Oradea Journal of Business and Economics, Volume VII, Issue 1
Published on March 2022

EXPLORING THE DETERMINANTS OF R&D INVESTMENT IN THE ASIAN CONTEXT BEFORE AND AFTER COVID19

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Abstract: *The article aims to study the mechanisms underlying the development of research and development (R&D) through investment in renewable energies and in ICTs before and after the Covid19 pandemic. First, we perform a dynamic panel regression through panel data from 2000 to 2019 for 14 Asian countries. In addition to economic and environmental determinants, the empirical study reveals that variables linked to intellectual property are the drivers of R&D investment in the Asian region. It is interesting to note that while brand requests stimulate R&D, industrial applications hamper this type of investment. Second, we provide an OLS regression of 38 Asian countries to analyze the effect of Covid-19 on research and development. Our empirical results encourage governments to invest more in renewable energies not only to reduce the greenhouse effect, but also to increase investment in R&D. In addition, policymakers are urged to apply more incentives to expand the export of ICT in both services and products.*

Keywords: Dynamic panel regression, research and development, pollution exposure, renewable energy, ICT export.

JEL Classifications: O14, O16, Q43, Q56.

1. Introduction

Innovation is one of the main determinants of economic development for countries around the world. Several researchers have analyzed innovation indicators including research and development (Chawla 2019 and patent filings (Crepon and Duguet 1994). A significant number of studies have analyzed the role of innovation mechanisms in companies within the industrial sector (Jegede et al. 2019) and services (Jegede et al. 2013). Although these studies have made important contributions to better understand the dynamics of innovation (Olaoye et al. 2020; Evangelista 2006; Qiu et al. 2020) the question of the determinant of technological development is still limited. Fewer studies have developed the stimulating factors for these research and development (R&D) mechanisms. Or it seems paradoxical, because in recent years, the R&D indicator has accumulated remarkable growth in 2017 like France which has accumulated an increase of 1.5% with an amount of 50.6 billion euros (€).

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Cite as:
Loukil, S., Kammoun, S., and Ben Romdhane, Y., 2022. Exploring the Determinants of R&D Investment in the Asian Context Before and After Covid19. *Oradea Journal of Business and Economics,* 7(1), pp. 30-44, http://doi.org/10.47535/1991ojbe136

In the same year, the OECD countries made strong progress, with an increase of 4.1% compared to 2016. China and South Korea tend to increase their global weight in terms of business research in the sectors of industries such as ICT. Between 2007 and 2015, R&D spending did increase only by 2% in Europe, while it soared by 40% in North America and 60% in Asia. This explains the orientation of the center of gravity of global innovation which is rapidly shifting towards China. According to the consulting firm PwC, Asia dethroned, in 2015, the United States which recorded (33%) of the total expenditure of R&D while European countries realized (28%). For example, in 2018, French public spending on energy, research and development (R&D) reached 1,098 million euros. As a share of GDP, public energy R&D spending puts France in second place among the G7 countries, after Japan.

The scope of this research is motivated by several reasons. Firstly, R&D is one of the major challenges for the economy as a growth factor. From the perspective of Mowery and Rosenberg (1989), research and development facilities play an important role in the innovation process. Secondly, empirical studies on innovation have focused on investigating the impacts of public R&D spending on innovation performance (Sarwar and Maqbool. 2019). However, the determinants of R&D investment have received much less attention (Grafström et al. 2020). More specifically, R&D efforts in renewable energy should be scaled up to meet existing global commitments to climate change mitigation (Del Río.2004). Furthermore, in recent times, it has become increasingly clear that the COVID-19 pandemic has not only fundamentally changed the way many organizations operate, but it also precipitated the acceleration of digitalization, paving the way for changes in lifestyle, work patterns and business strategies (Amankwah-Amoah et al. 2020). The range of measures, including local and national closures, social distancing measures, government-led border closures and quarantines have forced many businesses to adapt their short-term business models (Sostero et al. 2020). However, businesses have yet to realize the full potential of digitization, and the COVID-19 pandemic is driving the adoption of emerging technologies.

Previous research has shown that improving business process skills, new forms of cooperation and customer engagement, as well as a faster pace of innovation are drivers of digitalization (Adomako et al. 2020). Baldwin and Johnson (1995) found that ICT has already had a significant impact on R&D activities, both in terms of operating conditions of operations and research teams and in the management of these activities.

The main contribution of our paper is to provide an econometric analysis the driving factors of R&D investment. The empirical study aims to extend this framework to the Asian region, as a region that includes large industrial countries like China, and also as the Asian countries are characterized by a high level of exports. In fact, Asia is the largest carbon emitter in the world (Tang et al. 2018) and the rapid growth of its exports has largely contributed to the increase in carbon emissions (Zhang and Liu 2015). In addition, strong export growth in the Asian region has exacerbated environmental pollution, which calls on the authorities to strengthen environmental governance. In this research, we present theoretical arguments and empirical results that suggest identifying the complexity of the relationship between research and development through economic and environmental variables. In this context, dynamic regression of panel data was used. This methodology will make it possible to identify more precisely the origin of the stimulation of innovation. The results of the study will allow a reflection on the national innovation policy, which is mainly oriented towards the promotion of R&D spending and therefore the development of technological innovations.

There is evidence from the results of our study that R&D investments are driven by both polluted and renewable sources of energy proving the increased interest to clean energy. Besides, as expected, we find that ICT export is a significant determinant of R&D. Finally, we interestingly prove that trade applications and not industrial ones are drivers of investment in R&D. The overarching goal of the empirical study is to prove that the Asia

region needs to more invest in renewable sources of energy given its beneficial impact on research and development and apply more incentives to ICT export both in products and services to enhance investment in R&D. During the period of Covid-19, we confirm that R&D is increasing while air pollution is reduced. In addition, the industrial export of ICT is reduced while the export of ICT services thrives. We also report a significant reduction in renewable energies and therefore in the use of these natural resources in industries.
The first section presents an introduction while the second one provides an overview of the relevant literature on the topic. Section three presents the methodological framework, highlights and discusses the main empirical findings. Section four concludes and sets up some policy implications.

2. Literature Review

R&D and innovations–technological, environmental, and digital are drivers for development in all societies. Nevertheless, the question of the effect of research and development on market investments and its indirect consequences such as pollution have received considerable attention in the existing literature, but no consensus was reached in theoretical and empirical work, Roda and Perry (2014). From a theoretical standpoint, the literature review intends to examine the ways in which innovations have to be studied and how can they be used for sustainability. From an empirical standpoint, the analysis aims to extend our understanding of the drivers of innovation. Beyond technologies, we will show how Sustainable development constitutes a lever for innovation, ICT is a digital infrastructure for Innovation and intellectual property is a driver of innovation.

Sustainable development, a lever for innovation

For too long, industrial development has had an environmental and social cost. Indeed, rapid changes in technology and lifestyle have led to an increasing energy demand which has become the main cause of environmental deterioration, both in terms of pollution and above all in the intensive use of natural resources such as excessive fuel consumption (Rust and Leslie, 2020; Olivier et al. 2012). From this point of view, environmental economics, environmental pollution and especially air pollution constitute an inevitable problem for economic development during industrialization (Aldakhil et al.2019, Shu et al. 2020). Hence, environmental issues (climate change, scarcity of natural resources) combined with societal pressures represent real opportunities for innovation (Landrigan 2017). In this line of thinking, R&D, innovation and new technologies constitute important accelerators to push forward sustainable development in Asia region, especially for improving energy efficiency and developing renewable energy and related technologies for combating atmosphere pollution and climate change. On these grounds, R&D and innovations must create pathways towards sustainable development. For instance, Destek and Aslan (2020) found that R&D significantly reduces CO_2 emissions. This justifies that R&D investments by governments and businesses are both conducive to promoting the level of innovation. Within this context, sustainable development seems to be a vector for innovation.
In this sobering context, it’s worth noting that the pandemic crisis has had a significant negative impact on sustainable development efforts in every corner of the world. Digitization also facilitates a greater ease of doing business in the external activities of companies and can enable organizations to improve and improve overall competitiveness (Ritter and Pedersen, 2020). Amankwah-Amoah (2020) found Innovation and its diffusion have already played an important role in the global response to the pandemic; with rapid progress on the development of Covid-19 vaccines and treatments, and more generally through the increased adoption of digital technologies that have allowed businesses and individuals to adapt to social distancing requirements. This makes the adoption of Sustainable Development Goals more relevant, as

they are intended to transform the systemic conditions of our economies. Even though, the human, social and economic impacts of the health crisis could reverse progress made in achieving such goals. In the same line, Amankwah-Amoah (2020) found that sustainable and SDG-aligned recovery requires cross-sectoral actions and mechanisms. The author presents a roadmap for governments policy coherence to guarantee recovery from the pandemic.

ICT, digital infrastructure for Innovation
In this connected world, innovations need a digital infrastructure to innovate on and it would be interesting to investigate its potential for the benefit of innovation. According to KangKi and Kang (2014), a large number of tools developed have transformed research activities, have facilitated certain operations by integrating automated routines and have broadened the scope of accessible information, even if they sometimes present certain limitations. Qi et al. (2020) and Zhang (2019) confirm the positive correlation between the level of high-tech exports and total R&D spending. In this context, Salman et al. (2019) concluded that research and development spending is seen as a comparative advantage for ICT exports but a disadvantage for environmental pollution. Furthermore, the economic recovery and the resumption of sustainable economic growth in Asia, particularly in countries like China, are largely supported by the stimulation of high-tech exports.

Intellectual property: a driver of innovation
In today's economy, the role of intellectual property (IP) has changed considerably, both in developed and developing economies. Nevertheless, the relationship between innovation and IP protection is not yet clear, where the question is whether IP enforces or impedes innovation (Brem et al. 2017). Empirical evidence on the impacts of intellectual property rights (IPR) protection in promoting innovation in developing countries remain sunder explored and inconclusive (Kumar 2002; Brem et al. 2017). West and Gallagher (2006), the primary purpose of IPRs is to secure and promote investment in innovation. These results are confirmed with the studies of Kanwar and Evenson (2003). In Asia, the protection is not only to stimulate short-term R&D investment, but also affords the opportunity to reinvigorate the social and culture value system, which have positive impacts on innovation and competitiveness. A well-performing IP regime appears as a tool to improve the innovative capacity and competitiveness of the economy (United Nations 2011). Currently, some Asian countries have made great progress in IPR protection. In this paper, we will examine the role of intellectual property protection in fostering innovation and whether the likelihood of investing in technological product innovation depends on a country's ability to manage intellectual property.
The COVID-19 pandemic is causing widespread and deep suffering and misery across the world. Measures taken by governments to combat the pandemic, reduce suffering and stop the spread of the virus are also causing, as a necessary side effect, widespread economic disruption, which in turn causes and will cause widespread suffering as businesses stagnate, global value chains cease to function and employees, entrepreneurs and the many participants in the odd-job economy lose their livelihoods (OECD 2020; Chesbrough 2020). Kuckertz et al. (2020) found that the policy measures available in international and national intellectual property law to manage and mitigate emergencies and disasters include the use of exceptions for cultural and educational works to ensure the availability of vital data, information and knowledge for the purposes of combating and containing the virus, reducing the human suffering it causes, and enabling people to disrupt institutions, such as schools and universities, to continue to carry out their missions in remote or virtual conditions.

3. Methodology and sample collection

This section explains the sample and data sources. We then describe the measures of the key variables used in this study and the methodological approach.

a. Sample collection and variables

We collect information from data bases on emissions, telecommunications, technology and environment for 14 Asian countries from 2000 to 2019 and 38 Asian countries during the year 2020. We get information on communications from the International Telecommunication Union (ITU), World Telecommunication/ICT (WT/ICT), Development Report and database, the National Science Foundation, Science and Engineering Indicators and the Netcraft (http://www.netcraft.com/). We also gather information on technology from the World Intellectual Property Organization (WIPO), WIPO Patent Report: Statistics on Worldwide Patent Activity and the UNESCO Institute for Statistics http://uis.unesco.org/) and information about emissions from the Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United State and the report of Brauer et al. (2017), for the Global Burden of Disease Study 2017. In addition, we collect information about Economic Policy & Debt from the World Bank national accounts data, and OECD National Accounts data files. Finally, we gather information about Energy production and use from the World Bank, Sustainable Energy for All database from the Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program. The variables included in our models and their definitions are summarized in Table 1.

b. Scope and aim of the study

To identify the complexity of the relationship between environment and technology through economic variables, we use dynamic panel data regression (Yang et al. 2004; Qiu et al. 2020). This regression captures the dynamic relationship between the endogenous variables, its lagged value, and the other exogenous variables. Through the studies of Arellano and Bond (1998, 1991), we implement the System-GMM estimator that uses moment conditions. In addition, this approach is more consistent than Difference GMM in the existence of endogenous variables and fixed effects (Bond, 2002). To structure the empirical model, we propose three assumptions namely:

H_1: Renewable energy enters improve investing in R &D.
H_2: Information and communication technology is in favor of investing in R &D.
H_3: The global pandemic COVID-19 intensifies investing in R &D.

Finally, we specify the following pooled panel OLS regression model to investigate the impact of technology and renewable energy and other control variables on investment in research and development.

$$Y_{c,t} = \alpha_c + \beta_1(\Delta Environnement_{c,t}) + \beta_2(RENEW_{c,t}) + \beta_3(CV_{c,t}) + \varepsilon_{c,t}$$

Here, Y measures investment in research and development in county c on day t. α is a constant term and ε is the error term.

Table 1: Variables presentation

Variables	Indication	Definition and measurement
Research and Development	R&D	The gross domestic expenditures on Research & Development expressed as a percent of GDP. In this field, both capital and current expenditures are included mainly in the following sectors: Government, Business enterprise, Private non-profit and Higher education. R&D includes basic research, applied research, as well as experimental development. (https://databank.worldbank.org; http://uis.unesco.org)
ICT industrial exportation	ICT.IND.exp	The annual weighted average of total goods exports. Information and communication technology (ICT) goods exports encompass communication equipment, computers and peripheral equipment, electronic components, consumer electronic equipment and other IT goods. (https://databank.worldbank.org; http://unctadstat.unctad.org).
Atmospheric pollution	ATMOS. poll	The average level of exposure of a population to concentrations of some suspended particulate matter that measure less than 2.5 microns in aerodynamic diameter, which can deeply affect the respiratory tract and even cause serious health damage. (https://databank.worldbank.org).
Renewable energy consumption	RENEW	The share of renewable energy in total final energy consumption.
ICT service exports	ICT.SER.exp	Information and communication technology service exports encompass computer and communication services and some other information services such as news-related service transactions or computer data. (https://databank.worldbank.org).
Industrial design applications	INDUSTRIAL.app	Industrial design applications encompass all applications to register an industrial design with the national or regional IP offices as well as designations received by a relevant office through the Hague System. Moreover, industrial designs could be applied to a great variety of industrial products and handicrafts. They concern the aesthetic or ornamental aspects of a useful product, involving compositions of colors or lines or may be any three-dimensional forms that add a special appearance to a product or handicraft. (www.wipo.int/ipstats; https://www.indexmundi.com).

Trademark applications	TRADE.app	Trademark applications filed involve all applications to register a trademark with the national or regional IP offices as well as designations received by all relevant offices through the Madrid System. (https://databank.worldbank.org; www.wipo.int/ipstats).
Covid	Covid	Number of infected cases accumulated.

4. Results

The descriptive statistics and correlations for the studied variables are presented in Table 2 and 3before and during COVID-19. Both tables statistics display average values and standard deviations for each variable. Before COVID-19, considering the amount of investment in research and development, we record a value of 75% reflecting the big interest of Asian countries in R&D. We also notice that the standard deviation is almost high for industrial and trade applications reflecting that there is a high dispersion of values among the 14 studied Asian countries. This is explained by the diversified sample consisting of emerging countries and developed ones. For the left variables, the value of standard reflects more homogenous values.

Table 2: Descriptive statistics before Covid19

Variable	Obs	Mean	Std. Dev.	Min	Max
R&D	229	0.7565397	0.8830631	0.00325	3.555854
ATMOS. poll	229	93.62885	18.9162	24.66203	100
INDUSTRIAL.app	229	115071.8	375916.5	105	2153827
TRADE.app	229	14428.85	25168.32	85	156769
ICT.SER.exp	229	1.33	3.07	532819.8	2.87
RENEW	229	30.19779	25.14664	0.3251189	85.47206
ICT.IND.exp	229	12.02443	14.62228	-0.0058052	54.97448

Source: Authors' computation

After COVID-19, we remarkably note that R&D is multiplied while atmospheric pollution is reduced. In fact, faced with the pandemic and the economic difficulties it causes, the entire governments in Asia are mobilized. For example, Singapore is in a position to act on the financing of medical research and development (R&D) and to mobilize its army in the distribution of masks. Considering pollution, this result is quite understandable. When part of the productive tool of the world's leading economic power, China, stops, it's a real breath of fresh air for the atmosphere. The pollution monitoring satellites of NASA and the European Space Agency (ESA) have thus detected significant reductions in nitrogen dioxide (NO_2) concentrations over China. Besides, we find that ICT industrial exportation is reduced while ICT service exportation prospers. The World investment report 2021 documented the big reduction in high skill industries especially from 2019 to 2020. The increase of ICT service export is expected. The crisis associated with the COVID-19 pandemic has accelerated the expansion of e-commerce to new categories of businesses, consumers and products. This boom has allowed consumers to access a wide range of products while remaining comfortably and safely at home, and businesses to continue operating despite restrictions on physical contact and other containment measures. Finally, we report a serious reduction in renewable energy and thus the use of such natural resources in industries.

Table 3: Descriptive statistics after Covid19

Variable	Obs.	Mean	Std. Dev	Min	Max
RD	38	9.93936	5.150566	.0387	24.80659
COVID	38	94.10095	52.31106	7.12548	182.6985
ATMOS. poll	38	26.20683	8.461013	11.53418	42.53086
RENEW	38	22.77799	12.36615	4.177775	57.13312
ICT.IND.exp	38	6.220518	2.503476	4.439544	9.722147
ICT.SER.exp	38	31.39346	18.93342	3.125489	67.82078

Source: Authors' computation

Before running our empirical model, we test for the existence of bi-variate and multivariate correlation through the Pearson matrix and the variance inflation factor (VIF). Examination of the correlation matrix shows that all correlation coefficients are less than 0.9. According to Kennedy (1985), there is no serious problem of multi-collinearity before and during COVID-19.

Table 4: Pairwise correlation matrix before Covid-19

	RD	ATMOS. poll	INDUSTRIAL. App	ICT. SER.exp	RENEW	ICT.IND.exp
RD	1.0000					
ATMOS. Poll	0.4198*	1.0000				
	0.0000					
INDUSTRIAL.app	0.0442*	-0.0758*	1.0000			
	0.0000	0.2535				
ICT. SER.exp	0.4007*	-0.0473	0.5021*	1.0000		
	0.0000	0.4767	0.0000			
RENEW	0.3923	0.2777*	-0.2718*	-0.2803*	1.0000	
	0.0000	0.0000	0.0000	0.0000		
ICT.IND.exp	0.2040*	0.2084*	0.3806*	0.3532*	-0.3232*	1.0000
	0.0019	0.0015	0	0	0	

Source: Authors' computation

Table 5: Pairwise correlation matrix during Covid-19

	RD	**covidc~u**	**ATMOS. poll**	**RENEW**	**ICT.IND. exp**	**ICT.SER. exp**	**INDUSTRIAL. app**
RD	1.0000						
Covidcumu	-0.0036	1.0000					
	0.8827						
ATMOS. Poll	0.3838*	0.8032*	1.0000				
	0.0174	0.0000					
RENEW	0.0896	0.1698	0.6096*	1.0000			
	0.5928	0.3082	0.0000				
ICT.IND. exp	0.3004	-0.8084*	-0.3142	0.3366	* 1.0000		
	0.0669	0.0000	0.0547	0.0388			
ICT.SER. exp	0.3009	0.8311*	0.8524*	0.1249	-0.6478*	1.0000	
	0.0664	0.0000	0.0000	0.4550	0.0000		
INDUSTRIAL. app	0.0485	0.0000	0.0000	0.5247	0.000	0.0000	1.0000

Source: Authors' computation

Considering the possibility of multicollinearity in the regression analysis, the variance inflation factor (VIF-test) was calculated. The variance inflation factors were all lower than the critical value of 10, which indicates that the regression performed in this study, does not present a multicollinearity problem (Aiken and West, 1991).

Table 6: Variance inflation factor

Variable	**VIF**	**1/VIF**
RENEW	1.34	0.749035
ICT.IND.exp	1.32	0.757618
ATMOS. poll	1.22	0.822017
INDUSTRIAL.app	1.13	0.881557
ICT.SER.exp	1.11	0.904012
Mean VIF	1.22	

Source: Authors' computation

Next, we test for the determinants of investing in research and development before COVID-19. We interestingly find that both atmospheric pollution and investment in renewable energies enter positive impact on R&D. Our findings join those of Rust (2020), He and Wang (2020) and Olivier et al. (2012). This reflects the fact that economies are still relying on polluted industries while clean energies are gaining more and more importance. Our results are in line with Bertarelli and Lodi (2019) who concludes that small firms adopt polluting technology. On the other hand, Wang et al. (2020) approve the positive link between ICT export and R&D expenditure. In fact, in 2015, Asian governments adopted an inspirational goal of 23% renewable energy by 2025. Besides, the total power generation would double by 2025 to counterpart energy demand growth. Encouragingly, 62% of the world's renewable energy jobs are in Asian countries. It can therefore be concluded that, given the foreseeable

rise in energy prices in Asia over the next 20 years, there is a need to direct industrial innovation efforts and the supply of goods and services towards energy-efficient technologies.
We also find that export of ICT of industrial product and ICT services is in favor of the development of investing in R&D. This result is quite predictable since ICT are related to investment in R&D. In this line of thoughts, Destek and Aslan (2020), He and Wang (2020) confirm the positive correlation between the level of high-tech exports and total R&D spending. According to Huang and Liu (2005), the interaction between firms' innovation capital (R&D rate) and ICT capital (ICT expenditure rate) is positively related to performance, showing a synergy effect. Moreover, ICT tools constitute a new factor in the apprehension of problems and solutions, at the different levels of localization, organization, management and practice of R&D.
In order to improve the robustness of our results, we include as control variables the number of industrial applications and trade applications measuring the applications to register an industrial design or trademark with the regional or national IP office. We empirically find that while TRADE.app enters positive impact on research and development investment, INDUSTRIAL.app has a negative impact. This result may reflect that research and development are more oriented to service and IP plays a key role in driving innovation. Our results are consistent with studies by Whicher et al. (2011) who confirmed that the trademark of a product is a factor that links the development of new products and the commercialization of innovation.

Table 7: Dynamic panel-data estimation before COVID-19, one-step difference GMM

R&D	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval
R&D L1.	0.9667923***	0.0954783	10.13	0.000	0.758763	1.174822
ATMOS. poll	0.022414**	0.0088949	2.52	0.027	0.0030337	0.0417944
INDUSTRIAL.app	-4.10***	1.08	-3.79	0.003	-6.46	-1.74
TRADE.app	0.0000122***	2.16	5.66	0.000	7.54	0.000017
ICT.SER.exp	1.66*	7.69	2.16	0.051	-1.22	3.34
RENEW	0.0268671***	0.0066149	4.06	0.002	0.0124545	0.0412796
ICT.IND.exp	0.0079756***	0.0026022	3.06	0.01	0.0023059	0.0136452

Source: Authors' computation

We can conclude that globally the Asian countries investment in research and development is positively determined by both polluted and renewable source of energies, ICT industrial, service export and trade applications. Nevertheless, industrial design has a negative impact on investment in research and development. The empirical results confirm the first and second hypotheses. These findings show that the use of clean energy is gaining more and more importance compared to polluted energy resources. Also, as expected ICT exportation boost R&D especially in technological services. Our results allow us to draw some managerial implications. In fact, governments are urged to more invest in renewable energies especially in consequence of augmented pressure from civil society and warnings of global health organizations. This decision is beneficial in both senses. In fact, while governments reduce polluted emissions and improve environment quality, they boost investment in research and development. But, after COVID-19, a dramatic change in economy is perceived.

Table 8: Dynamic panel-data estimation during COVID 19 one-step difference GMM

RD	Coef.	Std. Err.	T	P>|t|	[95% Conf.Interval	
COVID	4.86e-06***	1.65e-06	2.96	0.006	1.51e-06	8.21e-06
ATMOS. poll	-2.973464***	3.10e-06	9.6e+05	0.000	2.973457	2.97347
RENEW	-1.172711***	2.99e-06	-3.9e+05	0.000	-1.172717	-1.172705
ICT.SER.exp	0.8007638***	3.45e-06	-2.3e+05	0.000	-.8007708	-.8007568
ICT.IND.exp	1.10***	1.04	2.12	0.001	0.682	1.14
INDUSTRIAL.app	2.08***	1.27	2.85	0.004	1.46	1.14
_cons	-27.34715***	1.6e+05		0.000	-27.3475	-27.34681

Source: Authors' computation

The intense spread of COVID-19 has threatened human lives, disrupted livelihoods and affected trade, the economy and businesses around the world. First, we find that during the global pandemic, the investment of Asian countries in research and development during the pandemic is not determined by renewable and polluted energy sources as we found in our first model before COVID-19. In time of global health crisis, it is more important than ever to protect the health of the billions of people who do not have clean cooking facilities. Clearly, the pandemic is deterministic of the prosper of research and development. This finding confirms the third hypothesis. Besides, both ICT industrial and service export are in favor of research and development. Which is confirmed by the WIPO (2020) which found that the Global Innovation Index in 2020 shows that R&D spending is highly concentrated in a few thousand companies active in this sector around the world - the 2,500 companies that spend the most on R&D are thus responsible for more than 90% of the R&D funded by companies in the world. Most of these companies place innovation at the heart of their business strategy. They noted that the ICT (information and communication technology) and software sectors are expected to experience sustained growth in their revenues and R&D activities. These results are confirmed with United Nation reports.
We conclude that governments, foundations, donors and the private sector must work together to accelerate the transition to clean and sustainable fuels and technologies to protect the health of the most vulnerable populations. In fact, access to reliable energy is of vital importance, especially during mitigated period. It is essential not only to prevent and fight the pandemic, but also to accelerate the return to normalcy and better rebuild by providing everyone with a more sustainable and resilient future. The COVID-19 pandemic has highlighted the deep inequalities that exist in the world in terms of access to modern, affordable and sustainable energy. Electricity is an essential part of the response to the public health emergency in many countries. Second, Asian countries' investment in research and development during the pandemic is determined by industrial and commercial applications of ICTs. This is confirmed by the work of Candelaa et al. (2020) who found that the coronavirus pandemic has made Internet access an essential condition for continued growth. Around the world, digital solutions have become fundamental to protecting supply chains, sustaining public services, and ensuring the continuity of business and education. In short, ICT infrastructure has become essential to the functioning of an economy, alongside water, electricity and food supply networks.
Heart of the matter of this historic transformation, Sein (2020) has confirmed that ICT infrastructure is the main catalyst - along with the right policy - for future competitiveness and innovation. ICT adoption is considerably varying between economies in the region since Internet usage rates array from more than 90% in developed economies to less than 15% in emerging one in the region.

5. Conclusion

This article examines the effect of the mechanisms underlying the development of research and development (R&D) through investment in renewable energy and ICTs before and after the Covid19 pandemic. First, we propose an OLS regression of 38 Asian countries to analyze the effect of this pandemic on research and development we confirm that R&D is increasing while air pollution is reduced. In addition, the industrial export of ICT is reduced while the export of ICT services thrives. We also report a significant reduction in renewable energies and therefore in the use of these natural resources in industries. Second, we perform a second dynamic panel regression using panel data from 2000 to 2019 for 15 Asian countries. We see that before this virus that the variables related to intellectual property were the drivers of R&D investments in the Asian region. It is interesting to note that while the demands of brands stimulate R&D, industrial applications slow down this type of investment. We empirically argue that while economies still rely on polluted industries, clean energy is gaining more and more importance. In addition, as expected, the export of ICT industrial products and ICT services is in favor of the development of investment in R&D. Based on the above findings, we can provide some key policy implications for Asian authorities. In a normal context, policymakers are urged to invest in renewable energy not only because of global pressure but also because of its positive impact on R&D during stable periods. In this context of a pandemic, the ability of companies to cope with these changes is a key competitive advantage that will require the adoption and mastery of certain digital tools. This is due to the transition to Industry 4.0, which is therefore not only a temporary means of dealing with the crisis, but a lasting solution to become more competitive in the medium and long term. In addition, the ability of companies to begin their transition to this model will result in better customer relations, increased competitiveness and increased market share. Therefore, the coronavirus pandemic has made digital solutions an essential condition for continued economic growth.

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