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The Drivers of National System of Innovation in Portugal: A Panel Data Analysis

Marcelo Duarte [1]*, Fernando Carvalho [1]

[1] University of Coimbra, CeBER, Faculty of Economics, PORTUGAL
***Corresponding Author:** mpd@fe.uc.pt

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ABSTRACT

The growing awareness of the importance of national systems of innovation on countries' development led to an increased availability of instruments designed to measure and compare the innovative capacity of countries. Such instruments provide policymakers with a panoply of relevant information, with which they can stimulate innovation within their territory, thereby increasing national competitiveness. Among the most used innovation indices, the Global Innovation Index (GII) stands out by explicitly distinguishing innovation inputs and outputs, hence, drawing from its input-output framework and extant literature on innovation, we intend to answer the question: Which innovation inputs are more strongly related to innovative outputs? Thus, deriving policy implications aimed at improving Portugal's innovative readiness. To answer this question, and due to the cross-sectional nature of the GII, we have developed our own panel dataset version composed by 92 countries in the period 2013-2018, which we then analyse through a series of multiple regression techniques, emphasising the results of Eurozone countries and comparing Portugal to them. Results suggest a strong, positive influence of Business Sophistication on innovation outputs in Eurozone countries, derived mainly from the capacity of domestic firms to absorb knowledge. Possible policy implications are derived from this fact, such as, for instance, an encouragement to inward foreign direct investment. However, further research is needed to analyse the differentiated effects of such encouragement, as well as for other surprising results of our study.

Keywords: innovation, global innovation index, innovation inputs, innovation outputs, panel data, Portugal

INTRODUCTION

National Systems of Innovation (NSI) are recognised as cornerstones for countries' development and international competitiveness (Fagerberg and Srholec, 2008; Freeman, 1987, 1995; Furman *et al.*, 2002; Lundvall, 1992; Nelson, 1993), being recognised by the United Nations as part of one Sustainable Development Goal (SDG, UN, 2015). Edquist (2006: 182) defined NSI as

> "all important economic, social, political, organisational, institutional, and other factors that influence the development, diffusion, and use of innovations",

which highlights the essentially systemic nature of innovation, involving both organisations and state in the innovation process within a nation. In order to improve a country's innovative capacities, policy decisionmakers must be able to understand which factors are driving innovation within their economies (Kuhlman *et al.*, 2017). Following the *you cannot manage what you cannot measure* rationale, it becomes necessary to find ways of measuring the investment made in NSI and the resulting outcomes of such investments (Borrás and Laatsit, 2019). In fact, Archibugi *et al.* (2009) argues that there are at least three reasons that justify a systematic collection of innovation data. First, from a theoretical standpoint it allows academics to test innovation theories, since innovation has been considered a determinant of economic growth, employment, productivity, and competitiveness (Fagerberg and Srholec, 2008; Porter and Stern, 1999). Second, NSI measures allow policy decision makers to identify national strengths and weaknesses by comparison with other countries, as well as assessing the effectiveness of adopted policies. Third, they are extremely useful for business strategies, particularly as an aid to decision making regarding localisation of innovative activities along a company's global value chain (Khan & Yu, 2019). To that end, several authors and major international organisations have developed frameworks to analyse the innovation readiness of countries, such as Porter and Stern (1999),

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Archibugi and Coco (2004), the European Innovation Scoreboard (European Comission, 2018), the OECD Science, Technology and Industry Scoreboard (STI, OECD, 2017), or the Global Innovation Index (GII, Cornell University *et al.*, 2018).

These composite indicators are rather common in empirical research (Archibugi *et al.*, 2009), having been used as tools to conduct case studies (Alfantookh and Bakry, 2015; Erciş and Ünalan, 2016; Iqbal, 2011; Marxt and Brunner, 2013), to rank countries according to their innovative capacity (Barragán-Ocaña *et al.*, 2020; Edquist *et al.*, 2018; Pençe *et al.*, 2019), to assess ideal configurational conditions of NSI (Crespo and Crespo, 2016; Khedhaouria and Thurik, 2017), or to analyse the relationships between the various NSI dimensions (Nasierowski and Arcelus, 1999; Sohn *et al.*, 2016). However, although some empirical studies consider an input-output framework (Crespo and Crespo, 2016; Edquist *et al.*, 2018; Khedhaouria and Thurik, 2017; Nasierowski and Arcelus, 1999; Sohn *et al.*, 2016), very few adopt a longitudinal perspective, considering at best a comparison between two consecutive years (Edquist *et al.*, 2018; Zabala-Iturriagagoitia *et al.*, 2007). The use of a cross-sectional perspective renders a static picture of the relationships between NSI dimensions in a given moment, thus failing to find evidence of the medium- long-term impact of innovation inputs on innovative outputs. Therefore, to address this gap, we analyse the relationships between innovation inputs and outputs, while controlling for the effects of time. Drawing from the input-output framework (Godin, 2007), we intend to answer the question: Which innovation inputs are more strongly related to innovative outputs? Thus, deriving policy implications aimed at improving Portugal's innovative readiness. To answer it, we rely on the framework provided by the GII due to its clear distinction between innovation inputs and outputs, based on more than 80 comparable indicators (Cornell University *et al.*, 2018). The index, besides being developed by major international organisations, is audited by European Commission's Joint Research Centre to attest its statistical validity. Therefore, it may be used as a leading reference for policymakers, business executives, as well as for researchers (Archibugi *et al.*, 2009; Sohn *et al.*, 2016). Nonetheless, the GII methodology gives rise to a number of difficulties if one aims to compare countries' scores over time (Cornell University *et al.*, 2018). The major concern in this respect is that reports are conducted to assess innovation readiness of countries in a given year, lacking a longitudinal framework to track changes over time. One of the GII's aims is to include as many middle- and low-economies as possible, which, depending on the availability of data, results in different sample sizes throughout the years. To address this, and other methodological limitations of the GII, we have developed our own panel dataset version of the GII by following its methodology, to the extent possible, resulting in a set of 92 countries for six years (2013-2018). Our hypotheses are then tested by means of multiple regression analyses, in order to understand which inputs have a greater contribution to innovative outputs. Furthermore, we narrowed the analyses, focusing exclusively on a group of countries that, besides being subjected to similar innovation regulations and demands as Portugal, also share a deeper European integration in terms of currency, the Eurozone, which allowed us to make meaningful comparisons with Portugal.

The remainder of this paper is structured as follows. In section 2, we make a brief description of the GII, its components, methodology and limitations, followed, in section 3, with a development of our own panel dataset version of the GII. Next, in section 4, we elaborate on Portugal's performance over time and compare it with the Eurozone average. In section 5, we propose a conceptual model to answer the research question and, following the literature review, we propose the hypothesis. The methodology used constitutes section 6. In section 7, results are presented and discussed, as well as the development of policy implications for Portugal. Lastly, section 8 concludes, including the study's limitations and directions for future research.

THE GLOBAL INNOVATION INDEX (GII)

As mentioned before, we make use of the GII framework to analyse which innovation inputs are more strongly related to innovative outputs. The GII was launched in 2007 by INSEAD to shed light on the measurement of innovation readiness of countries and to find means of generating meaningful comparisons (Dutta *et al.*, 2007), helping business leaders and public policymakers to understand the reasons of a nation's relative performance (Dutta, 2009).

The latest GII report (Cornell University *et al.*, 2018) covers 126 countries, compared along 80 indicators[1]. Its framework relies on the distinction between inputs and outputs to measure innovation in an economy, being inputs the elements of the national economy that enable innovative activities, and outputs the results of innovative activities within the economy. Indicators are aggregated in a total of 21 sub-pillars[2], which, in turn, are aggregated under seven pillars. Five of those are input pillars, consisting in Institutions, Human Capital and Research, Infrastructure, Market Sophistication, and Business Sophistication, while two are output pillar, namely Knowledge and Technology Outputs, and Creative Outputs. Both input and output pillars are then aggregated to form the Input and the Output sub-indices (**Figure 1**).

[1] The number of countries included in each report varies from one year to the next, and the same happens to the indicators used.

[2] Since 2013, only one sub-pillar had its name changed. Trade, competition, and market scale was called Trade and competition until 2015.

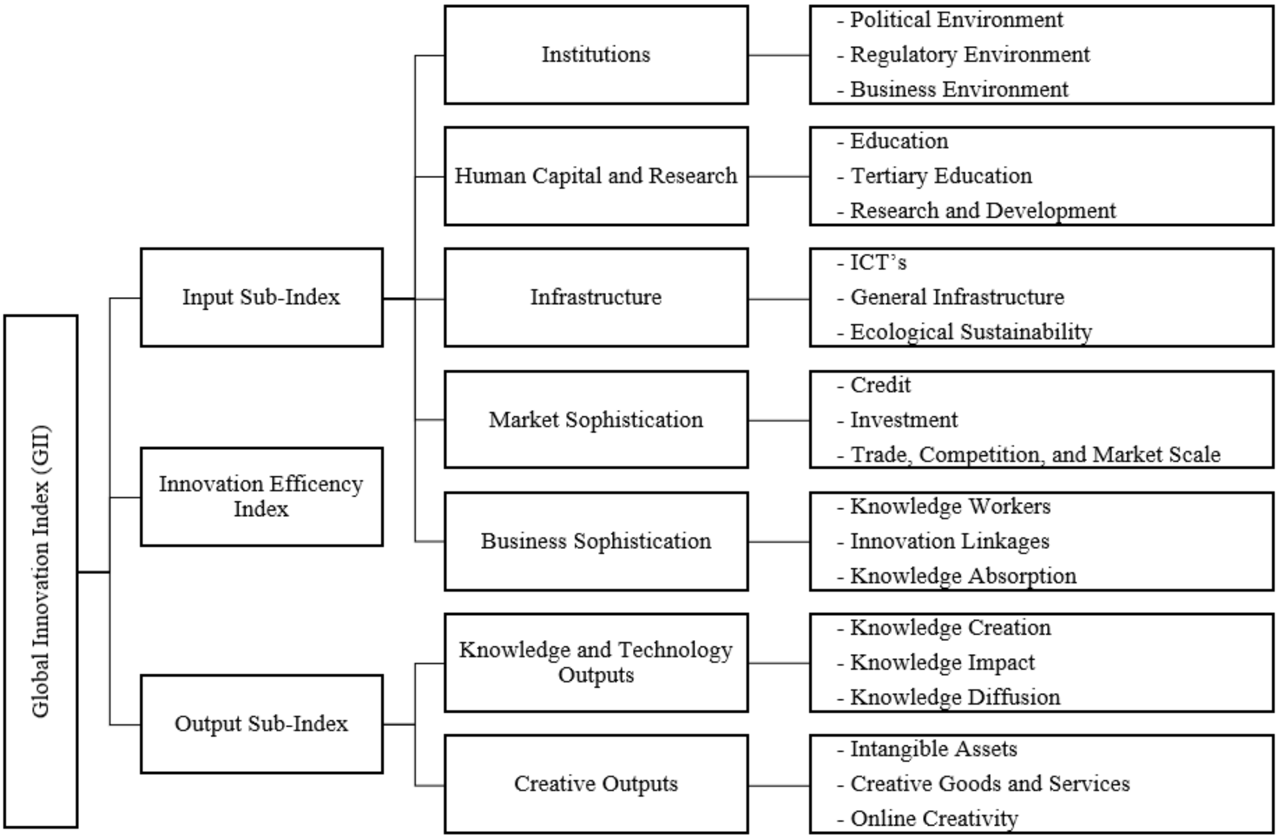

Figure 1. Global Innovation Index framework
Source: Cornell University et al. (2018)

A weighted average of the normalised indicators forms the sub-pillars' scores, which, with another weighted average, form the pillars' scores. The input sub-index is obtained through a simple average of the five input pillars and output sub-index from a simple average of the two output pillars. The final GII results from the simple average of input and output sub-indices. The framework also includes an Innovation Efficiency Index, which is the ratio of the output sub-index over the input sub-index, showing how much innovation outputs a country is obtaining for its inputs.

The index relies on numerous sources of data, such as the World Intellectual Property Organization (WIPO), World Economic Forum's (WEF) Executive Opinion Survey, World Bank's Worldwide Governance Indicators and Doing Business, among many others. As such, the resulting data comes in three forms: hard data, composite indicators, and survey questions of WEF's Executive Opinion Survey. In order to make meaningful comparisons, the indicators are subjected to a normalisation process using a min-max method.

Nevertheless, the use of GII scores as panel data is discouraged due to several methodological issues (Cornell University *et al.*, 2018). First, the GII is compiled on an annual basis, providing a cross-country innovation performance assessment, hence presenting the characteristics of a cross-sectional study (i.e., several individuals at one moment in time) rather than panel data (several individuals tracked through several periods of time). As such, methodological changes from one year to the next distort the results in a panel study. Second, since 2007, the framework has undergone several changes in its structure, with the addition or removal of pillars, sub-pillars, and individual indicators. Third, from one year to the next, several countries are added or removed, based on the availability of indicators. Fourth, indicators' collection over time suffer from changes in definitions and methodologies. Fifth, collected data undergoes a process of normalisation, thus rendering it incomparable in the presence of changes from one year to the next.

PROPOSED PANEL DATASET VERSION OF THE GII

To address the constraints expressed above, we took the following steps.

Period Selection

GII raw data is available in the website only since the 2013 report, hence we have considered the period from 2013 to 2018.

Indicators Selection and Collection

As mentioned above, some indicators were added or removed during the period of analysis. As such, aiming to maximise the total number of indicators, we have taken the following steps: (1) we dropped seven indicators which appeared only in 2013 and 2014 (Press freedom, Gross tertiary outbound enrolment, Electricity consumption, Market access for non-agricultural exports, GMAT mean scores, GMAT test takers, and Daily newspapers circulation), and one whose only appearance is in 2018 (Mobile app creation); (2) we have also dropped two indicators for which we had only three consecutive years of data, due to lack of availability of data at the original source (Global R&D companies (average expenditure, top 3), and Patent families filled in at least two/three offices); (3) for two indicators, the last year was left blank due to a change in their collection methodology and lack of available data at the original source (High-tech and medium high-tech output, and Printing, publications and other media output). For the same reason, one indicator was left with the last two years blank (Wikipedia monthly edits) and one indicator was left with the first year blank (Entertainment and media market); (4) two other indicators were left with the last year blank due to their removal of the 2018 report (Ease of paying taxes, and Video uploads on YouTube). The complete list of indicators used, as well as their definitions, sources and time-series, is shown in **Table A1** in **Appendix**.

Country Selection

Since the number of countries present in GII reports varies from one year to the next, we have first selected those which are present in every report in the period of 2013 to 2018. Next, following Cornell University *et al.* (2018), we dropped countries which had more than 33% of missing values of the 53 input indicators (average for the period), and more than 33% of missing values of the 27 output indicators (average for the period). As such, we have obtained a sample of 92 countries (**Table A2** in **Appendix**) which, according to the World Bank's World Development Indicators, in 2017 accounted for 69.5% of the world GDP (PPP $) and about 84.4% of the world's population.

Identification and Treatment of Series with Outliers

Following the same methodology used in the GII, we have identified a total of 35 indicators with outliers that could polarise results: 34 out of the 57 hard data indicators and 1 out of the 18 composite indicators. The identification and treatment of series with outliers was done through the following steps: (1) first, we have used the criterion of absolute skewness greater than 2.25, or a kurtosis greater than 3.5 to identify problematic indicators; (2) then, series with one to five outliers (indicator 212) were winsorised, where the values distorting the indicator were assigned the next highest value, up to where the previous criterion was met (only one value was adjusted, from 64.997 to 64); (3) series with more than five outliers were multiplied by a given factor *f* (both positive and negative powers of 10 were used) and transformed into their natural logarithms according to the following formulas:

for 'goods' indicators:
$$\ln\left[\frac{(\max * f - 1)(\text{economy value} - \min)}{\max - \min} + 1\right]$$

for 'bads' indicators:
$$\ln\left[\frac{(\max * f - 1)(\max - \text{economy value})}{\max - \min} + 1\right]$$

Where 'min' and 'max' are the minimum and maximum indicator sample values, and 'goods' and 'bads' are indicators for which higher values indicates better and worse outcomes, respectively. For indicators 534 and 634, although the log transformation did lower their skewness and kurtosis values, it was not sufficient to meet the criterion (skewness 2.28 and kurtosis 34.33, and skewness 2.16 and kurtosis 43.21, respectively), hence we have decided to keep the transformed indicators avoiding further transformations.

Normalisation

According to the methodology of the GII, all 80 indicators were normalised into the [0,100] range, with higher score representing better outcomes. We used the min-max method to normalise indicators, where the min and max values were given by the minimum and maximum indicator sample value respectively, except for survey data and some indices, for which original ranges were kept as minimum and maximum values ([-2.5, 2.5] for the Worldwide Governance Indicators; [1, 7] for the World Economic Forum Executive Opinion Survey questions; [0, 100] for the QS World University Ranking; [0, 10] for the ITU indices; [0, 1] for the United Nations Public Administration Network indices; [1, 5] for the Logistics Performance Index; and [0, 100] for the Environmental Performance Index). Thus, we have applied the following formulas:

'Goods':
$$\frac{\text{economy value} - \min}{\max - \min} * 100$$

'Bads':
$$\frac{\max - \text{economy value}}{\max - \min} * 100$$

Aggregation and Indices Construction

Normalised indicators were aggregated at the sub-pillar level via arithmetic average, which is rather common in the literature (Becker *et al.*, 2018; Grupp and Schubert, 2010), with the weights proposed in Cornell University *et al.* (2018), namely 35 indicators were given a weight of 0.5 while the remaining 45 were given the weight of 1.0. These weights were used as scaling coefficients and not as importance coefficients, with the objective of obtaining indicators that can explain a similar amount of variance in their respective sub-pillar. Pillars were then created by a simple average of their respective sub-pillars, and the input and output sub-indices were created by a simple average of their respective pillars. Lastly, the overall index was created by a simple average of input and output sub-indices, while the efficiency index is the ratio of the output sub-index over the input sub-index.

Table 1. Top 10 ranking on the GII against the DuCa framework

Rank	2013		2014		2015		2016		2017		2018	
	GII	DuCa	GII	DuCa	GII	DuCa	GII	DuCa	GII	DuCa	GII	DuCa
1	CHE	DNK	CHE	USA	CHE	NLD	CHE	NLD	CHE	CHE	CHE	NLD
2	SWE	GBR	GBR	DNK	GBR	USA	SWE	USA	SWE	NLD	NLD	CHE
3	GBR	USA	SWE	IRL	SWE	GBR	GBR	CHE	NLD	USA	SWE	GBR
4	NLD	IRL	FIN	CHE	NLD	CHE	USA	GBR	USA	GBR	GBR	SWE
5	USA	FIN	NLD	FIN	USA	IRL	FIN	SWE	GBR	SWE	SGP	DNK
6	FIN	FRA	USA	DEU	FIN	DNK	SGP	FIN	DNK	DNK	USA	USA
7	HKG	SWE	SGP	SWE	SGP	DEU	IRL	DNK	SGP	FIN	FIN	DEU
8	SGP	NLD	DNK	GBR	IRL	SWE	DNK	DEU	FIN	DEU	DNK	FIN
9	DNK	CHE	LUX	NLD	LUX	FIN	NLD	FRA	DEU	FRA	DEU	FRA
10	IRL	DEU	HKG	KOR	DNK	FRA	DEU	KOR	IRL	KOR	IRL	KOR

Source: Cornell University et al. (2013, 2014, 2015, 2016, 2017, 2018) and own calculations.
Note: CHE – Switzerland; DEU – Germany; DNK – Denmark; FIN – Finland; FRA – France; GBR – United Kingdom; HKG – Hong Kong (China); IRL – Ireland; KOR – Republic of Korea; LUX – Luxembourg; NLD – Netherlands; SGP – Singapore; SWE – Sweden; USA – United States of America.

Table 2. Mean scores and yearly means

Variable	Mean	Yearly means					
		2013	2014	2015	2016	2017	2018
Input sub-index	35.08	34.04	34.33	34.93	35.52	36.29	35.35
Output sub-index	28.16	30.13	28.86	28.93	27.82	26.52	26.68
GII	31.62	32.09	31.60	31.93	31.67	31.40	31.01
Innovation Efficiency Index	0.802	0.895	0.847	0.827	0.779	0.721	0.743
Input pillars:							
Institutions	50.62	49.24	49.41	51.05	51.60	51.47	50.97
Human Capital and Research	25.41	25.50	24.85	25.82	25.74	25.83	24.71
Infrastructure	41.68	36.78	38.11	40.73	43.39	45.99	45.09
Market Sophistication	35.98	36.83	37.33	35.71	35.08	35.53	35.38
Business Sophistication	21.69	21.87	21.95	21.36	21.77	22.61	20.58
Output pillars:							
Knowledge and Technology Outputs	19.42	19.82	19.49	19.42	19.72	19.84	18.23
Creative Outputs	36.89	40.44	38.23	38.43	35.91	33.21	35.13

Source: Own calculations.

The resulting dataset is composed by 92 countries along six years (2013-2018). **Table 1** ranks the top 10 countries on the GII and compares it against the newly developed panel data version framework (DuCa). One particularly interesting fact is that Switzerland lose its ubiquitous first place to Denmark, United States of America, and Netherlands, with Netherlands achieving the first position in three of the six years studied. Also, in the DuCa framework, Hong Kong, Singapore and Luxembourg never reach the top 10, whereas Republic of Korea does, first appearing in the 10th position in 2014 and maintains it from 2016 onwards.

Table 2 shows the mean values on the DuCa framework, both sub-indices, and the seven pillars, as well as their yearly means for the period 2013-2018. When looking at the output pillars, it can be seen that, on average, countries are far more productive in Creative Outputs than on Knowledge and Technology Outputs. Regarding inputs, Business Sophistication, followed by Human Capital and Research, are the less developed enablers of innovation, with Institutions and Infrastructure being the most developed, in average terms. **Table 2** also reveals a negative trend of the overall index, with an increase in 2015. The Innovation Efficiency Index also decreases over time, although an improvement exists in the last year. This negative trend of innovation efficiency is due to both increases of inputs and decreases of outputs. Contrary to this overall negative trend, input pillars Institutions and Infrastructure revealed a positive evolution from 2013 to 2018.

From this point onwards, all analyses are based on the panel data version (DuCa) developed above. Nevertheless, the terms used will be those of the GII framework.

PORTUGAL'S PERFORMANCE

In this section, we describe Portugal's innovation performance over time and relative to Eurozone. **Table 3** shows Portugal's overall ranking and scores down to the pillar level, revealing an overall ranking drop from the 29th position in 2013 to the 30th in 2018, notwithstanding climbs in 2014 (27th), 2015 (25th) and 2017 (28th). This shift in position is explained partially by Portugal's performance and partially by other countries' performance. For instance, we can observe a drop on Portugal's GII score from 2013 to 2014, and yet it raised two positions on the ranking. **Table 3** also reveals some trends over time, at the pillar level, which are in line with the overall trends for the total sample. Almost all pillars present a deterioration from 2013 to 2018, with the exception being Institutions (+10.5%) and Infrastructure (+21.8%). The largest negative variations from 2013 to 2018 are Market Sophistication (-16.0%), Human Capital and Research (-15.2%), and Business Sophistication (-12.7%).

Table 3. Portugal's GII ranking and scores

Variable	2013	2014	2015	2016	2017	2018	Δ 13-18
Input sub-index	39.83	40.76	42.13	41.23	41.61	39.63	-0.5%
Output sub-index	35.35	34.30	36.27	34.00	33.75	33.88	-4.2%
GII score	37.59	37.53	39.20	37.61	37.68	36.75	-2.2%
GII ranking	29	27	25	29	28	30	-1
Innovation Efficiency Index	0.887	0.842	0.861	0.825	0.811	0.855	-3.6%
Input pillars:							
Institutions	54.54	57.32	60.66	60.44	61.42	60.24	10.5%
Human Capital and Research	37.25	36.89	37.89	37.21	36.37	31.60	-15.2%
Infrastructure	40.63	42.65	45.35	47.94	50.00	49.48	21.8%
Market Sophistication	43.16	43.28	42.25	37.66	37.01	36.25	-16.0%
Business Sophistication	23.55	23.64	24.47	22.87	23.24	20.56	-12.7%
Output pillars:							
Knowledge and Technology Outputs	21.53	20.84	22.53	22.31	23.01	20.93	-2.8%
Creative Outputs	49.17	47.76	50.01	45.68	44.49	46.83	-4.8%

Source: Own calculations.

Table 4. Eurozone countries GII scores

Country	2013	2014	2015	2016	2017	2018	Δ 13-18
Austria	42.24	42.05	42.47	41.99	42.00	41.49	-1.8%
Belgium	39.38	38.84	39.10	39.26	39.14	38.49	-2.3%
Cyprus	38.39	33.92	33.71	35.70	35.60	34.59	-9.9%
Estonia	39.26	38.30	39.70	39.21	39.02	37.71	-3.9%
Finland	45.33	45.21	44.96	45.33	45.06	42.93	-5.3%
France	45.09	44.45	44.93	44.36	43.95	42.54	-5.7%
Germany	44.16	45.18	45.47	44.43	44.48	44.10	-0.1%
Greece	32.83	33.08	35.07	33.79	32.82	32.79	-0.1%
Ireland	45.35	45.32	45.63	43.86	42.62	41.69	-8.1%
Italy	37.62	36.97	38.45	37.78	37.29	36.94	-1.8%
Latvia	-	35.00	36.39	36.92	36.71	34.57	-1.2%
Lithuania	-	-	34.57	34.35	33.90	33.28	-3.7%
Luxembourg	42.24	40.05	40.98	40.33	41.05	39.09	-7.5%
Malta	34.54	34.79	35.03	35.28	37.46	36.78	6.5%
Netherlands	44.54	44.76	47.32	47.54	46.70	46.53	4.5%
Portugal	**37.59**	**37.53**	**39.20**	**37.61**	**37.68**	**36.75**	**-2.2%**
Slovakia	33.31	32.82	34.04	33.34	33.25	32.50	-2.4%
Slovenia	39.03	38.17	38.63	37.87	37.89	37.57	-3.7%
Spain	40.06	39.94	40.47	39.15	38.86	38.23	-4.6%
Eurozone Mean	**40.06**	**39.24**	**39.80**	**39.37**	**39.24**	**38.35**	**-4.3%**

Source: Own calculations.

Note: Latvia and Lithuania only joined the Eurozone in 2014 and 2015, respectively, hence the lack of values for such years. The variation for Latvia is from 2014 to 2018, and for Lithuania from 2015 to 2018.

Table 4 present the overall scores of Eurozone countries on the DuCa framework, highlighting Portugal's scores and Eurozone mean. Overall, there is evidence of a decrease on the innovation index in the Eurozone, consistent with the tendency explored in the previous section (**Table 2**). However, some countries have evolved positively from 2013 to 2018, namely Malta (+6.5%) and Netherlands (+4.5%). As for Portugal, although a negative trend persists (-2.2%), its decline was less pronounced than that of the Eurozone mean (-4.3%).

Table 5 shows a comparison of Portugal's scores against Eurozone's and Eurozone Top 3 performers' means, down to the pillar level, revealing that Portugal has space for improvement regarding its innovation convergence with its monetary partners. In a first analysis, comparing with Eurozone, in terms of innovation efficiency, Portugal is very close to Eurozone mean, having surpassed it in the last two years of the study. **Table 5** also reveals a positive gap, towards Portugal, in the Human Capital and Research pillar, although the country has been losing ground since 2014. Market Sophistication in Portugal has been deteriorating, comparatively with Eurozone mean, where a positive gap existed in the early years of the study, it became a negative one in the latter years. Also worthy of highlight, Portugal's largest gap towards Eurozone mean concerns Business Sophistication, which, in the last year, reached its peak (-23.8%), revealing an area worthy of improvement. Besides Business Sophistication, Portugal also presents moderately large gaps, towards the Eurozone, in Knowledge and Technology Outputs (-8.2% in 2018) and Infrastructure (-6.0% in 2018).

Comparing Portugal to Eurozone Top 3 performers, **Table 5** reveals that, in 2018, the larger gap was in the Business Sophistication pillar (-38%), followed by Knowledge and Technology Outputs (-28.7%), and Human Capital and Research (-24.3%). Regarding the Human Capital and Research, even though Portugal stands above Eurozone mean, there is still a considerable gap towards the top performers, meaning there is plenty of space for improvement in this area.

Table 5. Portugal yearly scores *versus* Eurozone and Eurozone Top 3 means

Variable		2013	2014	2015	2016	2017	2018
Input sub-index	Portugal	39.83	40.76	42.13	41.23	41.61	39.63
	Eurozone	42.28	42.24	42.72	42.70	43.45	41.66
	Eurozone Top 3	48.46	48.68	49.01	48.55	49.07	47.10
	Δ PRT vs Eurozone	-5.8%	-3.5%	-1.4%	-3.4%	-4.2%	-4.9%
	Δ PRT vs Top 3	-17.8%	-16.3%	-14.0%	-15.1%	-15.2%	-15.9%
Output sub-index	Portugal	35.35	34.30	36.27	34.00	33.75	33.88
	Eurozone	37.83	36.24	36.87	36.05	35.02	35.04
	Eurozone Top 3	43.39	42.41	43.95	43.06	42.12	42.82
	Δ PRT vs Eurozone	-6.6%	-5.4%	-1.6%	-5.7%	-3.6%	-3.3%
	Δ PRT vs Top 3	-18.5%	-19.1%	-17.5%	-21.0%	-19.9%	-20.9%
GII	Portugal	37.59	37.53	39.20	37.61	37.68	36.75
	Eurozone	40.06	39.24	39.80	39.37	39.24	38.35
	Eurozone Top 3	45.25	45.24	46.14	45.77	45.41	44.52
	Δ PRT vs Eurozone	-6.2%	-4.4%	-1.5%	-4.5%	-4.0%	-4.2%
	Δ PRT vs Top 3	-16.9%	-17.0%	-15.0%	-17.8%	-17.0%	-17.5%
Innovation Efficiency Index	Portugal	0.887	0.842	0.861	0.825	0.811	0.855
	Eurozone	0.897	0.859	0.862	0.844	0.805	0.840
	Eurozone Top 3	0.953	0.918	0.930	0.950	0.917	0.964
	Δ PRT vs Eurozone	-1.1%	-2.0%	-0.1%	-2.3%	0.7%	1.8%
	Δ PRT vs Top 3	-6.9%	-8.3%	-7.4%	-13.2%	-11.6%	-11.3%
Input pillars:							
Institutions	Portugal	54.54	57.32	60.66	60.44	61.42	60.24
	Eurozone	59.82	59.44	60.14	60.71	60.72	59.74
	Eurozone Top 3	70.00	69.58	68.73	69.00	67.70	66.94
	Δ PRT vs Eurozone	-8.8%	-3.6%	0.9%	-0.4%	1.2%	0.8%
	Δ PRT vs Top 3	-22.1%	-17.6%	-11.7%	-12.4%	-9.3%	-10.0%
Human Capital and Research	Portugal	37.25	36.89	37.89	37.21	36.37	31.60
	Eurozone	36.32	35.16	36.36	35.99	35.98	31.44
	Eurozone Top 3	48.73	48.06	48.29	48.95	57.17	41.74
	Δ PRT vs Eurozone	2.6%	4.9%	4.2%	3.4%	1.1%	0.5%
	Δ PRT vs Top 3	-23.6%	-23.2%	-21.5%	-24.0%	-36.4%	-24.3%
Infrastructure	Portugal	40.63	42.65	45.35	47.94	50.00	49.48
	Eurozone	43.71	44.95	48.15	50.42	53.19	52.64
	Eurozone Top 3	50.90	52.64	54.54	56.59	57.63	58.82
	Δ PRT vs Eurozone	-7.0%	-5.1%	-5.8%	-4.9%	-6.0%	-6.0%
	Δ PRT vs Top 3	-20.2%	-19.0%	-16.9%	-16.1%	-13.2%	-15.9%
Market Sophistication	Portugal	43.16	43.28	42.25	37.66	37.01	36.25
	Eurozone	41.74	42.24	40.20	37.79	37.76	37.51
	Eurozone Top 3	51.20	51.02	48.67	45.88	44.70	43.97
	Δ PRT vs Eurozone	3.4%	2.5%	5.1%	-0.3%	-2.0%	-3.4%
	Δ PRT vs Top 3	-15.7%	-15.2%	-13.2%	-17.9%	-17.2%	-17.6%
Business Sophistication	Portugal	23.55	23.64	24.47	22.87	23.24	20.56
	Eurozone	29.81	29.43	28.77	28.58	29.58	26.97
	Eurozone Top 3	37.97	36.16	36.34	35.36	36.50	33.15
	Δ PRT vs Eurozone	-21.0%	-19.7%	-14.9%	-20.0%	-21.4%	-23.8%
	Δ PRT vs Top 3	-38.0%	-34.6%	-32.7%	-35.3%	-36.3%	-38.0%
Output pillars:							
Knowledge and Technology Outputs	Portugal	21.53	20.84	22.53	22.31	23.01	20.93
	Eurozone	25.45	24.03	23.84	24.60	24.85	22.79
	Eurozone Top 3	31.74	30.74	30.95	32.17	32.03	29.35
	Δ PRT vs Eurozone	-15.4%	-13.3%	-5.5%	-9.3%	-7.4%	-8.2%
	Δ PRT vs Top 3	-32.2%	-32.2%	-27.2%	-30.6%	-28.2%	-28.7%
Creative Outputs	Portugal	49.17	47.76	50.01	45.68	44.49	46.83
	Eurozone	50.22	48.45	49.90	47.50	45.19	47.28
	Eurozone Top 3	54.26	55.56	57.38	56.54	51.93	57.33
	Δ PRT vs Eurozone	-2.1%	-1.4%	0.2%	-3.8%	-1.5%	-1.0%
	Δ PRT vs Top 3	-9.4%	-14.0%	-12.8%	-19.2%	-14.3%	-18.3%

Source: Own calculations.

CONCEPTUAL MODEL, LITERATURE REVIEW AND HYPOTHESIS

Having perceived Portugal's innovation position inside the Eurozone and possible areas for improvement, in this section we review the literature of national systems of innovation (NSI) and propose a conceptual model which intends to explain the relationship between innovation inputs and outputs. Therefore, we intend to relate this section's results to the previous contextual analyses, hence deriving policy implication for Portugal.

The national systems of innovations (NSI) perspective was introduced in the late 1980s (see Freeman, 1995; Lundvall, 1992; Nelson, 1993) and its diffusion among academic and policy circles has been surprisingly rapid (Teixeira, 2014). This approach, instead of focusing on specific aspects of innovation, takes on a more holistic perspective, emphasising the interactions between different actors and the influence of broader environmental factors, such as institutions (Edquist, 2006; Fagerberg *et al.*, 2010). A consensual definitions of NSI is still non-existent. Freeman (1987: 1) considers it to be a "network of institutions in the public and private sector which activities and interactions initiate, modify, and diffuse new technologies". Similarly, Nelson (1993: 4) defines them as "a set of institutions whose interactions determine the innovative performance (…) of national firms". From a different perspective, Lundvall (1992: 13) sees them as "all parts and aspects of the economic structure and the institutional setup affecting learning as well as searching and exploring". Although these definitions differ from one another, they encompass communalities, such as the focus on the relationships between institutions and organisations, and the interactions between them.

The measurement of NSI is a topic of ongoing debate (Gault, 2018; Grupp and Schubert, 2010; Nelson *et al.*, 2014; Smith, 2006). In a seminal contribution to this issue, Smith (2006) revisited the traditional indicators used to measure innovation (R&D intensity and patents) as well as more recent approaches. In its conclusions, the author admitted that future developments could come from multi-indicator approaches. Indeed, several international organisations have developed efforts to measure NSI, such as the European Commission (Summary Innovation Index - SII), World Economic Forum (Global Competitiveness Report - GCR), Cornell University, INSEAD, and WIPO (Global Innovation Index - GII), the Organization for Economic Co-Operation and Development (OECD Science, Technology, and Industry Scoreboard - STI).

The main body of NSI research using composite indicators encompass four different types of research with distinctive methodologies associated. First, in-depth case studies use existing frameworks, such as the Global Competitiveness Report (GCR), the Summary Innovation Index (SII) or the GII to evaluate a country or region (Alfantookh and Bakry, 2015; Marxt and Brunner, 2013), usually by comparison with other countries or regions. Second, drawing from existing frameworks, several studies develop alternative indices to rank the relative position of countries or regions (Barragán-Ocaña *et al.*, 2020; Edquist *et al.*, 2018; Zabala-Iturriagagoitia *et al.*, 2007). This studies typically consider an input-output framework since they adopt an efficiency perspective of NSI by means of data envelopment analysis methodologies. Third, to identify optimal configurational conditions of innovation, authors made use the innovation dimensions of the GII framework and apply a fuzzy-set qualitative comparative analysis (Crespo and Crespo, 2016; Khedhaouria and Thurik, 2017). Lastly, studies aimed at identifying structural relationships between the various dimensions of innovation use the structural equations modelling methodology with both existing frameworks such as the GII (Sohn *et al.*, 2016) and a collection of innovation indicators (Nasierowski and Arcelus, 1999). All of this research supports the notion that innovation inputs are transformed into innovative outputs. Also, Cornell University *et al.* (2018) describe a positive relationship between innovation inputs and outputs in every income groups, hence we propose the following hypothesis.

H1: Innovation Inputs have a Positive Relationship with Innovation Outputs

This pillar refers to the political environment (i.e. stability and effectiveness), the regulatory environment (i.e. rule of law and labour regulations), and business environment (i.e. ease of starting and ending a business). Institutions are understood as "humanly devised constraints that structure human interaction" (North, 1994: 360), which take the form of rules, laws, conventions or norms of behaviour. Lundvall (1992) recognised the institutional set up to be part of the national system of innovation, which, along with other factors, is capable of affect learning, searching, and exploring. Empirically, using patent grant data, Tebaldi and Elmslie (2013) found that institutional quality is positively related to patent counts across countries. On another study with a large sample of advanced and emerging economies, Silve and Plekhanov (2015) found that institutions are important determinants of innovation and, further still, that industries involving higher levels of innovation develop faster in countries with better economic institutions. Using GII data, Sohn *et al.* (2016) found a positive and indirect relationship between institutions and both knowledge and technological outputs and Creative Outputs. Previous research suggests that an institutional environment that provides good governance as well as protection and incentives is essential to innovation, hence we propose the following hypothesis.

H2a: Institutions have a positive relationship with Knowledge and Technology Outputs.

H2b: Institutions have a positive relationship with Creative Outputs.

Human capital and research pillar refer to countries' education (i.e. government expenditure and student performance), tertiary education (i.e. enrolment, mobility, and graduates) and research (i.e. researchers and R&D intensity and activities). From the national systems of innovation perspective, education is one of the drivers of innovation (Freeman, 1995), encompassing university systems, available human capital resources, and the available knowledge stock (Abel and Deitz, 2012; Bendapudi *et al.*, 2018; Freeman, 1995). Van Hiel *et al.* (2018), using a large sample of countries with great variation in terms of Human Development Index (HDI), found that increasing levels of education, in high HDI countries, translates into better scores on national indices of innovation through the increase of liberalisation values in such societies. Also, Suseno *et al.* (2018) found that human capital, as well as social capital, have a significant effect on national innovation performance. Regarding the role of research on innovation, Bilbao-Osorio and Rodriguez-Pose (2004) conclude that private R&D activities are positively related to innovation in the European Union (EU). Sohn *et al.* (2016) found positive direct and indirect relationships between Human Capital and Research and both output pillars. Following the rationale where education can be considered an input to R&D activities, consequently resulting in increased innovation at the country level, we propose the following hypothesis.

H3a: Human Capital and Research have a positive relationship with Knowledge and Technology Outputs.

H3b: Human Capital and Research have a positive relationship with Creative Outputs.

Infrastructure pillar encompasses information and communication technologies (i.e. assess, use, and electronic government), general infrastructure (i.e. electricity, logistics, and physical infrastructures), and ecological sustainability (i.e. sound environmental practices). The infrastructural dimension assumes that good and ecological infrastructures facilitate the production and exchange of ideas, services and goods, which allows firms to increase their productivity, get better access to markets, and lower transaction costs (Arendt and Grabowski, 2017; Cornell University et al., 2018). For example, Cuevas-Vargas *et al.* (2016) found that the use of ICTs is a critical facilitator of innovation for micro, small, and medium sized enterprises in Mexico. Also, Martins and Veiga (2018) conclude that innovations in Portugal's electronic government can lead to a more business-friendly environment, by reducing the administrative and regulatory burden. When analysing the drivers of EU's circular economy, Cainelli *et al.* (2020) suggest that an environmental policy and green demand leads to an increase in eco-innovations by EU firms. Also, Sohn *et al.* (2016) discovered that Infrastructure has an indirect, positive, relationship with the two output pillars. Therefore, it is likely that well developed infrastructures positively affect innovation, hence we propose the following hypothesis.

H4a: Infrastructure has a positive relationship with Knowledge and Technology Outputs.

H4b: Infrastructure has a positive relationship with Creative Outputs.

Market sophistication pillar refers to domestic market quality, namely in terms of credit (i.e. ease of getting credit and its availability), investment (i.e. protection of minority investors and market value), and trade, competition, and market scale (i.e. tariff rates, competition, and GDP). Economic and finance literatures reveal a relationship between financial markets' development and economic growth (Beck and Levine, 2002; King and Levine, 1993; La Porta *et al.*, 1998). Fagerberg and Srholec (2008) stressed the importance of a country's financial system in mobilising the necessary resources for innovation. Empirically, based on a three-decade panel of U.S. issued patents, Kortum and Lerner (2000) found that venture capital has a positive and significant impact on technological innovation. More recently, in a cross-country longitudinal study of the impact of financial market development on innovation, Hsu *et al.* (2014) found that industries more dependent on external financing and are high-tech intensive exhibit higher innovation levels in countries with better developed equity markets. When analysing debtor's protection rights, Cerqueiro *et al.* (2017) suggest that when debtor's protection increases innovation decreases, due to a reduction in credit supply to small firms, particularly for those highly dependent on external financing. These findings are in line with those of Amore *et al.* (2013), who discovered that the availability and quality of credit by US banks had a positive impact on firms' innovation. Also, Sohn *et al.* (2016) discovered a positive direct relationship between this pillar and both output pillars. As such, following the rationale that a country with sophisticated financial markets has better conditions for innovation to thrive, we propose the following hypothesis.

H5a: Market Sophistication has a positive relationship with Knowledge and Technology Outputs.

H5b: Market Sophistication has a positive relationship with Creative Outputs.

Business Sophistication pillar refers to knowledge workers (i.e. human capital employed by businesses), innovation linkages (i.e. linkages and partnerships between private, public and academic actors), and knowledge absorption (i.e. all high-tech and ICTs imports, intellectual property payments, FDI inflows, and researchers in business enterprises). For instance, Love and Mansury (2007), studying US business services, found that a highly qualified working force increases the probability of innovation. The authors also found that external linkages improve innovation performance. A study on Italian firms conducted by Maietta (2015) suggests that R&D collaboration between firms and universities have an impact on process innovation and a positive effect on product innovation for firms geographically closer to such entities. Also, Díez-Vial and Montoro-Sánchez (2016) found a positive relationship between the knowledge obtained by technology firms from universities and their levels of innovation. Regarding knowledge absorption, Liu and Zou (2008) found that R&D greenfield FDI significantly affects the innovation performance of domestic firms, finding evidence of both intra- and inter-industry spillovers. Also, Bertschek (1995) and Blind and Jungmittag (2004) found that both imports and inward FDI have positive and significant effects on product and process innovations. These results are in line with Khan and Yu (2019) suggestion that innovation is one the reasons why firms opt for global sourcing. Also, Sohn *et al.* (2016) discovered a positive direct relationship between the Business Sophistication pillar and the Creative Outputs pillar. Therefore, a country with higher business sophistication is likely to produce more innovative outputs, thus we propose the following hypothesis.

H6a: Business Sophistication has a positive relationship with Knowledge and Technology Outputs.

H6b: Business Sophistication has a positive relationship with Creative Outputs.

Figure 2 shows the proposed conceptual model, in which arrows represent the hypothesis developed above.

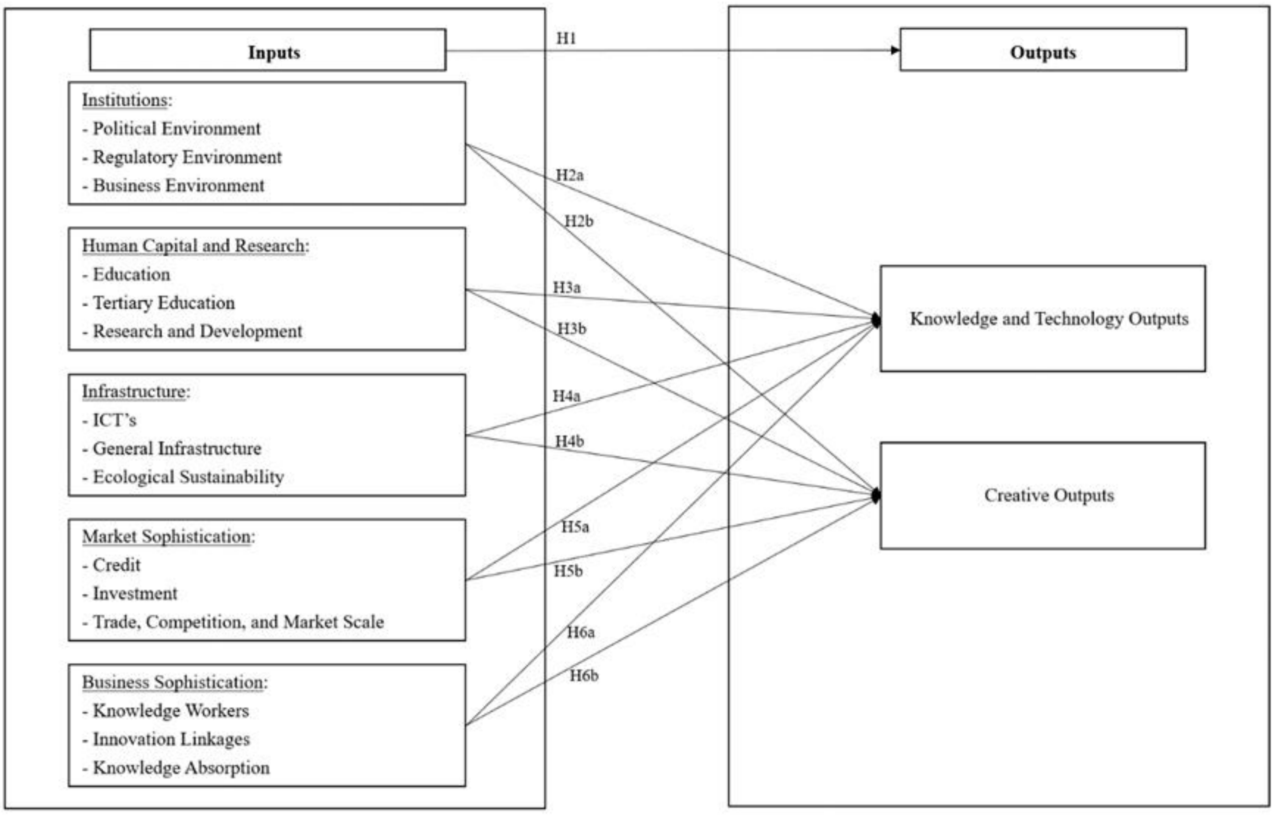

Figure 2. Conceptual model
Source: Own elaboration.

METHODOLOGY

Based on the DuCa framework put forth in section 3, we have developed a number of regression models in order to test the proposed hypothesis. We then applied the same models to a sub-sample composed exclusively of Eurozone members, in order to understand the behaviour of such relationships inside the European Monetary Union (EMU). All regressions were estimated using Gretl software (Cottrell and Lucchetti, 2009).

Data and Sample

As mentioned above, we have developed a panel dataset composed by 92 countries (see **Table A2** in **Appendix**) during the period 2013 to 2018. Besides GII raw data, other sources were used, namely the International Labour Organization statistics (ILOSTAT), the UNESCO Institute for Statistics (UIS), the UN Comtrade database, the World Development Indicators from the World Bank, the World Intellectual Property Organization (WIPO) database, and the World Trade Organization (WTO) DATA.

Variables

Dependent variables. To analyse the relationship between innovation inputs and outputs, we used three dependent variables in separate models. First, the output sub-index (Iout) is used to assess the effect of inputs on the overall score of innovation outputs. Then, we used the two output pillars (Knowledge and Technology Outputs (O6) and Creative Outputs (O7)) to further investigate the effects of innovation inputs in each outcome.

Independent variables. The explanatory variables used are the scores of the innovation input sub-index (Iin) and the five input pillars, Institutions (I1), Human Capital and Research (I2), Infrastructure (I3), Market Sophistication (I4), and Business Sophistication (I5).

Model Specification

When conducting linear regressions with panel data, several estimators could be used, being the most common the pooled ordinary least squares (pOLS), the fixed effects estimator (FE), and the random effects estimator (RE) (Baltagi, 2015; Wooldridge, 2016). To choose an appropriate estimator, one must consider the nature and source of the data, as well as the methodology used to obtain it (for a discussion, see Hsiao, 2007). Apart from the theoretical discussion, Gretl provides a set of three statistical tests can be used to choose a particular estimator, namely an F test, in which the null hypothesis favours pOLS and the alternative the FE estimator, a Breusch-Pagan test, in which the null hypothesis favours pOLS and the alternative the RE estimator, and the Hausman test, in which the null hypothesis favours the RE estimator and the alternative the FE estimator.

Table 6. Descriptive statistics, correlation matrix and variance inflation factors (VIF)

	N	Mean	S.D.	Iout	O6	O7	Iin	I1	I2	I3	I4	I5
Iout	552	28.16	8.26	-								
O6	552	19.42	6.10	0.908	-							
O7	552	36.89	11.27	0.974	0.789	-						
Iin	552	35.08	9.05	0.894	0.835	0.858	-					
I1	552	50.63	12.02	0.784	0.668	0.787	0.907	**3.387**				
I2	552	25.41	12.58	0.867	0.840	0.816	0.925	0.769	**4.189**			
I3	552	41.68	10.25	0.735	0.708	0.694	0.885	0.768	0.784	**3.197**		
I4	552	35.98	8.62	0.694	0.631	0.675	0.812	0.700	0.683	0.612	**2.212**	
I5	552	21.69	7.75	0.853	0.837	0.797	0.857	0.701	0.792	0.705	0.630	**2.945**

Source: Own calculations.

Note: Correlations values above 0.0835 are significant at the 5% level (two-tailed). VIF values are presented in the diagonal, in bold. Iout: Output sub-index; O6: Knowledge and technology outputs; O7: Creative outputs; Iin: Input sub-index; I1: Institutions; I2: Human capital and research; I3: Infrastructure; I4: Market sophistication; I5: Business sophistication.

In this sense, we developed four models in both pOLS and FE specification. The RE specification was not used, since the three tests indicated that a FE approach was appropriate. Therefore, to test hypothesis H1, we developed the following models:

$$Iout_{it} = \beta_0 + \beta_1 Iin_{it} + \delta_1 d14_t + \delta_2 d15_t + \delta_3 d16_t + \delta_4 d17_t + \delta_5 d18_t + \alpha_i + \mu_{it} \quad (1)$$

$$Iout_{it} = \beta_1 Iin_{it} + \delta_1 d14_t + \delta_2 d15_t + \delta_3 d16_t + \delta_4 d17_t + \delta_5 d18_t + \alpha_i + \mu_{it} \quad (2)$$

Where, Iout is the dependent variable for each country (*i*) in each year (*t*), β_0 is the intercept, β_1 is the slope of the variable of interest, δ_k (K=1,2,3,4,5) are the coefficients of year dummies included in the regression, α_i is the individual fixed effect that does not vary over time, and μ_{it} is the idiosyncratic error. We follow Wooldridge (2016) recommendation to include time dummies if T is small relative to N (in this case, T=6 and N=92), to capture secular changes that are not being modelled. Eq. 1 refers to the pOLS specification. Eq. 2 to the FE specification, which does not include a constant.

The following models were developed to test hypothesis H2a, H3a, H4a, H5a, and H6a:

$$O6_{it} = \beta_0 + \beta_1 I1_{it} + \beta_2 I2_{it} + \beta_3 I3_{it} + \beta_4 I4_{it} + \beta_5 I5_{it} + \delta_1 d14_t + \delta_2 d15_t + \delta_3 d16_t + \delta_4 d17_t + \delta_5 d18_t + \alpha_i + \mu_{it} \quad (3)$$

$$O6_{it} = \beta_1 I1_{it} + \beta_2 I2_{it} + \beta_3 I3_{it} + \beta_4 I4_{it} + \beta_5 I5_{it} + \delta_1 d14_t + \delta_2 d15_t + \delta_3 d16_t + \delta_4 d17_t + \delta_5 d18_t + \alpha_i + \mu_{it} \quad (4)$$

Where Eq. 3 refers to the pOLS specification and Eq. 4 to FE.

Lastly, to test hypothesis H2b, H3b, H4b, H5b, and H6b, we developed the following models:

$$O7_{it} = \beta_0 + \beta_1 I1_{it} + \beta_2 I2_{it} + \beta_3 I3_{it} + \beta_4 I4_{it} + \beta_5 I5_{it} + \delta_1 d14_t + \delta_2 d15_t + \delta_3 d16_t + \delta_4 d17_t + \delta_5 d18_t + \alpha_i + \mu_{it} \quad (5)$$

$$O7_{it} = \beta_1 I1_{it} + \beta_2 I2_{it} + \beta_3 I3_{it} + \beta_4 I4_{it} + \beta_5 I5_{it} + \delta_1 d14_t + \delta_2 d15_t + \delta_3 d16_t + \delta_4 d17_t + \delta_5 d18_t + \alpha_i + \mu_{it} \quad (6)$$

Where Eq. 5 refers to pOLS specification and Eq. 6 to FE.

RESULTS AND DISCUSSION

Table 6 shows the main descriptive statistics, the correlation matrix, and variance inflation factors (VIF). An analysis of the correlation matrix reveals the existence of significant correlations between the variables. Although a high correlation was expected between the input and output sub-indexes and their respective pillars, the existing correlations between the five input pillars could result in multicollinearity issues when regressed together. However, the highest VIF value (4.189 for variable I3) is below the common rule of thumb of 10 (Wooldridge, 2016), which indicates that multicollinearity should not be a problem.

Tables 7 and **8** displays the results of the regressions used to test our hypothesis. Starting with the simple pooled OLS (pOLS), we can see that all panel tests indicate that a fixed effect (FE) approach is adequate. Together, the F, Breusch-Pagan, and Hausman tests reject the pOLS and random effects (RE) specifications, in favour of the FE approach. Also, the Welch F test rejects the null hypothesis that groups have a common intercept, thus rendering pOLS inadequate. Regarding the inclusion of time dummies, a Wald joint test rejects the null hypothesis of no time effects. Both pOLS and FE specifications are reported, however only the results from FE are discussed.

With the first model we intended to test if, in our sample, innovation inputs (Iin) are, in fact, transformed into innovation outputs (Iout) (Column 2, **Table 7**). Results reveal a surprising negative relationship between Innovation Inputs and Outputs sub-indices, although without statistical significance. This seems to contradict Cornell University *et al.* (2018), however, the authors obtained such evidence using an OLS estimator in a cross-sectional sample and our pOLS results (Column 1, **Table 7**) seem to corroborate this finding. Therefore, our results do not support Hypothesis H1.

Table 7. Results of regressions

Dependent Variable	Iout	
Model	pOLS	FE
	(1)	(2)
Const.	1.814†	-
	(1.060)	
Iin	0.832***	-0.089
	(0.031)	(0.079)
N	552	552
Adj. R^2	0.8483	
Within R^2		0.5327
BIC	2 893.288	2 395.491
Time dummies	Yes	Yes
Wald F (5, 91)	77.141***	53.201***
Panel tests:		
F (91, 454)	29.820***	
Breusch-Pagan	754.472***	
Hausman	185.983***	
Welch F (91, 156.7)		24.503***

Source: Own calculation.

Note: † p ≤ 0.1; * p ≤ 0.05; ** p ≤ 0.01; *** p ≤ 0.001. Below the coefficients are heteroskedasticity and autocorrelation (HAC) robust standard errors, in parenthesis. Iout: Output sub-index; Iin: Input sub-index; I1: Institutions; I2: Human capital and research; I3: Infrastructure; I4: Market sophistication; I5: Business sophistication; pOLS: Pooled OLS estimator; FE: Fixed effects estimator.

Table 8. Results of regressions (continuation)

Dependent Variable	O6		O7	
Model	pOLS	FE	pOLS	FE
	(3)	(4)	(5)	(6)
Const.	5.473***	-	4.813†	-
	(1.304)		(2.653)	
I1	-0.054	-0.049	0.267***	-0.122
	(0.047)	(0.033)	(0.051)	(0.083)
I2	0.213***	0.018	0.184*	-0.088*
	(0.038)	(0.029)	(0.075)	(0.044)
I3	0.075†	0.047	0.220**	-0.081
	(0.045)	(0.036)	(0.082)	(0.064)
I4	0.032	-0.020	0.011	-0.107
	(0.042)	(0.040)	(0.072)	(0.080)
I5	0.348***	0.079†	0.424***	0.099
	(0.057)	(0.041)	(0.089)	(0.067)
N	552	552	552	552
Adj. R^2	0.7885		0.8285	
Within R^2		0.2847		0.5693
BIC	2 763.213	2 140.114	3 325.905	3 036.776
Time dummies	Yes	Yes	Yes	Yes
Wald F (5, 91)	5.370***	21.492***	48.484***	37.984***
Panel tests:				
F (91, 450)	38.325***		18.696***	
Breusch-Pagan	836.190***		570.579***	
Hausman	116.239***		159.923***	
Welch F (91, 156.7)		47.884***		18.582***

Source: Own calculation.

Note: † p ≤ 0.1; * p ≤ 0.05; ** p ≤ 0.01; *** p ≤ 0.001. Below the coefficients are heteroskedasticity and autocorrelation (HAC) robust standard errors, in parenthesis. O6: Knowledge and technology outputs; O7: Creative outputs; I1: Institutions; I2: Human capital and research; I3: Infrastructure; I4: Market sophistication; I5: Business sophistication; pOLS: Pooled OLS estimator; FE: Fixed effects estimator.

Table 8 shows the results of regressing the five input pillars on both output pillars. When analysing the effects of input pillars on Knowledge and Technology Outputs (O6) (Column 4, **Table 8**), we found that only Business Sophistication has a significant effect (p = 0.0575) with a positive sign, thus supporting Hypothesis H6a. As such, results do not support Hypothesis H2a, H3a, H4a, and H5a. However, we also found negative effects, albeit not statistically significant, of Institutions (I1) and Market Sophistication (I4) on Knowledge and Technology Outputs (O6). On Column 6 (**Table 8**), only Human Capital and Research (I2) was found to have a statistically significant relationship with Creative Outputs (O7) (p = 0.0483) which, having a negative sign, rejects Hypothesis H3b. The remaining input pillars did not attain statistical significance, hence failing to support Hypothesis H2b, H4b, H5b, and H6b.

Of the two output pillars, results suggest that Business Sophistication relates more to the traditional measures of innovation (i.e., Knowledge and Technology Outputs) than to more creative forms of innovation (i.e., Creative Outputs), suggesting that the employment of knowledge workers, the quality of linkages between public organisations, universities, and private firms, and the

Table 9. Results of Fixed Effects regressions (Eurozone sub-sample)

Dependent Variable	Iout	O6	O7
Model	FE	FE	FE
	(7)	(8)	(9)
Iin	0.254	-	-
	(0.226)		
I1	-	0.055	-0.093
		(0.142)	(0.115)
I2	-	0.007	-0.117
		(0.048)	(0.073)
I3	-	0.091	-0.095
		(0.114)	(0.089)
I4	-	-0.025	0.023
		(0.118)	(0.126)
I5	-	0.298†	0.300*
		(0.153)	(0.132)
N	111	111	111
Within R^2	0.3893	0.4183	0.6183
BIC	447.751	466.980	516.625
Time dummies	Yes	Yes	Yes
Wald F (5, 18)	14.896***	8.153***	18.993***

Source: Own calculation.
Note: † p ≤ 0.1; * p ≤ 0.05; ** p ≤ 0.01; *** p ≤ 0.001. Below the coefficients are heteroskedasticity and autocorrelation (HAC) robust standard errors, in parenthesis. Iout: Output sub-index; O6: Knowledge and technology outputs; O7: Creative outputs; Iin: Input sub-index; I1: Institutions; I2: Human capital and research; I3: Infrastructure; I4: Market sophistication; I5: Business sophistication; FE: Fixed effects estimator.

economy's knowledge absorption capacity are strong inducers of technological innovation. Similar conclusions can be found in several studies (Bertschek, 1995; Blind and Jungmittag, 2004; Díez-Vial and Montoro-Sánchez, 2016; Liu and Zou, 2008; Love and Mansury, 2007; Maietta, 2015).The negative relationship observed between Human Capital and Research and Creative Outputs could probably be one of methodological concern. One could argue that investments in education and research are not instantaneously transformed into innovation outputs. To this end, we have introduced time lags, up to two years, in this variable. In both cases, it loses its statistical significance but remains with a negative sign. It is likely that longer time-series are needed to properly assess this relationship. It is also likely that mediating and/or moderating effects could be present, as noted by Sohn *et al.* (2016), thus explaining the negative direct relationship. Also, by pooling a large number of countries with very different levels of development of education, research and innovation, the negative influences could outweigh the positive ones in our sample.

Eurozone Analyses

In order to approximate our estimations to Portugal, in this section we conduct similar analyses with a Eurozone sub-sample. Therefore, results could serve as references to derive policy implication for Portugal. **Table 9** presents the results of FE regressions conducted in the Eurozone sub-sample, which is composed by the 19 countries using the Euro during the period 2013-2018, excluding Latvia in 2013 and Lithuania in 2013 and 2014 since their affiliation happened afterwards. Only FE regressions are presented for the sake of brevity, but pOLS estimations are available upon request.

Contrary to previous findings using the full sample (Column 2, **Table 7**), the relationship between innovation inputs and outputs changes its sign in Eurozone countries, although without attaining statistical significance (p = 0.2763). By analysing the five input pillars, only Business Sophistication revealed a positive statistically significant relationship with both Knowledge and Technology Outputs (O6) (Column 8, **Table 9**) and Creative Outputs (O7) (Column 9, **Table 9**), with p = 0.0678 and p = 0.0361, respectively. The relationship with Creative Outputs now visible, is in line with findings of Sohn, Kim and Jeon (2016). Although none of the remaining input pillars showed a statistically significant relationship with either Knowledge and Technology Outputs or Creative Outputs, their signs change according to the dependent variable used. While Institutions (I1), Human Capital and Research (I2), and Infrastructure (I3) showed a positive sign when regressed over Knowledge and Technology Outputs, those variables revealed a negative sign when regressed over Creative Outputs, with Market Sophistication (I4) having the opposite behaviour.

Next, we make a deeper analysis of the Eurozone sub-sample, by decomposing the five input pillars into their 15 input sub-pillars (**Table 10**) and using them as explanatory variables.

This detailed analysis reveals which sub-pillars are responsible for the results presented above in the Eurozone sub-sample. A negative and statistically significant relationship was found between Research and Development (I23) and Creative Outputs (p = 0.0013) (Column 15, **Table 10**), while the same statistical significance is not present regarding its relationship with Knowledge and Technology Outputs (O6), albeit remaining with a negative sign (Column 14, **Table 10**). This result could be due to different R&D sectors. Bilbao-Osorio and Rodriguez-Pose (2004) argue that public R&D may not be a net contributor to the innovation process since it is mainly associated with basic research. Ecological Sustainability (I33) shows a positive, statistically significant, relationship with Knowledge and Technology Outputs (p = 0.0048). This is in line with Cainelli *et al.* (2020), who suggest that environmental policies drive the adoption of eco-innovation by firms. Trade, Competition, and Market Scale (I43) also presents a positive and statistically significant relationship, below the 10% level, with Creative Outputs (p = 0.0718). Perhaps the most revealing result is the positive relationship, with a strong statistical significance, between Knowledge Absorption (I53) and both

Table 10. Results of Fixed Effects regressions using all input sub-pillars (Eurozone sub-sample)

Dependent Variable	O6	O7
Model	FE	FE
	(10)	(11)
I11	0.035	0.113
	(0.116)	(0.183)
I12	0.023	-0.151
	(0.039)	(0.095)
I13	0.032	0.036
	(0.067)	(0.066)
I21	0.025	-0.005
	(0.021)	(0.032)
I22	-0.093	-0.093
	(0.090)	(0.056)
I23	-0.042	-0.165**
	(0.033)	(0.043)
I31	-0.014	-0.065
	(0.043)	(0.043)
I32	-0.002	-0.035
	(0.097)	(0.101)
I33	0.163**	0.065
	(0.051)	(0.088)
I41	-0.047	-0.003
	(0.053)	(0.072)
I42	0.018	-0.018
	(0.055)	(0.057)
I43	0.168	0.205†
	(0.108)	(0.107)
I51	0.037	0.078
	(0.052)	(0.077)
I52	-0.019	-0.013
	(0.059)	(0.107)
I53	0.228**	0.195***
	(0.069)	(0.041)
N	111	111
Within R^2	0.5795	0.6785
BIC	478.036	544.667
Time dummies	Yes	Yes
Wald F (5, 18)	6.186**	9.807***

Source: Own calculation.
Note: † p ≤ 0.1; * p ≤ 0.05; ** p ≤ 0.01; *** p ≤ 0.001. Below the coefficients are heteroskedasticity and autocorrelation (HAC) robust standard errors, in parenthesis. O6: Knowledge and technology outputs; O7: Creative outputs; I11: Political environment; I12: Regulatory environment; I13; Business environment; I21: Education; I22: Tertiary education; I23: Research and development; I31: Information and communication technologies; I32: General infrastructure; I33: Ecological sustainability; I41: Credit; I42: Investment; I43: Trade, competition, and market scale; I51: Knowledge workers; I52: Innovation linkages; I53: Knowledge absorption; FE: Fixed effects estimator.

Knowledge and Technology Outputs (p = 0.0041) and Creative Outputs (p = 0.0002). This is in line with the absorption capacity perspective (Cohen and Levinthal, 1990), in which the ability to recognise and incorporate external knowledge into the firm's products and processes leads to higher levels of innovation (Gkypali *et al.*, 2018).

Implications for Portugal

Following the results obtained in previous section, we now derive some policy implication for Portugal regarding improvements in its comparative levels of innovation. We start with a simple exercise, with which we intend to demonstrate the importance of certain policies on the convergence of Portugal with the Eurozone. First, we have selected the Knowledge Absorption sub-pillar due its significant effects on both innovations outputs and because it belongs to the pillar in which Portugal has a larger gap towards the Eurozone. Then, we have computed the difference between Portugal average score (25.356) and Eurozone's (32.410) (averages for the period 2013-2018). The value was then multiplied by the estimated coefficient of Knowledge Absorption (I53) in each of the regressions presented in **Table 10**. The same reasoning was made for the top Eurozone performer, which, for this sub-pillar, is the Netherlands (48.441).

Table 11 shows potential benefits for innovation outputs if policies are developed to improve Business Sophistication areas in Portugal, namely those related to Knowledge Absorption. As mentioned above, Business Sophistication is the area where Portugal has a larger gap toward the Eurozone, having an average difference of 20% to other Eurozone countries and more than 35% to Eurozone top performers. Recalling **Table 10**, policies towards the attraction of FDI, or incentives to high-tech imports, are likely to enhance Portugal's innovation output performance. However, caution must be taken when interpreting this results, since, as suggested by Liu and Zou (2008), different kinds of FDI might have differentiated effects on Portugal's innovation performance. Another area where Portugal stands behind the Eurozone is Infrastructure. Results suggest that Ecological Sustainability has a

Table 11. Estimated impact of Portugal's convergence on the Knowledge Absorption sub-pillar with the Eurozone average and top performer

Variable	Estimated coefficient for Knowledge Absorption	Impact of convergence to the Eurozone average	Impact of convergence to the top Eurozone performer (Netherlands)
O6 (Eurozone)	0.228	1.608	5.263
O7 (Eurozone)	0.195	1.376	4.502

I. Source: Own calculations.

Note: O6: Knowledge and technology outputs; O7: Creative outputs.

positive effect on Knowledge and Technology Outputs, hence, improving Portugal's environmental performance, as well as having more firms with ISO 14001 certificates, could result in higher innovation outputs. Regarding negative relationships found, further research is needed to understand their causes before implications can be drawn.

CONCLUSIONS

With this paper we sought to understand which innovation inputs had a greater contribution to innovative outputs. In an effort to derive policy implication for Portugal, we narrowed our analysis to a group of countries that share innovation policies and regulations, as well their national currencies, with Portugal, the Eurozone. To that end, we have adopted the framework provided by the Global Innovation Index, due to its clear distinction between innovation inputs and outputs, and, acknowledging methodological limitations induced by its own cross-sectional nature, we have developed our own panel data version (DuCa framework).

Overall, results suggest some surprising negative relationships between Institutions, Human Capital and Research and innovation outputs. Such results should be taken with some caution, since those are areas where investments tend to require some years to pay off, as is the case of institutional change, education and R&D. Furthermore, Goedhuys *et al.* (2016) suggest that corruption can take the role of "grease in the wheels" when institutional obstacles are encountered, being otherwise an impediment to firm's innovation in sound business environments. Positive relationships have also been found, namely in Business Sophistication area, which revealed to be stronger when analysing Eurozone alone. Further analyses revealed that those effects came essentially from areas such as the imports of high-tech goods, ICT services, and knowledge, as well as the presence of researchers in businesses and inward FDI. This suggest that the overall Knowledge Absorption of countries in the Eurozone is key in determining their innovative readiness.

Therefore, we argue that policies directed at improving domestic firms' knowledge absorption capacity are likely to enhance Portugal's innovative outputs, especially benefiting from the convergence to average Eurozone levels.

Limitations and Future Research

As with every research, our study has its limitations which ought to be acknowledged. The use of an index could be, in itself, a limitation. Nonetheless, we consider it a solid indicator of national innovativeness, since it blends hard data with experts' opinions on a number of issues. Also, the GII is developed by some of the most important business and economics schools in cooperation with major international organisations.

The limited time period available impedes a longer analysis of the influence of certain variables, which we believe could have their impact felt further down the road. This limitation could be of extreme importance regarding the negative effects found throughout the paper, since investments in certain areas, such as education, R&D, or public infrastructures, might require several years to attain the desired outcome. As such, further research is necessary to explore the causes of negative relationships between innovation inputs and outputs found in this paper.

Another possibly relevant constraint is the absence of control variables, commonly found in this type of empirical analyses (e.g. Martins and Veiga, 2018). However, the indicators used in the construction of this index already contemplate the vast majority of controls used in the literature.

Lastly, research is needed regarding the most significant results of this study, the impact of Knowledge Absorption on both innovation outputs. Notwithstanding the other indicators relating to imports of goods, services, and knowledge, and the presence of researchers in businesses, we consider that inward FDI plays a major role in the innovative capacity of a country, mainly due to its dual effect on domestic firms: first, by increasing the competition in the local market, domestic firms tend to innovate to maintain their market position (Bertschek, 1995; Blind and Jungmittag, 2004); and second, different types of FDI could have differentiated effects on domestic firms capacity to innovate (Liu and Zou, 2008). Owing to the latter effect, Liu and Zou (2008) found that greenfield R&D FDI presented both intra- and inter-industry spillovers, while mergers and acquisitions produced only inter-industry spillovers. To derive more fine-grained policy implication to Portugal, one should rely on inward FDI data at the firm level, thus being able to control other firm's factors that cannot be measured at the country level.

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APPENDIX

Table A1. Variables used, codes, definitions, sources and time-series

Code	Indicator	Definition	Source	Period
111	Political stability and absence of violence / terrorism	Political stability and absence of violence / terrorism index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
112	Government effectiveness	Government effectiveness index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
121	Regulatory quality	Regulatory quality index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
122	Rule of law	Rule of law index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
123	Cost of redundancy dismissal	Sum of notice period and severance pay for redundancy dismissal (in salary weeks, averages for worker with 1, 5, 10 years of tenure, with a minimum threshold of 8 weeks)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
131	Ease of starting a business	Ease of starting a business (distance to frontier)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
132	Ease of resolving insolvency	Ease of resolving insolvency (distance to frontier)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
133	Ease of paying taxes	Ease of paying taxes (distance to frontier)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2017
211	Expenditure on education	Government expenditure on education (% of GDP)	UNESCO Institute for Statistics (http://data.uis.unesco.org/#)	2011 – 2016
212	Initial government funding per secondary student	Initial government funding per secondary student (% of GDP per capita)	UNESCO Institute for Statistics (http://data.uis.unesco.org/#)	2011 – 2016
213	School life expectancy	School life expectancy, primary to tertiary education, both sexes (years)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
214	Assessment in reading, mathematics, and science	PISA average scales in reading, mathematics, and science	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
215	Pupil-teacher ratio, secondary	Pupil-teacher ratio, secondary	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
221	Tertiary enrolment	School enrolment, tertiary (% gross)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
222	Graduates in science and engineering	Tertiary graduates in science, engineering, manufacturing, and construction (% of total tertiary graduates)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
223	Tertiary-level inbound mobility	Tertiary-level inbound mobility rate (%)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
231	Researchers	Researchers, full-time equivalent (FTE) (per million inhabitants)	UNESCO Institute for Statistics (http://data.uis.unesco.org/#)	2011 – 2016
232	Gross expenditure on R&D (GERD)	GERD: Gross expenditure on R&D (% of GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
233	QS university ranking average score of top 3 universities	Average score of the top 3 universities at the QS world university ranking	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
311	ICT access	ICT access index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
312	ICT use	ICT use index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
313	Government's online service	Government's online service index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
314	Online e-participation	E-participation index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
321	Electricity output	Electricity output (kWh per capita)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
322	Logistics performance	Logistics Performance Index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
323	Gross capital formation	Gross capital formation (% of GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
331	GDP per unit of energy use	GDP per unit of energy use (2010 PPP$ per kg of oil equivalent)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
332	Environmental performance	Environmental Performance Index	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
333	ISO 14001 environmental certificates	ISO 14001 Environmental management systems – Requirements with guidance for use: Number of certificates issued (per bn PPP$ GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
411	Ease of getting credit	Ease of getting credit (distance to frontier)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
412	Domestic credit to private sector	Domestic credit to private sector (% of GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
413	Microfinance institutions' gross loan portfolio	Microfinance institutions: Gross loan portfolio (% of GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
421	Ease of protecting minority investors	Ease of protecting minority investors (distance to frontier)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018

Source: Own elaboration.

Table A1 (continued). Variables used, codes, definitions, sources and time-series

Code	Indicator	Definition	Source	Period
422	Market capitalisation	Market capitalisation of listed domestic companies (% of GDP)	World Bank, World Development Indicators (https://databank.worldbank.org/data/source/world-development-indicators)	2012 – 2017
423	Total value of stocks traded	Stocks traded, total value (% of GDP)	World Bank, World Development Indicators (https://databank.worldbank.org/data/source/world-development-indicators)	2012 – 2017
424	Venture capital deals	Venture capital per investment location: Number of deals (per bn PPP$ GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
431	Applied tariff rate, weighted mean	Tariff rate, applied, weighted mean, all products (%)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
432	Intensity of local competition	Average answer to the survey question: In your country, how intense is the competition in the local markets? [1 = not intense at all; 7 = extremely intense]	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
433	Domestic market scale	Domestic market as measured by GDP, PPP (current international $)	World Bank, World Development Indicators (https://databank.worldbank.org/data/source/world-development-indicators)	2012 – 2017
511	Employment in knowledge-intensive services	Employment in knowledge intensive services (% of workforce)	International Labour Organization ILOSTAT (https://www.ilo.org/ilostat/)	2012 – 2017
512	Firms offering formal training	Firms offering formal training (% of firms)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
513	GERD performed by business enterprise	GERD: Performed by business enterprise (% of GDP)	UNESCO Institute for Statistics (http://data.uis.unesco.org/#)	2011 – 2016
514	GERD financed by business enterprise	GERD: Financed by business enterprise (% of total GERD)	UNESCO Institute for Statistics (http://data.uis.unesco.org/#)	2011 – 2016
515	Females employed with advanced degrees	Females employed with advanced degrees, % of total employed (25+ years old)	International Labour Organization ILOSTAT (https://www.ilo.org/ilostat/)	2012 – 2017
521	University / industry research collaboration	Average answer to the survey question: In your country, to what extent do businesses and universities collaborate on research and development (R&D)? [1 = do not collaborate at all; 7 = collaborate extensively]	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
522	State of cluster development	in the economy: In your country, how widespread are well-developed and deep clusters (geographic concentrations of firms, suppliers, producers of related products and services, and specialized institutions in a particular field)? [1 = non-existent; 7 = widespread in many fields]	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
523	GERD financed by abroad	GERD: Financed by abroad (% of total GERD)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
524	Joint venture / strategic alliance deals	Joint ventures / strategic alliances: Number of deals, fractional counting (per bn PPP$ GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
531	Intellectual property payments	Charges for use of intellectual property n.i.e., payments (% of total trade)	World Trade Organization (https://data.wto.org/)	2012 – 2017
532	High-tech imports	High-tech net imports (% of total trade)	United Nations Comtrade database (https://comtrade.un.org/data/)	2012 – 2017
533	ICT services imports	Telecommunications, computers, and information services imports (% of total trade)	World Trade Organization (https://data.wto.org/)	2012 – 2017
534	Foreign direct investment net inflows	Foreign direct investment (FDI), net inflows (% of GDP)	World Bank, World Development Indicators (https://databank.worldbank.org/data/source/world-development-indicators)	2012 – 2017
535	Research talent in business enterprise	Researchers in business enterprise (%)	UNESCO Institute for Statistics (http://data.uis.unesco.org/#)	2011 - 2016
611	Patent applications by origin	Number of resident patent applications filed at a given national or regional patent office (per bn PPP$ GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
612	PCT international applications by origin	Number of international patent applications filed by residents at the Patent Cooperation Treaty (per bn PPP$ GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
613	Utility model applications by origin	Number of utility model applications filed by residents at the national patent office (per bn PPP$ GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
614	Scientific and technical publications	Number of scientific and technical journal articles (per bn PPP$ GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
615	Citable documents H index	The H index is the economy's number of published articles (H) that have received at least H citations	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
621	Growth rate of GDP per person engaged	Growth rate of GDP per person engaged (constant 2011 PPP$)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
622	New business density	New business density (new registrations per thousand population 15–64 years old)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
623	Total computer software spending	Total computer software spending (% of GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018

Source: Own elaboration.

Table A1 (continued). Variables used, codes, definitions, sources and time-series

Code	Indicator	Definition	Source	Period
624	ISO 9001 quality certificates	ISO 9001 Quality management systems—Requirements: Number of certificates issued (per bn PPP$ GDP)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
625	High-tech and medium-high-tech output	High-tech and medium-high-tech output (% of total manufactures output)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2017
631	Intellectual property receipts	Charges for use of intellectual property n.i.e., receipts (% of total trade)	World Trade Organization (https://data.wto.org/)	2012 – 2017
632	High-tech exports	High-tech net exports (% of total trade)	United Nations Comtrade database (https://comtrade.un.org/data/)	2012 – 2017
633	ICT services exports	Telecommunications, computers, and information services exports (% of total trade)	World Trade Organization (https://data.wto.org/)	2012 – 2017
634	Foreign direct investment net outflows	Foreign direct investment (FDI), net outflows (% of GDP)	World Bank, World Development Indicators (https://databank.worldbank.org/data/source/world-development-indicators)	2012 – 2017
711	Trademark application class count by origin	Number of trademark applications issued to residents at a given national or regional office (per billion PPP$ GDP)	World Intellectual Property Organization, WIPO Statistics Database (https://www3.wipo.int/ipstats/index.htm)	2012 – 2017
712	Industrial designs by origin	Number of designs contained in industrial design applications filled at a given national or regional office (per billion PPP$ GDP)	World Intellectual Property Organization, WIPO Statistics Database (https://www3.wipo.int/ipstats/index.htm)	2012 – 2017
713	ICTs and business model creation	Average answer to the question: In your country, to what extent do ICTs enable new business models? [1 = not at all; 7 = to a great extent]	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
714	ICTs and organizational model creation	Average answer to the question: In your country, to what extent do ICTs enable new organizational models (e.g., virtual teams, remote working, telecommuting) within companies? [1 = not at all; 7 = to a great extent]	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
721	Cultural and creative services exports	Cultural and creative services exports (% of total trade)	World Trade Organization (https://data.wto.org/)	2012 – 2017
722	National feature films produced	Number of national feature films produced (per million population 15–69 years old)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
723	Entertainment and media market	Entertainment and media market (per thousand population 15–69 years old)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2014 – 2018
724	Printing publications and other media output	Printing publications and other media (% of manufactures total output)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2017
725	Creative goods exports	Creative goods exports (% of total trade)	United Nations Comtrade database (https://comtrade.un.org/data/)	2012 – 2017
731	Generic top-level domains (gTLDs)	Generic top-level domains (gTLDs) (per thousand population 15–69 years old)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
732	Country-code top-level domains (ccTLDs)	Country-code top-level domains (ccTLDs) (per thousand population 15–69 years old)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2018
733	Wikipedia monthly edits	Wikipedia monthly page edits (per million population 15–69 years old)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2016
734	Video uploads on YouTube	Number of video uploads on YouTube (scaled by population 15–69 years old)	Global Innovation Index (https://www.globalinnovationindex.org/analysis-indicator)	2013 – 2017

Source: Own elaboration.

Table A2. Countries in the sample

Albania	Egypt	Kyrgyz Republic	Romania
Algeria	Estonia	Latvia	Russian Federation
Argentina	Finland	Lithuania	Saudi Arabia
Armenia	France	Luxembourg	Senegal
Australia	Georgia	Madagascar	Serbia
Austria	Germany	Malaysia	Singapore
Azerbaijan	Greece	Malta	Slovak Republic
Bahrain	Guatemala	Mauritius	Slovenia
Bangladesh	Hong Kong	Mexico	South Africa
Belarus	Hungary	Moldova	Spain
Belgium	Iceland	Mongolia	Sri Lanka
Bolivia	India	Morocco	Sweden
Bosnia and Herzegovina	Indonesia	Netherlands	Switzerland
Brazil	Iran	New Zealand	Tajikistan
Bulgaria	Ireland	Nigeria	Thailand
Canada	Israel	North Macedonia	Tunisia
Chile	Italy	Norway	Turkey
China	Jamaica	Pakistan	Uganda
Colombia	Japan	Panama	Ukraine
Costa Rica	Jordan	Peru	United Kingdom
Cyprus	Kazakhstan	Philippines	United States of America
Czech Republic	Kenya	Poland	Uruguay
Denmark	Korea, Republic of	Portugal	Vietnam

Source: Own elaboration.