Research and Development Expenditure at World Level

Between 2010 and 2020 it grew by an average of 19.93% for the countries analysed.

The World Bank calculates gross R&D expenditure as a percentage of GDP. The data takes into account both capital and current expenditures in the four main sectors: Enterprise, Government, Higher Education and Private Non-Profit. R&D covers basic research, applied research and experimental development. Let's consider the period between 2010 and 2020. Only countries with complete historical series have been considered to avoid the problem of dealing with missing values during clustering with the k-Means algorithm.

Ranking of countries by value of R&D expenditure as a percentage of GDP in 2020. Israel ranks first by value of R&D expenditure as a percentage of GDP in 2020 with a value of 5.44%, followed by Korea South with a value of 4.81%, from Sweden with a value of 3.53%, from Belgium with 3.48%, and from the United States with a value of 3.45%. In the middle of the table are Ireland with a value of 1.23%, Lithuania with 1.16%, Luxembourg with 1.13%, Russia with 1.10% and Turkey with 1.09%. Kuwait closes the ranking with a value of 0.19%, followed by Uzbekistan with a value of 0.14%, Mongolia and Kazakhstan with 0.13%, the Kyrgyz Republic and Tajikistan with 0.09%.

Ranking of countries by the value of the percentage change in R&D expenditure relative to GDP between 2010 and 2020. Macao ranks first in the percentage change of R&D expenditure relative to GDP with a value of 795.78%, followed by Greece with a value of 147.92%, Egypt with 121.98%, Poland with 93.36%, Cyprus with 85.17%. In the middle of the table are Austria with a value of 17.43%, followed by Latvia with an amount of 16.47%, Malta with a value of 15.74%, Germany with 15.16%, and 'Estonia with 13.52%. Moldova closes the ranking with a value of -37.92%, followed by Mexico with -39.18%, the Kyrgyz Republic with -42.54%, Mongolia with -45.57% and Ukraine with -49 ,42%. Between 2010 and 2020, the value of research and development grew by an average of 19.93% for the countries analysed.

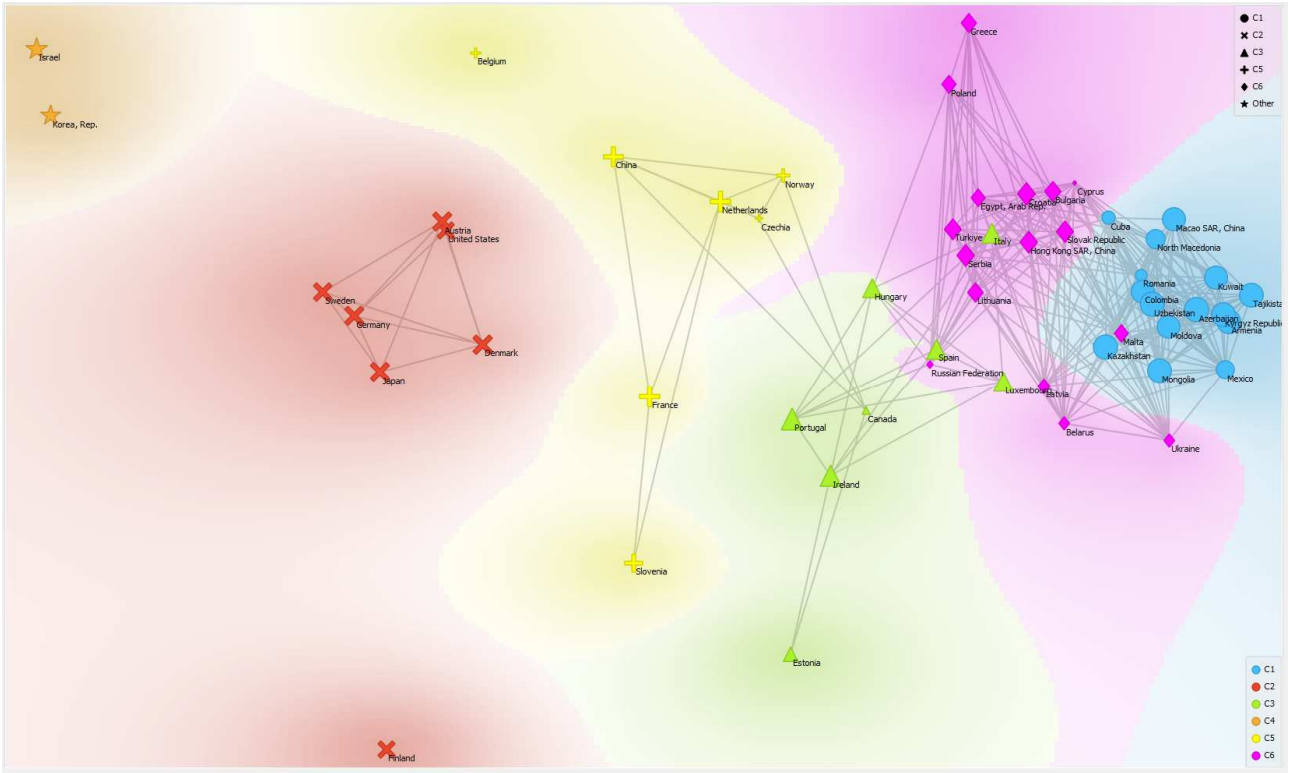
Clusterization with k-Means algorithm optimized with the Silhouette coefficient. Below we present a clustering with the k-Means algorithm optimized with the Silhouette coefficient. Specifically, 6 clusters are identified, namely:

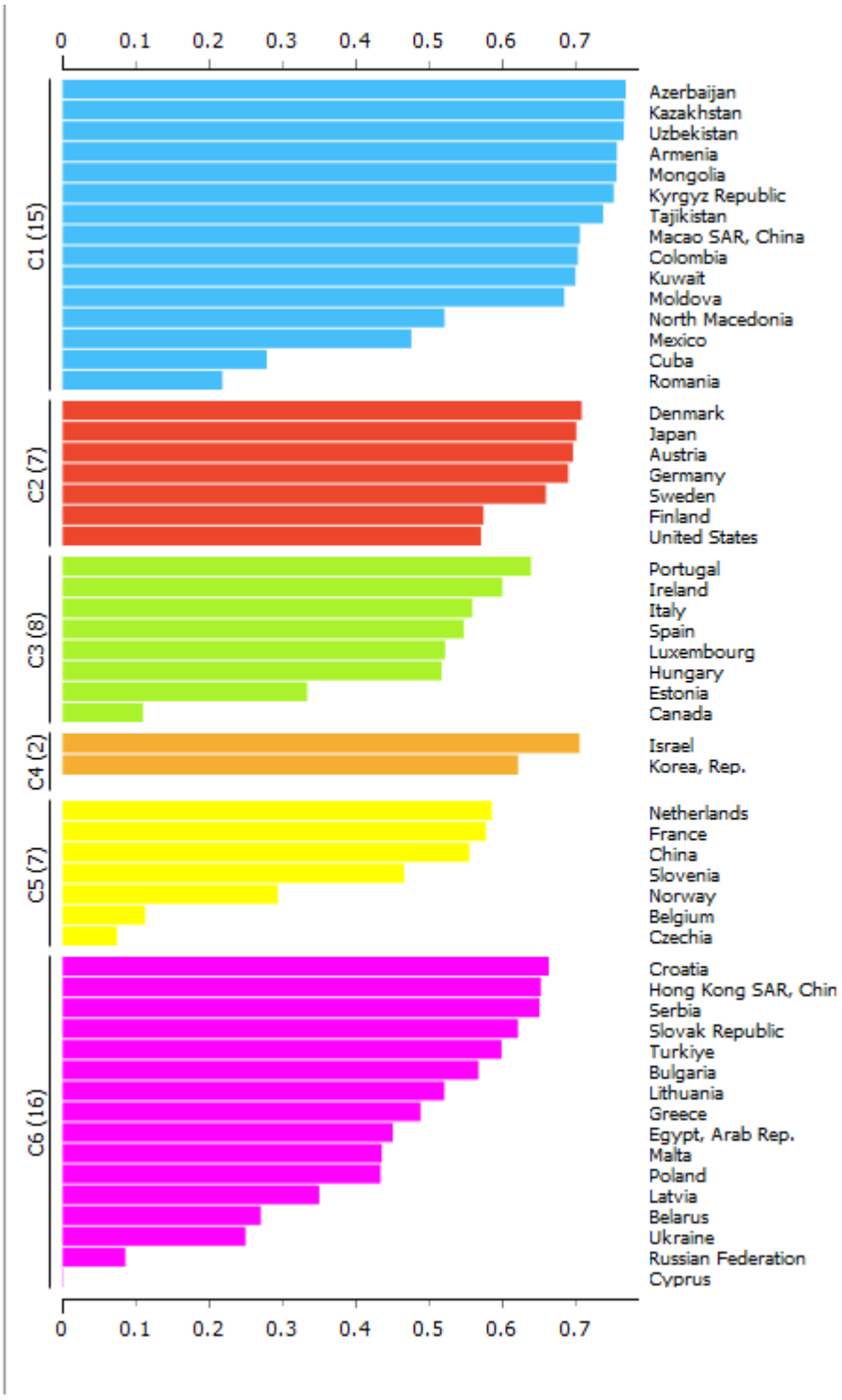
- Cluster 1: Azerbaijan, Kazakhstan, Uzbekistan, Armenia, Mongolia, Kyrgyz Republic, Tajikistan, Macao, Colombia, Kuwait, Moldova, North Macedonia, Mexico, Cuba, Romania;
- Cluster 2: Denmark, Japan, Austria, Germany, Sweden, Finland, United States;
- Cluster 3: Portugal, Ireland, Italy, Spain, Luxembourg, Hungary, Estonia, Canada;
- Cluster 4: Israel, South Korea;
- Cluster 5: Netherlands, France, China, Slovenia, Norway, Belgium, Czech Republic.
- Cluster 6: Croatia, Hong Kong, Serbia, Slovak Republic, Turkey, Bulgaria, Lithuania, Greece, Egypt, Malta, Poland, Latvia, Belarus, Ukraine, Russia, Cyprus.

From the point of view of the clusters we can see the following ordering: C4=5.13>C2=3.20>C5=2.29>C3=1.57>C6=0.94. We can therefore note that there are two countries that lead research and development worldwide, i.e. Israel and South Korea, i.e. the countries of Cluster 4. In second place are the countries of central and northern Europe and the United States. This is followed by 5 Central-Northern European countries and China in the Cluster. Finally, the last cluster is very diverse from a geographical point of view and contains both European and non-European countries such as China and Egypt. It must be considered that investment in research and

development has a significant impact in terms of gross domestic product and economic growth. In fact, both in the classic models of economic growth and in endogenous modeling, investment in research and development is essential to grow GDP. One of the reasons that favor the use of research and development spending as a driver of growth is technological innovation. In fact, technological innovation is generally a product generated because of investment in research and development. Economists, starting as early as Joseph Alois Schumpeter, had wondered what allowed GDP to grow from one year to the next while keeping the endowment of factors fixed, i.e. capital, land and labour. And through empirical research already at the beginning of the 20th century it was clear that the only opportunity to increase GDP was to invest in technological innovation, which is achieved through research and development. Of course, even research and development are not an element that can self-produce within an economic system. In fact, it requires investment in human capital and therefore a close connection between the university system, companies, and research institutions. Finally, countries that have a financial system more ready to take on the risks of scientific research are also able to obtain better results by further increasing their GDP.

Conclusions. Although it is known that in the knowledge economy, investment in research and development is necessary to increase GDP, not all countries take this recommendation seriously, even if it is supported by ample empirical evidence. And, even among European countries there are many, such as Italy, Croatia, Serbia, Slovakia, Bulgaria, Greece, Poland, Malta, Latvia, and Cyprus, which has a low value in terms of investment in research and development. On which circumstance the European Union intervened and ordered that 3% of GDP be invested in research and development. As a result, many European countries will need to increase their R&D spending as a share of GDP to meet EU demands. However, non-European countries still have an interest in increasing spending on research and development to increase competitiveness at the country level and access higher levels of productivity and per capita income. Furthermore, the current challenges of artificial intelligence and climate change, together with the risk of new pandemics, require countries to invest in research and development also for reasons related to national security, environmental and health.

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C1 (15)
Azerbaijan
Kazakhstan
Uzbekistan
Armenia
Mongolia
Kyrgyz Republic
Tajikistan
Macao SAR, China
Colombia
Kuwait
Moldova
North Macedonia
Mexico
Cuba
Romania
C2 (7)
Denmark
Japan
Austria
Germany
Sweden
Finland
United States
C3 (8)
Portugal
Ireland
Italy
Spain
Luxembourg
Hungary
Estonia
Canada
C4 (2)
Israel
Korea, Rep.
C5 (7)
Netherlands
France
China
Slovenia
Norway
Belgium
Czechia
C6 (16)
Croatia
Hong Kong SAR, Chin
Serbia
Slovak Republic
Turkiye
Bulgaria
Lithuania
Greece
Egypt, Arab Rep.
Malta
Poland
Latvia
Belarus
Ukraine
Russian Federation
Cyprus
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0.7