diffusion of innovations in a country.

3.2.2 Economic impact by income level

From the description of the economic impacts of innovative activity on productive densification, we observe that the analysis by income level also reflects a hierarchical composition of the impacts on the dependent variables H_TECH_EXP, LN OUTSHARE, and LN EMPSHARE. The results suggest that the level of income, measured by the level of per capita income, is a relevant factor for the differentiation of the impact of the innovative process on the industrial structure, employment, and competitiveness of the countries.

The impact of indicators related to the innovative process on industrial structure, in most cases, in middle-income countries is lower than in low-income countries, considering a variation of 10% or 1 standard deviation. Exceptions are for variables related to higher education and R&D in suits of LN OUTSHARE and RESEARCHERS and INES in terms of LN EMPSHARE. Considering the transition from middle to the high-income stage, most results suggest a downward movement, i.e., the impact of innovation in high-income countries is greater than for high-income countries, in terms of a 10% variation and 1 standard deviation, according to the map of impacts described in Table 8. The downward movement is concentrated in terms of LN EMPSHARE and H_TECH_EXP, mainly in terms of variation of 1 standard deviation, considering variables of innovative effort and scientific structure related to the educational system, according to Tables 8, 9, and 10.

The impact of innovation differs in high-income countries compared to low-income countries. One can observe that in the high income it is lower than in the low-income countries. Considering the whole analysis of the impacts by income level, most indicate

Table 9 Measuring the impact of innovation on LN EMPSHARE, by income level

Dependent variable: ***LN EMPSHARE***						
Variables	**Low income**		**Middle income**		**High income**	
	10%	**1 S.D**	**10%**	**1 S.D**	**10%**	**1 S.D**
R&D	0.06%	0.61%	0.03%	0.2%	0.07%	0.38%
RESEARCHERS	0.05%	0.75%	0.08%	0.65%	0.08%	0.4%
TECHNICIANS	5.1%	88.81%	0.15%	1.13%	0.12%	0.82%
ARTICLE	0.1%	2.26%	0.03%	1.03%	0.12%	2.44%
PATENTS	0.08%	2.59%	0.01%	0.6%	0.05%	1.28%
TRADEMARK	0.12%	4.43%	0.01%	0.25%	0.04%	0.56%
INCENG	0.42%	2.95%	0.26%	1.01%	0.13%	0.52%
INDOUT	0.11%	0.73%	0.05%	0.46%	0.11%	0.7%
INES	0.08%	0.92%	0.11%	0.62%	0.12%	0.37%

Table 10 Measuring the impact of innovation on H_TECH_EXP, by income level

Dependent variable: ***H_TECH_EXP***						
Variables	**Low Income**		**Middle Income**		**High Income**	
	10%	**1 S.D**	**10%**	**1 S.D**	**10%**	**1 S.D**
R&D	5.43%	52.01%	1.32%	8.68%	2.34%	12.22%
RESEARCHERS	7.2%	117.26%	5.14%	42.21%	5.19%	25.16%
TECHNICIANS	2.14%	37.19%	2.1%	15.52%	0.68%	4.6%
ARTICLE	1.1%	25.51%	0.27%	10.43%	0.67%	13.29%
PATENTS	3.13%	105.62%	0.56%	30.94%	− 2.46%	− 66.14%
TRADEMARK	3.64%	136.96%	0.19%	7.31%	1.74%	25.54%
INCENG	25.18%	174.92%	14.11%	55.56%	8.65%	33.84%
INDOUT	21.71%	144.92%	3.56%	30.35%	2.34%	14.64%
INES	7.01%	80.41%	6.16%	33.66%	2.78%	8.71%

a decreasing effect of the impact of the innovation dynamics on industrial structure as a country moves forward in terms of per capita income, still with benign impacts on industrial muscle.

The effect of the R&D over the industry density increases as the income increases, especially in terms of LN OUTSHARE. The bibliography points out this variable as an indication of the intensity of commitment in the discovery and creation of new production methods and codification of advanced knowledge, capable of altering the scientific and technological frontier. This result in terms of LN OUTSHARE indicates that whoever is closer to the technological frontier has as a priority to create conditions for the industrial segment to dominate and become a leader in technological transformation, gaining extraordinary competitive advantages.

In this case, it was found that in most of the results, either in terms of estimated coefficient or in terms of economic impact measurement, the respective results for the innovative activity of low-income countries are higher than those for middle-income countries, which in turn are higher than those for high-income countries. In addition, these parameters can be interpreted as a measure of the technological distance between countries.

The verification of the results of the variables related to the innovative activity for low-income countries reinforces the hypothesis that they are still in the early stages of technological and economic development, whose impact on industrial structure, industrial employment, and international competitiveness is greater, given the high distance of low-income countries from the technological frontier. Thus, a network of poorly integrated causal relationships and coevolution patterns characterizes the national innovation system of these economies, as well as the absence of a set of feedback effects, which are capable of generating cumulative dynamics of technological growth and recovery [e.g., Lundvall et al. (2009) and Castellaci and Natera (2013)].

The results of innovation activity for middle-income countries show weaknesses in the dynamism of national innovation systems. Following Castellaci and Natera (2013), the weak link between the innovative process and the scientific production shows that the secondary role assumed by business R&D capabilities. This hypothesis may be related to the heterogeneity of the results found in the empirical analysis and to the reduction of the impact of the innovative process in the transition from the low to the middle-income stage. Hence, it is important to note that middle-income countries persist in learning construction through imitation, which is limited and exhaustive over time. The change in a country's technological structure consists of the change from a capacity building through imitation activities to innovative activities, a relevant factor to explain development and differentiation among countries [e.g., Fagerberg et al. (2007)].

For high-income countries, the results—especially R&D—show their proximity to the technological frontier. They are characterized by NIS that have an absorbing capacity based on interaction in international trade and the generation of qualified human capital, dynamic capacities, and diversified sources of learning, besides intense interaction among NIS agents. Even if the effect of innovative capacity on the industrial densification of high-income countries is lower than other income levels, this effect on industrial activity remains benign. R&D activities are considered essential to boost the dynamics of innovation, with the co-evolving nature of innovative and absorbing capacity, building a sustainable trajectory for raising the level of per capita income [e.g., Castellaci and Natera (2013)], in addition to directing the level of learning, dynamic capabilities of organizations and the process of knowledge accumulation to advanced levels.

Thus, the results suggest that the effects of innovative dynamics on industrial structure reduce as countries approach the technological frontier, which, in turn, leads to higher income levels. However, the effect of the innovative dynamics on structural change remains beneficial for the strengthening of industry, regardless of income level. The absence or reduction of efforts to boost national innovation systems can have severe effects on productive activity and the competitiveness of countries. It can interrupt the mechanisms that drive the development of economies and increases the distance from the technological and productive frontier. It is also evident that, regardless of income level, it is necessary to be persistently innovative over time.

The results presented may also indicate that some middle-income countries have the fragility of the innovation systems as one of its causes of the premature deindustrialization process so that the effects of innovative activity are not perceived in industrial activity and society. Thus, the persistence of this scenario has as a probable result the limitation of economic growth, with the possibility of technological regression, thus deepening the premature deindustrialization process.

3.3 Public policy implications

The results suggest relevant implications for policymakers to adopt necessary measures to leverage productivity and industry competitiveness. Industrial policy should consider the level of income and the technological structure, where investments and incentives aimed at promoting technological, scientific, and innovative training are relevant to strengthening the industrial fabric.

Many middle-income countries find issues to change to a strategy to create their conditions for innovation and technology, reinforcing the thesis of the "middle-income trap" (middle-income trap). The results reinforce that to overcome this condition, investments in innovative effort activities, scientific and technological basis, and scientific structure related to the educational system can present satisfactory results in terms of industrial densification, industrial employment, and export quality.

Nearly, considering the results exposed follows below the guidelines of an industrial policy to reverse the low dynamism and atrophy of the countries' industrial muscles:

a) Direct efforts to increase R&D investments in the industrial sector (public and private), both as a proportion of GDP, with synergy between the parties;
b) Incentive mechanisms for the expansion and improvement of the quality of higher education, given that the effects of the qualification of human capital on productive densification, employment, and industrial competitiveness are benign, in addition to encouraging careers in science, engineering, and industrial production;
c) Encouragement of research related to postgraduate centers stricto sensu, given the beneficial effects of the gross enrollment rate in doctorate courses on the productive structure;
d) An increase in the number of publications of scientific articles, patent applications, and trademarks, which represent constructed and codified knowledge which, on the one hand, represents the result of researches and investigations and, on the other hand, represents the stock of inputs for the development of future researches and scientific investigations;
e) Industrial policy should consider the level of per capita income that a given country has, to direct efforts to relevant areas of greater impact, to increase the dynamism of the NIS.

Thus, if national states and organizations neglect the elements related to innovative activity, learning process, and knowledge construction, economies may severely deindustrialize, increasing the technological gap. An innovation-based development strategy can be successful for countries and industrial companies, which will be stronger, more dynamic, and more competitive in the international marketplace.

4 Concluding remarks

The main objective of the present work is to analyze the relationship between the innovative process and the deindustrialization process. As a secondary objective, we verify whether there is a difference in the magnitude of the impact of the innovation process on industrial production and employment,

To achieve the objectives, we use dynamic panel technics to estimate the parameters. The results suggest that the variables related to the innovative effort, the variables related to the scientific and technological basis, as well as the variables related to the educational system directly affect the participation of industry in GDP and the relative participation of industrial employment in the total employment of the economy. These results are statistically significant. In addition, we conclude that the impact of the variables related to the innovative activity is greater on output than on industrial employment.

Regarding the share of exports of the high-tech sector in the industrial sector, the estimates presented the same behavior as the estimates in terms of industrial production and employment. Regarding the order of impact of the innovative activity on the dependent variables, one can see that the impact on export quality is higher than the participation of industry in GDP, which in turn is higher than the relative participation of industrial employment.

When evaluating the respective independent variables used to measure the determinants of the deindustrialization process, considering per capita income levels, most of the estimates suggest that the impact of innovative activity on production, employment, and industrial competitiveness performance is stronger in low-income countries than in middle-income countries, which in turn is stronger than in high-income countries. This result suggests that as the countries get closer to the technological frontier, the marginal impact tends to decrease, but with significantly beneficial impacts on the productive muscle of the countries. The estimated coefficients by income level can be a proxy for the countries' technological gap, given their level of per capita income. These results are in line with the average pattern of countries' behavior by income level. The results of this research highlight the need to incorporate the mutability of learning strategies, construction of dynamic, technological, and absorbing capacities throughout the development process in industrial policy design**.**

Appendix

See Tables 11, 12, 13, 14, 15, 16, 17.

Table 11 List of countries in the database

#	Country	Code country	#	Country	Code country
1	Algeria	DZA	41	Israel	ISR
2	Armenia	ARM	42	Italy	ITA
3	Australia	AUS	43	Japan	JPN
4	Austria	AUT	44	Korea, Rep	KOR
5	Bahamas, The	BHS	45	Lithuania	LTU
6	Bahrain	BHR	46	Luxembourg	LUX
7	Belgium	BEL	47	Macedonia, FYR	MKD
8	Belize	BLZ	48	Malaysia	MYS
9	Bolivia	BOL	49	Malta	MLT
10	Brazil	BRA	50	Mexico	MEX
11	Bulgaria	BGR	51	Moldova	MDA
12	Cameroon	CMR	52	Morocco	MAR
13	Canada	CAN	53	Netherlands	NLD
14	Central African Republic	CAF	54	New Zealand	NZL
15	Chile	CHL	55	Nicaragua	NIC
16	China	CHN	56	Nigeria	NGA
17	Colombia	COL	57	Pakistan	PAK
18	Congo, Dem. Rep	COD	58	Papua New Guinea	PNG
19	Costa Rica	CRI	59	Paraguay	PRY
20	Cote d'Ivoire	CIV	60	Philippines	PHL
21	Croatia	HRV	61	Poland	POL
22	Cyprus	CYP	62	Portugal	PRT
23	Czech Republic	CZE	63	Romania	ROU
24	Denmark	DNK	64	Russian Federation	RUS
25	Dominican Republic	DOM	65	Sierra Leone	SLE
26	Equatorial Guinea	GNQ	66	Singapore	SGP
27	Fiji	FJI	67	Slovak Republic	SVK
28	Finland	FIN	68	Slovenia	SVN
29	France	FRA	69	South Africa	ZAF
30	Gabon	GAB	70	Spain	ESP
31	Gambia, The	GMB	71	Sweden	SWE
32	Georgia	GEO	72	Switzerland	CHE
33	Germany	DEU	73	Togo	TGO
34	Greece	GRC	74	Uganda	UGA
35	Guyana	GUY	75	Ukraine	UKR
36	Hong Kong SAR, China	HKG	76	United Kingdom	GBR
37	Hungary	HUN	77	United States	USA
38	Iceland	ISL	78	Uruguay	URY
39	Iran, Islamic Rep	IRN	79	Venezuela, RB	VEN
40	Ireland	IRL	80	Zambia	ZMB

Source: World Bank

Table 12 Summary of variables

Variable ranking	Variables	Description	Source	Expected signal	References
Dependent variables	LN OUTSHARE	Logarithm of value added of the manufacturing sector, as a proportion of GDP	World Bank	Not available	Rowthorn and Ramaswamy (1999)
	LN EMPSHARE	Logarithm of Industrial Employment, as a proportion of total Employment	World Bank	Not available	Rowthorn and Ramaswamy (1999)
	H_TECH_EXP	Export of High Technology products, as a proportion of the export of manufacturing	World Bank	Not available	Hausmann et al. (2007); UNIDO (2018)
Innovation capacity variables	R&D	Expenditure on R&D as a proportion of GDP	World Bank	+	Nelson (1993); Fagerberg and Srholec (2009); Castellaci and Natera (2013)
	RESEARCHERS	Researchers in R&D per capita (per million people)	World Bank	+	Cruz et al. (2015); Pérez Hernandéz et al. (2018)
	TECHNICIANS	R&D technicians per capita (per million people)	World Bank	+	Cruz et al. (2015); Pérez Hernandéz et al. (2018)
	ARTICLE	Articles published in technical and scientific journals covered by SCI and SSCI	World Bank	+	Archibugi and Coco (2004); Grupp (2007); Santos (2017); Ribeiro (2019)
	PATENTS	Patent Applications (Resident and Non-Resident)	World Bank	+	Archibugi e Coco (2004); Grupp (2007); Santos (2017); Ribeiro (2019)
	TRADEMARK	Trademark Registration Requests (Resident and Non-Resident)	World Bank	+	Fagerberg and Srholec (2009); Castellaci and Natera (2013)
	INDOUT	PhD students, expressed as a percentage of the population of higher education age	World Bank	+	Fagerberg and Srholec (2009); Castellaci and Natera (2013); Jaguaribe (2015); Grupp and Mogee (2004)
	INCENG	Students in science, engineering, industrial production, expressed as a percentage of the population of higher education age	World Bank	+	Freeman (1995); Fagerberg and Srholec (2009); Grupp and Mogee (2004)
	INES	Number of gross enrollments in Higher Education, as a proportion of the population of higher education age	World Bank	+	Fagerberg and Srholec (2009); Grupp and Mogee (2004)

Table 12 (continued)

Variable ranking	Variables	Description	Source	Expected signal	References
Control variables	LN Y	Logarithm of GDP per capita, in Purchasing Power Parity (PPP), in international dollars and constant 2011 values	World Bank	+	Rowthorn and Ramaswamy (1999); Rowthorn and Coutts (2004); Marconi and Rocha (2012); Rodrik (2015); Haraguchi et al. (2017)
	$(LN\ Y)^2$	Logarithm square of GDP per capita, in Purchasing Power Parity (PPP), in international dollars and constant 2011 values	World Bank	−	Rowthorn and Ramaswamy (1999); Rowthorn and Coutts (2004); Marconi and Rocha (2012); Rodrik (2015); Haraguchi et al. (2017)
	LN RELPRICE	Logarithm of implicit manufacturing deflator to GDP deflator ratio	UN / National Account-AMA	±	Rowthorn and Ramaswamy (1999); Marconi and Rocha (2013)
	FIXCAP	Gross Fixed Capital Formation as a proportion of GDP	World Bank	+	Rowthorn and Ramaswamy (1999)
	TRADEBAL	Trade Balance, as a proportion of GDP	World Bank	+	Rowthorn and Ramaswamy (1999)
	RER	Effective Real Exchange Rate Index (2010 = 100)	World Bank/EUROSTAT	+	Marconi and Rocha (2012)
	RIR	Interest Rate Real, in %	World Bank	−	Sonaglio et al. (2010)

Table 13 Descriptive statistics

Variables	Mean	Std. Dev	Median	Min.	Max.	Obs
LN OUTSHARE	2.55	0.55	2.66	0.07	3.92	1668
LN EMPSHARE	3.02	0.44	3.1	1.29	3.76	1760
H_TECH_EXP	13.49	14.17	8.71	0	90.02	1598
LN Y	9.49	1.13	9.73	6.3	11.49	1757
$(\text{LN Y})^2$	91.29	20.51	94.59	39.72	132.05	1757
LN RELPRICE	4.66	0.19	4.64	2.53	5.56	1750
FIXCAP	22.06	5.97	21.66	− 2.42	53.61	1703
TRADEBAL	− 0.62	11.28	− 0.61	− 52.78	49.76	1746
RIR	7.32	10.52	5.49	− 70.43	93.92	1410
RER	99.99	29.29	99.11	42.04	779.77	1758
R&D	1.3	1	1.03	0.01	4.43	1055
RESEARCHERS	2439	1875	2152	10	8250	940
TECHNICIANS	737	679	513	2	3766	684
ARTICLE	21,194	58,235	3133	1	440,230	1106
PATENTS	27,515	99,043	2034	0	1,338,503	1292
TRADEMARK	36,891	115,319	11,572	1	2,104,409	1414
INCENG	15.9	6.55	16.61	0.04	39.04	637
INDOUT	2.48	1.9	1.89	0.02	8.96	874
INES	44.99	24.73	45.86	1.05	126.38	1225

Table 14 Mean and standard deviation of the variables used per income level

Classification	Variables	Mean			Standard deviation		
		Low income	Middle income	High income	Low income	Middle income	High income
Dependent variables	LN OUT-SHARE	2.17	2.66	2.57	0.58	0.49	0.55
	LN EMP-SHARE	2.41	3.06	3.17	0.46	0.41	0.24
	H_TECH_EXP	5.79	11.46	17.55	10.55	15.43	12.29
Control variables	LN Y	7.46	9.18	10.49	0.63	0.58	0.3
	$(\text{LN Y})^2$	56.1	84.66	110.07	9.66	10.64	6.27
	LN RELPRICE	4.6	4.68	4.66	0.34	0.18	0.11
	FIXCAP	17.1	22.7	22.81	7.92	6.07	4.32
	TRADEBAL	− 8.32	− 2.23	3.6	10.86	11.87	8.73
	RIR	12.16	8.36	4.09	11.26	12.72	3.77
	RER	107.68	96.88	100.68	48.52	32.16	11.98
Innovation capacity variables	R&D	0.27	0.61	1.86	0.26	0.4	0.97
	RESEARCH-ERS	121.54	1019	3478	198.06	836.29	1688
	TECHNI-CIANS	48.09	318	1055	83.76	235.43	712
	ARTICLE	252	12,705	34,774	587	49,579	69,218
	PATENTS	2010	18,409	37,495	6791	101,313	100,956
	TRADEMARK	6305	41,361	38,651	23,727	162,908	56,673
	INCENG	12.23	17.9	14.92	8.49	7.05	5.84
	INDOUT	1.31	1.59	3.17	0.88	1.35	1.98
	INES	11.43	34.71	61.04	13.11	18.96	19.11

Table 15 Correlation matrix

Ordem	Variável	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	LN OUT-SHARE	1																		
2	LN EMP-SHARE	0.56271	1																	
3	H_TECH_EXP	0.08687	−0.1645	1																
4	LN_Y	-0.0688	−0.164	0.40985	1															
5	$(LN\_Y)^2$	−0.0793	−0.1833	0.4084	0.99936	1														
6	LN REL-PRICE	0.32534	0.46447	−0.2643	−0.1629	−0.1706	1													
7	FIXCAP	0.4542	0.4259	−0.0562	−0.0057	−0.0108	0.06106	1												
8	TRADEBAL	0.35422	−0.0063	0.41401	0.53027	0.52033	0.09627	−0.2424	1											
9	RIR	−0.0439	−0.0712	−0.0771	−0.1556	−0.1569	−0.1231	−0.1027	−0.0386	1										
10	RER	−0.158	−0.3413	0.32389	0.3074	0.316	−0.5679	0.18291	−0.0449	−0.2607	1									
11	R&D	0.23642	−0.261	0.3129	0.60117	0.61102	−0.2415	0.19037	0.33165	−0.0351	0.4483	1								
12	RESEARCH-ERS	−0.0059	−0.3125	0.27896	0.66077	0.67209	−0.3279	0.08462	0.20049	−0.072	0.5086	0.89289	1							
13	TECHNI-CIANS	0.00933	−0.1226	0.15869	0.7257	0.73897	−0.2162	0.06349	0.29253	−0.0284	0.2647	0.70176	0.7592	1						
14	ARTICLE	−0.0684	−0.322	0.14964	0.36736	0.3726	−0.0517	−0.1829	0.12108	−0.1526	0.2619	0.44062	0.40212	0.18295	1					
15	PATENTS	0.36995	−0.1146	0.23529	0.16088	0.15986	−0.0907	0.35251	0.14341	−0.056	0.3841	0.61987	0.39766	0.04485	0.48511	1				
16	TRADE-MARK	0.33638	−0.1957	0.14189	0.0484	0.04644	−0.0474	0.19753	0.20374	0.06549	0.255	0.45848	0.18958	−0.0624	0.49664	0.85834	1			
17	INCENG	0.66665	0.35597	−0.1145	−0.412	−0.4206	0.22149	0.44053	0.04231	−0.2144	−0.0178	0.05837	−0.1824	−0.3436	−0.0592	0.46353	0.46238	1		
18	INDOUT	0.32751	0.25837	−0.0836	0.31843	0.32427	0.28135	0.12432	0.1983	−0.0336	−0.2182	0.24931	0.24929	0.47781	0.24748	−0.0854	−0.102	−0.062	1	
19	INES	0.15483	−0.1028	−0.0967	0.30585	0.30949	−0.1008	0.28896	0.1236	−0.1583	0.4047	0.58047	0.57125	0.37596	0.24453	0.49956	0.27127	0.2203	0	1

Table 16 List of instruments used in the estimations in Tables 1, 2 and 3

Dependent variable: LN OUTSHARE	
BASELINE	(LN OUTSHARE,-2 TO -4) LN Y(-1 TO -2) LN Y^2(-1 TO -3) TRADEBAL(-1 TO -2) RER(-1 TO -3) RIR(-1 TO -3)
R&D	(LN OUTSHARE,-2 TO -3) LN Y^2(-3 TO -4) R&D(-1 TO -2) RER(-1 TO -3) FIXCAP(-2 TO -3)
INCENG	(LN OUTSHARE,-2 TO -3) RER(-1 TO -4) TRADEBAL(-1 TO -4) RIR(-2)
INDOUT	(LN OUTSHARE,-2 TO-3) LN Y(-1 TO -4) LN Y^2(-1 TO -3) INDOUT(-1 TO -3)
TRADEMARK	(LN OUTSHARE,-2 TO-3) LN Y(-1 TO -2) LN Y^2(-1 TO -3) RER(-1 TO -3) TRADEMARK(-1 TO -3) RIR(-2 TO -3)
PATENTS	(LN OUTSHARE,-2 TO -3) LN Y(-1 TO -2) LN Y^2(-1 TO -3) TRADEBAL(-1 TO -2) RER(-1 TO -3) PATENTS(-1 TO -2)
ARTICLES	(LN OUTSHARE,-2 TO -4) LN Y(-2 TO -4) ARTICLE(-1 TO -2) RIR(-2 TO -4) RER(-1 TO -2) FIXCAP(-1 TO -3)
RESEARCHERS	(LN OUTSHARE,-2 TO -3) RER(-3) FIXCAP(-2) TRADEBAL(-1) RESEARCHERS(-1)
TECHNICIANS	(LN OUTSHARE,-4 TO -5) RER(-5) RIR(-3) R&D(-4) FIXCAP(-4 TO -6)
INES	(LN OUTSHARE,-2 TO -4) RER(-3) LN Y(-2) INES(-1)
Dependent variable: LN EMPSHARE	
BASELINE	(LN EMPSHARE,-2 TO -4) LN Y(-1 TO -4) RER(-1 TO -4) TRADEBAL(-1 TO -2)
R&D	(LN EMPSHARE,-2 TO -3) LN Y(-1 TO -2) TRADEBAL(-1 TO -4) RER(-1 TO -4) RIR(-1 TO -4) R&D(-1)
INCENG	(LN EMPSHARE,-2 TO -3) RER(-1 TO -5) RIR(-2 TO -5) TRADEBAL(-1 TO -4)
INDOUT	(LN EMPSHARE,-2 TO -3) RER(-1 TO -4) TRADEBAL(-1 TO -4) RIR(-1 TO -3)
TRADEMARK	(LN EMPSHARE,-2 TO -3) LN Y(-1 TO -4) LN Y^2(-1 TO -3) RER(-1 TO -4) TRADEMARK(-1 TO -3) RIR(-1 TO -4)
PATENTS	(LN EMPSHARE,-2 TO -3) LN Y(-1 TO -2) LN Y^2(-1 TO -3) RER(-1 TO -3) PATENTS(-1 TO -2)
ARTICLES	(LN EMPSHARE,-2 TO -3) LN Y(-1 TO -4) ARTICLE(-1 TO -2) RIR(-2 TO -4) RER(-1 TO -2) FIXCAP(-1 TO -3)
RESEARCHERS	(LN EMPSHARE,-2 TO -3) LN Y(-1 TO -3) RER(-1 TO -4) R&D(-1) INES(-1)
TECHNICIANS	(LN EMPSHARE,-2 TO-3) RER(-1 TO -4) FIXCAP(-2) RIR(-5) R&D(-4)
INES	(LN EMPSHARE,-3 TO -5) LN Y(-5) RIR(-1 TO -4) RER(-1 TO -3) INES(-1) LN OUTSHARE(-2 TO -4)
Dependent variable: H_TECH_EXP	
BASELINE	(H_TECH_EXP,-2 TO -4) RER(-1 TO -4) RIR(-1 TO -5)
R&D	(H_TECH_EXP,-2 TO -3) RER(-2 TO -5) RIR(-1 TO -5) FIXCAP(-1) ARTICLE(-4)
INCENG	(H_TECH_EXP,-2 TO -3) RER(-1 TO -3) RIR(-1) LN OUTSHARE(-1) TRADEBAL(-2)
INDOUT	(H_TECH_EXP,-3 TO -4) RER(-1 TO -2) RIR(-1 TO -4) FIXCAP(-1 TO -4) INDOUT(-1)
TRADEMARK	(H_TECH_EXP,-3 TO -4) RER(-1 TO -5) RIR(-2 TO -5) FIXCAP(-1 TO -4) TRADEMARK(-1)
PATENTS	(H_TECH_EXP,-4 TO—5) RIR(-3 TO -4) TRADEBAL(-4 TO -4) RER(-2 TO -4) LN Y^2(-1)
ARTICLES	(H_TECH_EXP,-2 TO -5) ARTICLE(-1 TO -4) RIR(-4) RER(-1 TO -2) FIXCAP(-1 TO -3)
RESEARCHERS	(H_TECH_EXP,-4) RER(-1 TO -4) RIR(-1 TO -4) TRADEBAL(-1 TO -2) INDOUT(-1 TO -2) R&D(-1 TO -2) LN OUTSHARE(-2) FIXCAP(-1 TO -4)
TECHNICIANS	(H_TECH_EXP,-4) RER(-1 TO -4) INDOUT(-1 TO -2) R&D(-2) RIR(-1 TO -4) FIXCAP(-2 TO -5) LN OUTSHARE(-4)
INES	(H_TECH_EXP,-3 TO -5) LN OUTSHARE(-3 TO -5) LN Y(-2 TO -5) RER(-1 TO -4)

Table 17 List of instruments used in the estimations in Tables 4, 5 and 6

Dependent variable: LN OUTSHARE	
BASELINE	(LN OUTSHARE,-2 TO -4) LN Y(-1 TO -2) LN Y^2(-1 TO -3) TRADEBAL(-1 TO -2) RER(-1 TO -3) RIR(-1 TO -3)
R&D	(LN_OUTSHARE,-2 TO -3) R&D(-4) RER(-1) TRADEBAL(-2) FIXCAP(-4) LN Y^2(-1 TO -5) LN Y(-1 TO -2)
INCENG	(LN OUTSHARE,-2 TO -3) RER(-1 TO -2) LN Y(-1 TO -4) TRADEBAL(-1)
INDOUT	(LN OUTSHARE,-2 TO -3) RER(-1 TO -4) RIR(-1)
TRADEMARK	(LN OUTSHARE,-2, TO 4) TRADEMARK(-1 TO -4) RER(-1) FIXCAP(-2) LN Y(-1)
PATENTS	(LN OUTSHARE,-3 TO -4) LN Y(-1 TO -5) LN Y^2(-2 TO -5) TRADEBAL(-4 TO -5) RER(-1 TO -5) PATENTS(-1 TO -3) RIR(-2) FIXCAP(-1 TO -3)
ARTICLES	(LN OUTSHARE,-2 TO-5) LN Y(-1 TO -2) TRADEBAL(-2 TO -5) RIR(-2 TO -3) ARTICLE(-2 TO -4) RER(-1)
RESEARCHERS	(LN OUTSHARE,-2 TO -3) RER(-1) FIXCAP(-3) TRADEBAL(-1) RESEARCHERS(-1)
TECHNICIANS	(LN OUTSHARE,-3 TO -4) R&D(-4) FIXCAP(-3 TO -4) RER(-5)
INES	(LN OUTSHARE,-3 TO -5) RER(-3) LN Y(-3) INES(-1) TRADEBAL(-1)
Dependent variable: LN EMPSHARE	
BASELINE	(LN EMPSHARE,-2 TO -4) LN Y(-1 TO -4) RER(-1 TO -4) TRADEBAL(-1 TO -2)
R&D	(LN EMPSHARE,-3 TO -4) RER(-1 TO -5) R&D(-4) LN Y(-2 TO -4) TRADEBAL(-1 TO -5) RIR(-1 TO -4) LN Y^2(-4)
INCENG	(LN EMPSHARE,-2 TO-3) RER(-3 TO -4) RIR(-2 TO -5) TRADEBAL(-1 TO -5)
INDOUT	(LN EMPSHARE,-2 TO -3) RER(-1 TO -4) TRADEBAL(-1 TO -4) RIR(-1 TO -4)
TRADEMARK	(LN EMPSHARE,-2 TO -3) LN Y(-1 TO -4) LN Y^2(-2 TO -5) RER(-1 TO -4) TRADEMARK(-1 TO -3) RIR(-2 TO -5)
PATENTS	(LN EMPSHARE,-3 TO-5) LN Y(-1 TO -2) TRADEBAL(-1) RER(-1) LN Y^2(-1)
ARTICLES	(LN EMPSHARE,-2 TO -5) LN Y(-2 TO -5) RIR(-5) TRADEBAL(-2 TO -3) LN Y^2(-5) RER(-1)
RESEARCHERS	(LN EMPSHARE,-2 TO -3) LN Y(-1 TO -3) RER(-1 TO -4) R&D(-1) INES(-1)
TECHNICIANS	(LN EMPSHARE,-4 TO-5) LN Y(-1) LN Y^2(-4) RER(-1 TO -3) RIR(-5) R&D(-4)
INES	(LN EMPSHARE,-4 TO -5) LN Y(-4 TO -5) RIR(-1 TO -4) RER(-1 TO -5) INES(-1) LN Y^2(-3 TO -5) FIXCAP(-1)
Dependent variable: H_TECH_EXP	
BASELINE	(H_TECH_EXP,-2 TO -4) RER(-1 TO -4) RIR(-1 TO -5)
R&D	(H_TECH_EXP,-3) LN Y(-1 TO -3) RIR(-2 TO -6) RER(-1 TO -6) INDOUT(-4) TRADEBAL(-4 TO -6) LN Y^2(-3)
INCENG	(H_TECH_EXP,-4) LN Y^2(-4) RIR(-1) RER(-1) LN Y(-2 TO -3) TRADEBAL(-1 TO -4)
INDOUT	(H_TECH_EXP,-4 TO -6) RER(-4) RIR(-4)
TRADEMARK	(H_TECH_EXP,-3) RER(-4 TO -5) RIR(-2 TO -4) FIXCAP(-1 TO -5) LN Y^2(-3 TO -5) LN Y(-1 TO -2) TRADEBAL(-4 TO -5)
PATENTS	(H_TECH_EXP,-4 TO -5) RIR(-2 TO -5) RER(-1 TO -5) PATENTS(-5) LN Y(-4 TO -5)
ARTICLES	(H_TECH_EXP,-4 TO-5) RIR(-1 TO -3) RER(-2 TO -6) INDOUT(-1) ARTICLE(-1) TRADEBAL(-3) LN Y^2(-1) FIXCAP(-4)
RESEARCHERS	(H_TECH_EXP,-4) RESEARCHERS(-1) RIR(-3 TO -3) INDOUT(-1) RER(-1) LN Y(-1 TO -4)
TECHNICIANS	(H_TECH_EXP,-3 TO -4) INDOUT(-1) R&D(-2) RER(-2 TO -5)
INES	(H_TECH_EXP,-3 TO -5) LN OUTSHARE(-4 TO -5) LN Y(-2 TO -5) RER(-1 TO -4)

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Author contributions
BF analyzed, estimated and interpreted the data related to the relationship between innovative capacity and the deindustrialization process, as well as consolidated the literature review. RN analyzed the methodological part of the study, as well as reviewed all sections of the study. Both authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated and analyzed during the current study are available in the World Bank Data (https://data.worldbank.org/), National Accounts–Analysis of Main Aggregates (UN–AMA) (https://unstats.un.org/unsd/snaama), and Eurostat (https://ec.europa.eu/eurostat). However, the datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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