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RESEARCH AND DEVELOPMENT IN THE EUROPEAN UNION: AN ANALYSIS OF TWO DECADES

Original Research

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Abstract

Innovative activities are vital for countries' economic growth and competitiveness in the same way research and development (R&D) is vital for innovation. Expenditure on R&D is an apt indicator to assess countries' R&D input. This article statistically reviews the European Union's gross domestic expenditure on research and development (GERD) and its components for 2000-2020 to uncover trends and patterns. Business enterprise, higher education and government components of GERD are selected as indicators to assess the sectoral trends in R&D. Furthermore, to give more insight, conceptualised income groups are used to identify any pattern between countries' R&D expenditures and income levels. The United States, Korea and China are chosen as benchmarks for R&D based on their income level. Additionally, based on the EU27 countries' historical progress and final figures, R&D leaders and laggers are appointed.

INTRODUCTION

Innovation is the driving factor behind countries' economic growth and competitiveness, making innovation studies important to policymakers, academics, and public and private organisations (OECD & Eurostat, 2018). With innovation being a focal point for studies, the determinants of innovation also receive attention. One of these determinants is research and development (R&D) activities. According to Love and Roper (1999), R&D activities are the first step of innovation when the process of innovation is viewed linearly. Since R&D activities are prerequisites to innovation, they impact innovation positively. Current literature on innovation suggests a similar relationship between R&D activities and innovation (Pegkas, Staikouras & Tsamadias, 2019).

In a broad definition, any novel, creative, uncertain about its outcome, systematic and reproducible activity qualifies as an R&D activity (OECD, 2015). Research and development comprise three types of activity that differ in nature and purpose: basic research, applied research, and experimental development. Frascati Manual further categorises R&D activities based on their source of funding and sector of performance. There are five sources of funds: business enterprise, government, higher education, private non-private (PNP) and the rest of the world. Parallel to the sources of funds, there are five sectors of performance that R&D activities can take place: business enterprise sector, government sector, higher education sector, private non-private (PNP) sector and rest of the world (OECD, 2015).

The relationships among the sources of funds, sectors of performance, type of R&D activity and innovation production are intricate, while the nature of these relationships is country and industry-specific. In some cases, expenditure on R&D performed in one sector can complement another sector's R&D, but only under specific conditions. For instance, Coccia (2010) found that expenditure on government R&D accompanies business R&D, but this is only valid if expenditure on business R&D exceeds the expenditure on government R&D. Moreover, expenditure on business R&D can function as a determinant for countries' productivity growth only when the stated condition is met. This research was conducted for the European Union (EU), so this relationship may not emerge outside the union. Additional, even inside the EU, the impact of this accompaniment may change based on the size, development level, and industry focus of the chosen country. In a similar line of reasoning, we can assume that sources of funds will affect the type of R&D being conducted and in which sector of performance. Bilbao-Osorio and Rodríguez-Pose (2004) found that in nine countries within the EU15, business R&D has the highest rate of return. The authors suggest that this higher rate of return results from the privately funded research to be more applied (profit-oriented) than basic, as the latter is mainly performed within government and higher education R&D sectors.

The literature on R&D, along with its determinants and effects, covers remarkably varied scopes. Economic researchers concern themselves with the methodological and empirical analysis of the drivers of R&D (Becker, 2015). Most of the studies use one of the two following indicators to represent R&D: expenditure on R&D and R&D intensity (the share of R&D expenditure to GDP). Gross domestic expenditure on R&D (GERD) contains the total expenditure on R&D conducted in all economies and is considered the principal R&D indicator (OECD, 2015). Components of GERD can offer a more targeted evaluation of R&D. Business enterprise expenditure on R&D (BERD), higher education expenditure on R&D (HERD), government expenditure on R&D, and private non-profit expenditure on R&D (PNP) constitute gross domestic expenditure on R&D (GERD). On the other hand, R&D intensity is a derivative of GERD and a useful cross-country comparison indicator. The components of GERD can also be expressed as a share of GDP, representing the R&D intensity of the sector.

Expenditure on R&D activities within a sector represents the part of GERD incurred by the same sector's units and is known as components of GERD. Components of GERD are measures of expenditure on intramural R&D within a specific sector and for a limited time (OECD, 2015). If we think of business enterprise expenditure on R&D (BERD) as an example, we can conclude that BERD includes all expenditures (e.g., R&D staff cost, material cost, equipment cost) incurred by the business enterprise units. Since GERD and its components represent the total performance within a sector, they function as viable indicators to researchers and policymakers. The studies especially need these indicators to discover any relationship between R&D activities, innovation, economic growth, and production on the macro and micro levels.

Due to their measurability and comparability, GERD and R&D intensity are used as indicators by institutions and organisations for policymaking. The European Union is one of these organisations, and it places special emphasis on R&D intensity. During Lisbon Council in 2000, the EU announced the need for strategic goals for the EU to achieve in the next decade to develop a knowledge-based economy that can grow sustainable while creating better jobs and unified society, hence be competitive (European Parliament, 2000). According to the Lisbon Council, R&D needed more resources, support for its business enterprise component, partnerships, venture capital and tax

incentives. The 2002 Barcelone EU Council set the R&D intensity target for the decade as 3%, with an additional target for business sector funding of 55% to two-thirds of R&D (European Commission, 2005). However, the EU never realised these targets.

Following 2007, the European Union faced the economic disruption caused by the global financial crisis and Greece's crisis within the union. The EU made new commitments to secure its balance against future economic disasters by learning from its mistakes. The EU decided that not just the Eurozone's but its entirety depended on the stability of the Euro. With this conviction, the EU developed an ambitious long-term policy, in which one of the five targets was to achieve stronger growth and higher productivity through knowledge and innovation through R&D (European Commission, 2010). This new set of objectives was named 'Europe 2020', which involved the same R&D intensity target of 3%. The EU also required more focus on business funding of R&D while increasing its financial incentives for R&D and providing more encompassing frameworks with guidelines to promote the determinants of R&D.

Besides their ambitious targets and goals, these two policies had another commonality: the EU's growing concerns against the economies of certain countries, including Unites States (U.S.), Japan, China, India, and Brazil. In the case of R&D, the U.S., Japan, and China propelled the EU's R&D efforts by either being ahead or growing too rapidly. According to the latest data available in the European Commission's Science and Technology and Innovation database (referred to as Eurostat), in 2020, the EU27's R&D intensity stood at 2.32%. When we look at the 2019 R&D intensity data released by Eurostat, we see the EU27 (2.23%) falling behind the competitors such as the U.S. (3.08%), Japan (3.2%) and South Korea (4.63%), whereas China (2.23%) catching up with the EU27. If we check the share of business funding in all R&D sectors for the same year, we find that the EU accomplished its goal of 55% set in 2002. However, since its competitors continued progressing, the EU fell behind again. In 2019, business funding's share in R&D was 59% in the EU27, 61% in the U.S., 76% in China, 79% in Japan and 77% in South Korea.

RESEARCH BACKGROUND

Bilbao-Osorio and Rodríguez-Pose (2004) investigated the relationship between R&D investments regarding its components and innovation. Additionally, the impact of innovation and its growth on economic growth was assessed. The study analysed nine EU15 member states using NUTS2 regions for 1990 and 1998. The results indicated a positive association between R&D investment and innovation, which is also correct for higher education R&D investment in the EU's peripheral regions. Additionally, BERD was found to have greater rates of return than the other components of R&D. Innovation growth as determined to be the key driver of economic growth in the EU's peripheral regions.

Van Pottelsberghe De La Potterie (2008) analyses the EU in conjunction with its 3% R&D intensity, its business funding share and countries' self-set goals. The analysis covers the EU member states and benchmark countries (U.S., Japan, and China) between 1995 and 2006. Results showed that none of the member states reached their self-set goals and the EU R&D intensity goal. Moreover, the countries reduced their government-funded R&D, whereas China caught up with the EU's business-funded R&D. The author argued that benchmarking each member state against 3% disregarding its industrial structure and market conditions, and academic research environment is not sensible.

Silaghi, Alexa, Jude and Litan (2014) analysed data from Central and Eastern European (CEE) countries to assess the role of business and government (with the higher education sector) R&D in economic growth. The study covered the years between 1998 and 2008 and then newly joined ten CEE countries. The results suggested that 1% increased business R&D can boost economic growth by 0.050% in the short and 0.213% in the long run. However, results showed that the government R&D (with the higher education sector) was insignificant. Still, government (with higher education sector) R&D does not crowd out the positive effect of business R&D.

Pegkas et al. (2019) investigated the impact of R&D expenditure, with special regard to its three components, on innovation using the data from EU28 member states between 1995 and 2014. The study analysed business enterprise, government and higher education R&D and separate effects on the innovation activity and output. Findings pointed to a cointegration between innovation and R&D and a positive and significant impact of R&D components on innovation. Out of three components, the study found business enterprise R&D most impactful. This impact existed even in the short run, which the authors interpreted as the EU's reactivity to technological changes.

Gumus and Celikay (2015) studied fifty-two countries between the years 1996 and 2020 and found that expenditure on R&D has a substantial and positive effect on economic growth for developed and developing countries in the long run. However, in developing countries, this effect is weak in the short run and strong in the long run.

Inekwe (2015) analysed sixty-six developing countries, divided by income level into lower and

upper-middle economies, between 2000 and 2009 to determine the impact of R&D expenditure on the economic growth of these countries. The author found that R&D expenditure positively affects economic growth in developing economies but with different impacts. Results suggested that the impact of R&D expenditure on economic growth is immediate in the short run for upper-middle-income countries. In contrast, R&D expenditure decreases the economic growth in lower-income countries in the short run while maintaining its expansionary effect in the long run.

Carrillo (2019) Studied thirty-three countries' efficiency in using R&D resources with the data envelopment analysis (DEA) method. Selected countries were members of the EU and OECD with moderate or high involvement in R&D activities and minimum R&D intensity of 1% as of 2015. Results showed that Germany, Iceland, Ireland, Italy, Luxemburg, Netherlands, Poland, Slovakia and the United Kingdom were the only efficient countries in the EU28 between 2004 and 2015.

Das and Mukherjee (2020) hypothesised whether R&D intensity was associated with GDP per capita and growth in the long run and whether these indicators were related in the short run. In order to test these hypotheses, the authors selected countries from different economies (OECD, high-income, upper-middle-income and low & middle income) which had available R&D intensity data. They analysed ten countries with the highest R&D expenditures, namely U.S., China, Japan, Germany, South Korea, India, France, the UK, Russia, and Brazil. According to the analysis, R&D expenditure is associated with GDP per capita growth in the long run for high-income and upper-middle-income countries.

RESEARCH METHODOLOGY

Research and development data for all selected countries were retrieved from the Science and Technology and Innovation database of the European Commission (Eurostat), and gross national income data were retrieved from The World Bank for the years 2000 to 2020. Table 1 lists the details of the data, selected indicators and countries.

This paper has two aims: to observe the trends in R&D between 2000 and 2020 among the EU27 member states and appoint R&D leaders and laggers among the EU27 member states based on the growth rate in R&D expenditure. European Union recognises the gross domestic expenditure on research and development (GERD) as a major driving force for economic growth in knowledge-based economies (European Commission, 2021). Thus, to compare the R&D activities of countries against each other and their yearly progress, GERD and its three main components were chosen as primary R&D indicators. Frascati Manual (OECD, 2015) states that representing GERD as a ratio of gross domestic product (GDP) normalises the differences that may occur due to size differences in economies. Thus, this study expressed GERD, BERD, HERD and GOVERD as percentages of GDP. R&D intensity figures were compared as percentage points (referred to as points or p.p.), i.e., the EU's R&D intensity was 2.23% in 2019 and 2.32% in 2020; thus, the increase is 0.09 percentage points. Each of these indicators shows the state of the corresponding performance sector: BERD indicates the business enterprise interest in R&D; GOVERD shows the government's efforts; HERD represents the higher education sector's performance.

This study also considered the countries' income levels while comparing GERD, BERD, GOVERD and HERD figures to offer some insight into countries' R&D progress. Conceptualised income groups were created to observe the development of R&D expenditures in countries with similar economic levels. Four income groups were created, similar to World Bank's classification. The EU27 member states were divided into the high, upper-middle, lower-middle and low income groups regarding their gross national income (GNI) per capita in 2020. Member states, sorted as highest to lowest income, were separated into four groups based on their quartile positions, where the first quartile represented the low-income groups and the fourth the high-income group (see Table 2). Alternative income groups were created using averaged GNI values between 2000 and 2020 to check whether there were significant differences. Only two countries were found in different income groups: Greece and Lithuania. In the alternative group, Greece descended to the lower-middle-income group instead low-income, whereas Lithuania ascended to lower-middle-income from the low-income group. Since most countries were unaffected, this study used the GNI per capita in 2020 to group countries.

R&D leaders and laggers of the EU27 were determined using a comparative analysis of historical R&D performance (2000-2020) and performance in 2020 to determine whether the R&D leaders in 2020 are the same countries that have determinately progressed. Performance scores were calculated based on a method derived from the European Union's Scoreboard's (European Commission, 2021) rescaling and relative performance score methodology. However, this study did not aggregate the indicators as a composite indicator. Moreover, to assess the progress between data for 2000 and 2020, new data series, named historical change, were created for each indicator. Each historical change series corresponded with one of the indicators and

consisted of differenced data for that indicator in 2020 and 2000 across all countries. Outliers for the series were ignored as they were found as natural occurrences, not errors. For each series, minimum and maximum data were found and rescaling was done by subtracting the minimum data from the country's data and dividing the first result by the difference between the maximum and minimum data. Finally, the relative performance score for each country was calculated by dividing the rescaled score by the EU's rescaled score and multiplying the result by 100. The same steps, except differencing 2020 and 2000, were also performed for the data for 2020.

After the calculations, there were eight relative performance series: four series showing the performance of the EU27 in 2020 and four series between 2000 and 2020 (see Table 4). The relative performance method takes the EU27's performance as a base at 100. Thus, member states' performances could be assessed objectively based on how they performed compared to the rest. Moreover, using European Union's Scoreboard (European Comssion, 2021) performance scale, this study identified the countries with above 125% of the EU's average as outperformers and below 70% as underperformers. Leaders were the top performer in each income group, whereas the laggers were the worst performer.

Finally, three non-EU countries whose data were available in Eurostat were selected as benchmarks against the EU27 member states: the United States, South Korea and China. A benchmark country could not be found for the lower-middle-income group as no country was within the income range had R&D intensity data available.

RESULTS AND DISCUSSION

Descriptive Analysis of Research and Development Expenditures

Gross Domestic Expenditure on Research and Development

Gross domestic expenditure on R&D (GERD) is constructed by adding intramural expenditure aggregates for the following sectors: business enterprise, government, higher education, and private not-for-profit (OECD, 2015). Increased gross expenditure on R&D may boost technological development, and researchers often expect the increase in GERD to have a positive and substantial effect on economic growth (Gumus & Celikay, 2015). Many studies on R&D determinants concentrate on R&D expenditure and R&D intensity and use these two measures as input (Becker, 2013). Similarly, empirical studies on the relationship between R&D and economic growth use R&D intensity as a variable or a measure. R&D intensity can be expressed as the share of R&D expenditure to GDP (Dougherty, Inklaar, McGuckin & Van Ark, 2007), which is also true for this study. Bilbao-Osorio and Rodríguez-Pose (2004) stated that the R&D intensity demonstrates the effort to create, spread and utilise knowledge within a region.

Figure 1 indicates a positive trend in GERD for most countries between 2000 and 2020, while some countries boosted their expenditures on R&D more significantly than the rest. South Korea takes the lead among them with a spiked increase from 2.13% to 4.64% in 2019 – this is double what the Europe Union (2.32% in 2020) and China (2.23%) spent on R&D and 50% more than what the United States (3.08%) spent. Belgium, Austria, China, and Estonia have also surpassed the other countries in growth in R&D expenditure. Belgium shows an increase in expenditure between 2000 and 2020 from 1.94% to 3.52%; Austria from 1.89% to 3.22%; China from 0.94% (in 2001) to 2.23% (in 2019); and Estonia from 0.6% to 1.79%.

It is worth highlighting that there is a negative trend in expenditures on R&D, which can be seen only in the high-income group. Luxemburg, Sweden, and Finland are the only countries with a negative change in R&D expenditure among the four income groups. Luxemburg, Sweden and Finland show a considerable cut in expenditure on R&D between 2000 and 2020 with -0.45, -0.36, and -.30 points, respectively.

Table 3 shows the difference in GERD for each income group between 2000 and 2020. Due to the negative trend mentioned above, the high-income group ranks last among the four groups in terms of change in R&D expenditure. High-income group shows the weakest development in increasing its GERD between 2000 and 2020. Countries in the upper-middle, lower-middle and low income groups increased their spending on R&D as a percentage of GDP more substantially while high-income group countries decreased their spending.

Observing the development of GERD in two decades may give more insight into a country's effort to boost its R&D activities. Here, this effort is recognised as the change in GERD as a percentage of GDP, and R&D leaders are the countries that achieved the most significant change in an income group, whereas R&D laggers achieved the poorest. The leaders of the high-income, upper-middle, lower-middle and low income groups are Austria (1.33 p.p.), Belgium (1.58 p.p.), Estonia (1.19 p.p.), and Greece (0.93 p.p.), respectively. The laggers of high, upper-middle, lower-middle and low income groups are Luxemburg (-0.45 p.p.), France (0.26 p.p.), Slovakia (0.28 p.p.), and Romania (0.10 p.p.), respectively.

Countries with more income can allocate more funds to research and development activities. In

2020, high-income group countries spent 2.48% of their GDP on R&D; upper-middle-income countries spent 2.14%; lower-middle-income countries spent 1.47%, and low-income countries spent 1.11%. In comparison, the United States (3.08% in 2019) exceeded the group average for the high-income group; South Korea (4.64% in 2019) for the upper-middle-income group; and China (2.23% in 2019) for the low-income group.

In 2020, on average, income groups spent on R&D according to their incomes – the higher the group income higher the expenditure. However, countries with the highest GNI per capita did not spend the most on R&D in income groups. For instance, Luxemburg and Ireland rank last at GERD in the high-income group despite having the highest GNI per capita. Similarly, Germany ranks behind Belgium in the upper-middle-income group, Malta has the lowest GERD in the lower-middle-income group, and Greece lags behind Hungary in the low-income group.

Expenditure on R&D varies significantly among the high-income and upper-middle-income group members. We can define the R&D leader as a country with the highest GERD in a year and the lagger with the smallest GDP. The gap between the leader and the lagger appears to be bigger among high- and upper-middle-income countries. Luxemburg is the lagger (1.13%) in the high-income group, while Sweden is the leader (3.51%) for 2020; and in the upper-middle-income group, Cyprus ranks last with GERD of 0.85%, and Belgium ranks first with 3.52%. In lower-middle and low income groups, Malta (0.66%) and Romania (0.47%) are laggers, whereas Slovenia (2.15%) and Hungary (1.62%) are leaders.

Figure 2 shows the share of GERD components in twenty years for the EU27 income groups and benchmark countries. Data were extracted in a million Euros for sectors, and the average of twenty years was taken as a representative figure for each country. According to Figure 3, all income groups and benchmark countries primarily made expenditures on business enterprise R&D. For all countries, except for China, higher education expenditure (HERD) and government expenditure (GOVERD) have the second and the third-largest share of GERD. In the following chapters, the growth of three major components of GERD within the income groups will be analysed.

GERD consists of three major components: business enterprise expenditure (BERD), government intramural expenditure (GOVERD), and higher education expenditure (HERD). As Figure 2 indicates private not-for-profit (PNP) sector, while being the fourth component, represents a meagre percentage of countries' GERD. Thus, PNP was not included as an indicator to assess the selected countries for this study.

Business Enterprise Expenditure on Research and Development

According to Frascati Manual (OECD, 2015), BERD is the share of gross expenditure on R&D incurred by the business enterprise sector units conducted within the national territory. Business enterprise R&D mainly focuses on applied research, which has a potential profitable interest. Therefore, BERD has been the biggest component of GERD as R&D activities performed in business enterprises have a higher rate of return than in the higher education and government sectors (Bilbao-Osorio & Rodríguez-Pose, 2004). Moreover, BERD is a key indicator of innovation activities, and it has a robust and significant impact on economic growth (Silaghi et al., 2014).

Figure 3 shows BERD growth for all countries between 2000 and 2020. South Korea has the highest increase in business expenditure on R&D, followed by Belgium and China. South Korea's BERD increased from 1.57% in 2000 to 3.73% in 2019, which is more than double the European Union's (1.53% in 2020) and China's (1.71%) and 50% more than the United States (2.27%). Belgium had an increase in expenditure between 2000 and 2020 from 1.40% to 2.56%; China from 0.57% (in 2001) to 1.71% (in 2019); and Hungary from 0.35% to 1.24%.

The negative trend observed in the high-income group's GERD is also present for BERD in Luxemburg, Sweden and Finland. Luxemburg reduced its business expenditure on R&D between 2000 and 2020 by 0.85 p.p.; Sweden by -0.47 p.p. (2001-2020); and Finland by -0.33 p.p. High-income group shows the weakest growth between 2000 and 2020 due to the negative development of BERD.

If we acknowledge the positive change in BERD (as a percentage of GDP) as the effort to boost the R&D activities within a country, we can categorise leaders and laggers of business sector R&D based on their expenditure growth between 2000 and 2020. Consequently, Austria (0.85 p.p.), Belgium (1.16 p.p.), Estonia (0.84 p.p.) and Hungary (0.89) emerge as leaders of high, upper-middle, lower-middle and low income groups, respectively. In contrast, Luxemburg (-0.85 p.p.) becomes the lagger of the high-income group; France (0.25 p.p.) of the upper-middle-income group; Slovakia (0.08 p.p.) of the lower-middle-income group; and Romania (0.03 p.p.) along with Latvia (0.3 p.p.) of low-income group.

In 2020, high-income group countries spent 1.66% of their GDP on BERD; upper-middle-income countries spent 1.39%; lower-middle-income countries spent 0.88%; and low-income countries spent 0.64%. United States (2.27% in 2019) surpassed the group average for the high-income group; South Korea (3.73% in 2019) for the upper-middle-income group; and China (1.71% in 2019)

for the low-income group. The group average shows that the European Union countries spent on BERD per their income. Table 3 contains BERD figures as a percentage of GDP in 2020 for all income groups. While the group average of BERD was parallel with the level of income of the EU27 countries, in some cases, individual spending records did not match with countries' income levels. In the case of Luxembourg, Germany, Malta, and Greece, the countries fell behind other group members with their BERD despite having the highest GNI per capita in their respective income groups.

Based on the definition of leader and lagger of R&D used in the previous subchapter, leader and lagger of business sector R&D in a year are the countries with the largest BERD and smallest BERD. The laggers of high, upper-middle, lower-middle and low income groups for 2020 are Luxemburg (0.61%), Cyprus (0.38%), Malta (0.42%) and Latvia (0.21%), respectively. For the same year, Sweden (2.53%), Belgium (2.56%), Slovenia (1.57%) and Hungary (1.24%) are the leaders of high, upper-middle, lower-middle and low income groups, in this order. Similar to GERD, the difference between the lagger and the leader is more evident in high-income and upper-middle-income groups than in lower-middle and low income groups.

Higher Education Expenditure on Research and Development

Higher education expenditure on R&D (HERD) is a component of GERD, and it represents the gross domestic expenditure on R&D incurred by the units within the higher education sector (OECD, 2015). Unlike business sector R&D, research activities performed in the higher education sector tend to be more basic than applied, leading to a lower count of new patents (Bilbao-Osorio & Rodríguez-Pose, 2004). Still, expenditure on higher education R&D is connected with the business sector as it creates new opportunities and knowledge for business sector R&D (Pegkas et al., 2019; Van Pottelsberghe De La Potterie, 2008).

Between 2000 and 2020, the majority of the EU27 member states increased their HERD. Figure 4 indicates a positive trend in HERD for most countries while pointing to stagnation for some countries. However, compared with the change in BERD within the same period, the change in HERD appears small. Moreover, the share of higher education expenditure on R&D in GERD remains significantly low compared with BERD. Denmark has the largest increase in HERD among all countries, from 0.43% in 2000 to 1.09% in 2020. Portugal (from 0.27% to 0.58%), Poland (from 0.20% to 0.49%) and Estonia (from 0.31% to 0.60) follow Denmark. In contrast to leaders, the EU27 and benchmark countries show minimal changes in HERD. The Europe Union raised its spending on higher education R&D to 0.51% in 2020 from 0.38% in 2020, South Korea to 0.38% in 2019 from 0.24% in 2000, China to 0.18% in 2019 from 0.09% in 2001 and United States to 0.37% in 2019 from 0.30% in 2000.

Contrasting GERD and BERD, there is no negative trend in higher education expenditures on R&D in any income group. However, four low-income countries stagnated over the years: Romania (0.04%) and Bulgaria (0.05%) kept their higher education expenditures on R&D the same while Hungary (0.02 p.p.) and Slovenia (0.03 p.p.) made very little progress. As a result, the low-income group ranks last among the four groups in change in HERD due to lack of progress. On the other hand, high-income and lower-middle-income groups, followed by upper-middle-income, slightly increased their HERD between 2000 and 2020.

Denmark (0.66 p.p.) is the higher education R&D leader for 2000-2020 in the high-income group; Cyprus (0.25 p.p.) in the upper-middle-income group; Portugal (0.31 p.p.) in the lower-middle-income group; and Poland (0.29 p.p.) in the low-income group. The laggers of high, upper-middle, lower-middle and low income groups, in order, are the Netherlands (0.05 p.p.), Italy (0.05 p.p.), Slovenia (0.03 p.p.), and Romania (0 p.p.) with Bulgaria (0 p.p.).

In terms of income and spending, similar to the case in GERD and BERD, countries with higher GNI per capita spent more on higher education research and development activities. Table 3 shows the HERD as a percentage of GDP in 2020 for all income groups. In 2020, high-income group countries spent 0.64% of their GDP on higher education R&D; upper-middle-income countries 0.45%; lower-middle-income countries 0.40%; and low-income countries 0.29%. In comparison, the United States (0.37% in 2019) fell behind the group average of the high-income group; South Korea (0.38% in 2019) in the upper-middle-income group; and China (0.18% in 2019) in the low-income group. Likewise, some EU member states fell behind with their spending on higher education R&D despite having the highest GNI per capita: Luxemburg and Ireland in the high-income group; Germany in the upper-middle-income group; Malta in the lower-middle-income group; and Greece in the low-income group. However, Germany and Greece rank second in their respective groups and remain close to the group leaders.

The gap between the leaders and laggers of higher education R&D in 2020 is substantial, especially when compared to the group averages. Denmark ranks first in HERD (1.09%), whereas Luxemburg ranks last (0.25%) in the high-income group and Belgium ranks first with 0.62%, whereas Cyprus ranks last with 0.31% in the upper-middle-income group. In lower-middle and low income groups,

Estonia (0.60%) and Poland (0.49%) are leaders, whereas Malta (0.24%) with Slovakia (0.24%) and Romania (0.04%) with Bulgaria (0.05%) are laggers, respectively.

Government Expenditure on Research and Development

Frascati Manual (OECD, 2015) defines government expenditure on R&D (GOVERD) as the primary cumulative statistic to describe the performance of government sector R&D and as a component of gross domestic expenditure on R&D (GERD). GOVERD, along with HERD, historically has a smaller share in GERD. Although both sectors fail to attract more expenditure against BERD, they have been more resistant to economic instabilities (Pegkas et al., 2019). Government expenditure on R&D is also closely linked to business R&D; Coccia (2011) suggests that when GOVERD is less than BERD, it can stimulate economic growth.

Figure 5 shows a negative trend in GOVERD for thirteen countries while pointing to stagnation for the others between 2000 and 2020. Among all countries, Greece has the largest increase in GOVERD with 0.12% in 2000 to 0.32% in 2020. Other noteworthy countries with an increase are Belgium (0.19 p.p.) and Luxemburg (0.16 p.p.). Similar to the HERD, the EU27 and benchmark countries show a minimal change in GOVERD. The European Union raised its spending on government R&D to 0.27% in 2020 from 0.25% in 2020, South Korea to 0.46% in 2019 from 0.28% in 2000, China to 0.35% in 2019 from 0.28% in 2001 and United States to 0.30% in 2019 from 0.28% in 2000.

All income groups have several countries with declined government expenditures on R&D. High-income and lower-middle-income groups have four countries each, as upper-middle-income and low-income groups have three. Regarding the change in percentage points, the upper-middle-income group is the only group with a total positive difference between 2000 and 2020. Low-income groups show no change in percentage points, while high-income and lower-middle-income groups show a negative change.

Based on the change between 2000 and 2020, the government R&D leaders are Luxemburg (0.16 p.p.) in the high-income group, Belgium (0.19 p.p.) in the upper-middle-income group, and Czechia (0.06 p.p.) in the lower-middle-income group, and Greece (0.20 p.p.) in the low-income group. On the opposite end, Denmark (-0.19 p.p.) is the lagger in the high-income group; France (-0.08 p.p.) in the upper-middle-income group; Portugal (-0.09 p.p.) in the lower-middle-income group; and Poland (-0.18 p.p.) in the low-income group.

In terms of income and spending, countries with lower GNI per capita spent more on government R&D. Table 3 shows the GOVERD as a percentage of GDP in 2020 for all income groups. In 2020, on average, high-income group countries spent 0.16% of their GDP on government R&D; upper-middle-income countries 0.26%; lower-middle-income countries 0.18%; and low-income countries 0.18%. In comparison, the United States (0.30% in 2019) exceeded the group average of the high-income group; South Korea (0.46% in 2019), the upper-middle-income group; and China (0.35% in 2019), the low-income group. Some EU members spent less on government R&D despite their high GNI per capita: Denmark in the high-income group and Malta in the lower-middle-income group.

Compared to the group averages, the gap between the leaders and laggers of government R&D in 2020 is noteworthy for all income groups. Leaders of government R&D are Luxemburg (0.27%) together with Austria (0.24%) are leaders, while Ireland (0.04%) is the lagger in the high-income group. Germany (0.45%) and Cyprus (0.06%) are the leader and lagger in the upper-middle-income group; Czechia (0.34%) with Slovenia (0.30%) and Malta (0.00%) in the lower-middle-income group; and Greece (0.32%) and Poland (0.03%) in the low-income group.

Leaders and Laggers of R&D Progress

Descriptive analysis showed that some countries with the highest R&D intensity levels in their income groups only retained their initial level in 2000. In other words, these countries did not substantially increase their R&D intensities compared to their group member, and in some cases, they digressed in their expenditures. Consequently, countries with poor initial levels of R&D intensity ranked lower in income groups despite the improvement they showed between 2000 and 2020.

This chapter will appoint leaders and laggers of R&D progress based on historical performance. In this comparative analysis, a country's performance corresponds with only its expenditure on R&D. As described in the methodology chapter, relative performance scores were calculated for GERD, BERD, HERD and GOVERD for 2020 and the change between 2000 and 2020 across countries. To appoint the leaders and laggers of R&D progress, only the performance analysis for 2000-2020 is sufficient. Still, performance analysis for 2020 is listed to show the contrast between the leaders and laggers of 2020 and R&D progress (see Table 4). Table 4 shows how countries performed compared with the EU27 average in a given period. Performance of more than 125% of the EU27 average (100) is considered outperformance (highlighted with green), whereas less than 70% is considered underperformance (highlighted with red).

Across the EU27, historical performance paints a more positive picture than the performance in 2020. The performance in 2020 indicates that the majority of the countries underperformed with GERD, BERD, HERD and GOVERD. This underperforming is expected as the high-income and some upper-middle-income group countries increase the average of the EU. However, the historical performance draws results from the change in values which leverages the initial advantage and disadvantages of the countries.

Between 2000 and 2020, in the EU27, Belgium emerges as the R&D leader with the highest relative performance score for GERD, as Austria, Estonia, Greece, and Czechia follow as the second, third, fourth and fifth top performers. These countries had the highest increase in R&D intensity (in terms of p.p.) compared to the EU's average. Austria, Belgium, Estonia and Greece are also the leaders of high, upper-middle, lower-middle and low income groups. Conversely, Luxemburg has the lowest relative performance score for GERD and it is the R&D lagger in the EU27. Sweden, Finland, Romania and Ireland follow Luxemburg as the worst performers. Luxemburg, France, Slovakia and Romania have the lowest scores in high, upper-middle, lower-middle and low income groups.

The business R&D leader in the EU27 is Belgium in terms of progress between 2000 and 2020. Hungary, Austria, Estonia, and Slovenia are the second, third, fourth and fifth best business R&D performers. Income group leaders of R&D are Austria in high-income, Belgium in upper-middle-income, Estonia with Slovenia in lower-middle-income and Hungary in low-income groups. Slovenia and Estonia share the leadership due to their very close scores. The top five laggers of the EU27 are Luxemburg, Sweden, Finland, Latvia and Romania, where Luxemburg has the lowest relative performance score.

Based on the progress in the given period, the top five performers in higher education R&D are Denmark, Portugal, Poland, Estonia, and Czechia, where Denmark is the leader across the EU27. Poland and Estonia share the fourth position with the same relative score. In this order, the higher education R&D leader in high-income, upper-middle-income, lower-middle-income, and lower-income groups are Denmark, Cyprus, Portugal, and Poland. The high education R&D laggers in the EU27 are Romania and Bulgaria, with the same relative performance score. The Netherlands is the worst performer in the high-income; Italy in the upper-middle-income; Slovenia in the lower-middle-income; and Romania and Bulgaria in the low income group.

Greece is the government R&D leader based on the growth between 2000 and 2020. It is followed by Belgium, Luxemburg, Germany and Austria. German and Austria share the same score and fourth position in top-performance. Luxemburg ranks first in the high-income; Belgium in the upper-middle-income; Czechia in the lower-middle-income; and Greece in the lower-income groups. Denmark is the worst performer in the EU27 and ranks last. Poland, Bulgaria, Finland, and Portugal are the second, third, and fourth worst performers in ascending score order. In the income groups, the laggers of high-income, upper-middle-income, lower-middle-income and low-income groups are Denmark, France, Portugal, and Poland.

When we compare the income group leaders in 2020 to the leaders of R&D progress, rankings change in many instances. Some of the leaders in 2020, even when they are not the leaders of R&D progress, can be justified by their relatively high historical performance scores. This justification also applies to the laggers in 2020. However, in some instances, the ranks in 2020 contradict the historical progress. For example, in 2020, Romania and Latvia appear as R&D and business R&D laggers. However, Luxemburg has the lowest historical performance scores for both expenditure types.

Similarly, Malta ranks last for government R&D in 2020, whereas Denmark is the worst performer between 2000 and 2020. Sweden occupies the second rank in R&D, business R&D, and higher education R&D in 2020. However, historical performance scores indicate that the following countries outperform Sweden: Austria, Hungary and Portugal. Sweden also appears to be the high-income group leader for R&D and business R&D in 2020, whereas Austria, with significantly greater historical performance scores, is the leader of R&D progress in these income groups.

Additionally, France should be the lagger of R&D and business R&D in the upper-middle-income group for 2020 instead of Cyprus, which has a significantly greater historical performance score than France between 2000 and 2020. In the same group, Cyprus appears as the group lagger for higher education R&D in 2020. However, Cyprus is the higher education R&D leader in terms of progress. In contrast, Italy, with the lowest score for 2000-2020, should be appointed as the lagger in this instance. Slovakia shares the worst performer position with Malta in the lower-middler-income group while having double Malta's relative performance score.

CONCLUSIONS

In the first part of this study, a descriptive analysis was performed on the European Union's gross domestic expenditure on R&D (GERD) data for the period between 2000 and 2020. Data for GERD and its components (BERD, HERD, GOVERD)

were retrieved from Eurostat (2022). For descriptive analysis, the EU27 member states were grouped based on their gross national income (GNI) per capita; data for this grouping were retrieved from World Bank (2022). Four income groups were created based on GNI per capita: high-income, upper-middle-income, lower-middle-income, and low-income. In the second part of this study, relative performance scores of the EU27 member states were calculated using a method derived from the European Scoreboard 2021. GERD, BERD, HERD, and GOVERD were taken as indicators, and two relative performance scores for each country were calculated: a historical relative performance score for 2000-2020 and a relative performance score for 2020.

This study indicates that the European Union still has not caught up with the United States and is strikingly behind South Korea in R&D expenditures, except for higher education expenditures on R&D (HERD). Meanwhile, China caught up with the EU in 2019 and is ahead of the EU's business expenditures on R&D (BERD). In twenty years, the EU increased its BERD most and then its HERD, whereas most member states reduced their government expenditure on R&D (GOVERD). This shift between sectoral R&D may have resulted from the higher rate of return that business R&D offers (Bilbao-Osorio & Rodríguez-Pose, 2004). An increase in HERD also may boost the business enterprise R&D in the long run through knowledge sharing and creating new opportunities (Pegkas et al., 2019; Van Pottelsberghe De La Potterie, 2008). The EU has been urging its member states to boost their R&D activities, mainly in the business enterprise sector, since 2000. However, the change in R&D intensity is only 0.51 p.p. for gross domestic R&D (GERD) and 0.36 p.p. for business R&D (BERD) between 2000 and 2020. As mentioned in the earlier chapters, the R&D activities are relative to countries' industrial structures. Based on the progress so far, we can speculate that the set goal for gross domestic expenditure on R&D, 3% of GDP, has not corresponded well with the EU member states' needs.

Descriptive analysis showed that among the income groups, in 2020, the high-income group had the highest expenditures on R&D in every sector of performance, except the government. Upper-middle-income and lower-middle-income groups had the second and third highest expenditures, whereas the low-income group had the lowest in 2020. However, the comparison of 2020 and 2000-2020 provided a striking contrast. When the initial conditions were eliminated and an assessment was made on the progress over the last twenty-one years, the high-income group became the worst performer in every R&D component, except for higher education. In other words, the high-income group showed the least growth in R&D expenditures. Meanwhile, the lower-income group emerged as the top performer in every sector except the government. Upper-middle-income group and the low-income group were second and third performers, respectively.

Most countries and income groups increased their BERD most and HERD the second. On the other hand, GOVERD stagnated or reduced across the countries and income groups. In contrast to the positive trend in the EU27, Luxemburg, Sweden, and Finland digressed in GERD and BERD. Several factors could cause this opposite development: market size and structure, economic structure, industrial structure, enterprise structure, and government incentives (Van Pottelsberghe De La Potterie, 2008; European Commission, 2021).

This study aimed to assess the development of R&D expenditures in performance sectors within the European Union. Thus, only expenditure indicators were used in the analysis. Therefore, rankings for countries and income groups in 2020 and 2000-2020 are only applicable to the expenditures on R&D sectors. For a comprehensive assessment of countries' R&D performance, in addition to R&D inputs (e.g. expenditure, researchers, foreign direct investments), we would also need some process indicators (e.g. researchers, patent filling per industry) and some output indicators (e.g. exports, patent fillings). Still, this study provides a detailed breakdown of the gross domestic expenditure on R&D (GERD) in the European Union in relation to income levels and sectors and presents a comprehensive analysis of member states' R&D expenditure growth in the last twenty-one years.

Biographical sketch

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Table 1
Data and Selected Indicators

Data collection
Data source: Eurostat
World Bank
Years: 2000–2020
Countries: The European Union 27, Unites States, South Korea, China
Indicator
Research and development:
Gross Domestic Expenditure on R&D (GERD) as a % of GDP
Business Enterprise Expenditure on R&D (BERD) as a % of GDP
Government Expenditure on R&D (GOVERD) as a % of GDP
Higher education expenditures on R&D (HERD) as a % of GDP
Economic:
Gross National Income per capita (GNI) in current $, Atlas Method

Source: The Author.

Table 2
Income Groups Based on Gross National Income of the European Union Member States and Benchmark Countries in 2020

Income Group	Country Name	GNI (Atlas Method, current $)	Income Group	Country Name	GNI (Atlas Method, current $)
High	Luxembourg	80860	Upper Middle	Germany	47470
	Ireland	65620		Belgium	45750
	Denmark	63010		France	39480
	Sweden	54050		Italy	32290
	Netherlands	51060		Spain	27360
	Finland	49780		Cyprus	26110
	Austria	48350			
Lower Middle	Malta	25370	Low	Greece	17930
	Slovenia	25360		Latvia	17880
	Estonia	23170		Hungary	15890
	Czechia	22070		Poland	15240
	Portugal	21790		Croatia	14530
	Lithuania	19620		Romania	12580
	Slovakia	18920		Bulgaria	9630
(High)	The United States	64550	(Upper Middle)	South Korea	32960
			(Low Income)	China	10550

Source: World Bank (2022).

Table 2
Gross Domestic Expenditure on R&D and Its Components as a Percentage of GDP for Income Groups in 2000 and 2020

Income Group	Country	GERD (%)			BERD (%)			HERD (%)			GOVERD (%)		
		2020	2000	Diff.	2020	2000	Diff.	2020	2000	Diff.	2020	2000	Diff.
High Income	Luxembourg	1.13	1.58	-0.45	0.61	1.46	-0.85	0.25	0.00	0.25	0.27	0.11	0.16
	Ireland	1.23	1.08	0.15	0.91	0.78	0.13	0.28	0.22	0.06	0.04	0.09	-0.05
	Denmark	3.03	2.19	0.84	1.84	1.46	0.38	1.09	0.43	0.66	0.09	0.28	-0.19
	Sweden	3.51	3.87	-0.36	2.53	3.00	-0.47	0.82	0.76	0.06	0.16	0.11	0.05
	Netherlands	2.29	1.79	0.50	1.54	0.99	0.55	0.62	0.57	0.05	0.13	0.22	-0.09
	Finland	2.94	3.24	-0.30	1.97	2.30	-0.33	0.72	0.58	0.14	0.22	0.34	-0.12
	Austria	3.22	1.89	1.33	2.23	1.38	0.85	0.73	0.56	0.17	0.24	0.12	0.12
	Median	**2.94**	**1.89**	**0.15**	**1.84**	**1.46**	**0.13**	**0.72**	**0.56**	**0.14**	**0.16**	**0.12**	**-0.05**
	Mean	**2.48**	**2.23**	**0.24**	**1.66**	**1.62**	**0.04**	**0.64**	**0.45**	**0.20**	**0.16**	**0.18**	**-0.02**
Upper Middle	Germany	3.14	2.41	0.73	2.11	1.69	0.42	0.57	0.40	0.17	0.45	0.33	0.12
	Belgium	3.52	1.94	1.58	2.56	1.40	1.16	0.62	0.39	0.23	0.31	0.12	0.19
	France	2.35	2.09	0.26	1.56	1.31	0.25	0.48	0.39	0.09	0.28	0.36	-0.08
	Italy	1.54	1.00	0.54	0.94	0.50	0.44	0.36	0.31	0.05	0.20	0.19	0.01
	Spain	1.41	0.88	0.53	0.78	0.47	0.31	0.37	0.26	0.11	0.25	0.14	0.11
	Cyprus	0.85	0.23	0.62	0.38	0.05	0.33	0.31	0.06	0.25	0.06	0.11	-0.05
	Median	**1.95**	**1.47**	**0.58**	**1.25**	**0.91**	**0.38**	**0.43**	**0.35**	**0.14**	**0.27**	**0.17**	**0.06**
	Average	**2.14**	**1.43**	**0.71**	**1.39**	**0.90**	**0.49**	**0.45**	**0.30**	**0.15**	**0.26**	**0.21**	**0.05**
Lower Middle	Malta	0.66	0.25	0.41	0.42	0.06	0.36	0.24	0.15	0.09	0.00	0.04	-0.04
	Slovenia	2.15	1.36	0.79	1.57	0.77	0.80	0.26	0.23	0.03	0.30	0.35	-0.05
	Estonia	1.79	0.60	1.19	0.98	0.14	0.84	0.60	0.31	0.29	0.18	0.14	0.04
	Czechia	1.99	1.11	0.88	1.21	0.67	0.54	0.43	0.16	0.27	0.34	0.28	0.06
	Portugal	1.58	0.72	0.86	0.89	0.20	0.69	0.58	0.27	0.31	0.08	0.17	-0.09
	Lithuania	1.17	0.59	0.58	0.56	0.13	0.43	0.43	0.21	0.22	0.18	0.25	-0.07
	Slovakia	0.92	0.64	0.28	0.50	0.42	0.08	0.24	0.06	0.18	0.18	0.16	0.02
	Median	**1.58**	**0.64**	**0.79**	**0.89**	**0.20**	**0.54**	**0.43**	**0.21**	**0.22**	**0.18**	**0.17**	**-0.04**
	Average	**1.47**	**0.75**	**0.71**	**0.88**	**0.34**	**0.53**	**0.40**	**0.20**	**0.20**	**0.18**	**0.20**	**-0.02**
Low Income	Greece	1.49	0.56	0.93	0.69	0.14	0.55	0.47	0.25	0.22	0.32	0.12	0.20
	Latvia	0.70	0.44	0.26	0.21	0.18	0.03	0.36	0.16	0.20	0.13	0.10	0.03
	Hungary	1.62	0.79	0.83	1.24	0.35	0.89	0.21	0.19	0.02	0.16	0.21	-0.05
	Poland	1.39	0.64	0.75	0.88	0.23	0.65	0.49	0.20	0.29	0.03	0.21	-0.18
	Croatia	1.27	0.95	0.32	0.61	0.41	0.20	0.41	0.33	0.08	0.25	0.21	0.04
	Romania	0.47	0.37	0.10	0.28	0.25	0.03	0.04	0.04	0.00	0.15	0.07	0.08
	Bulgaria	0.86	0.50	0.36	0.58	0.11	0.47	0.05	0.05	0.00	0.22	0.34	-0.12
	Median	**1.27**	**0.56**	**0.36**	**0.61**	**0.23**	**0.47**	**0.36**	**0.19**	**0.08**	**0.16**	**0.21**	**0.03**
	Average	**1.11**	**0.61**	**0.51**	**0.64**	**0.24**	**0.40**	**0.29**	**0.17**	**0.12**	**0.18**	**0.18**	**0.00**
	European Union 27	2.32	1.81	0.51	1.53	1.17	0.36	0.51	0.38	0.13	0.27	0.25	0.02
	United States	3.08	2.63	0.45	2.27	1.95	0.32	0.37	0.30	0.07	0.30	0.28	0.02
	South Korea	4.64	2.13	2.51	3.73	1.57	2.16	0.38	0.24	0.14	0.46	0.28	0.18
	China	2.23	0.94	1.29	1.71	0.57	1.14	0.18	0.09	0.09	0.35	0.28	0.07

Source: Eurostat (2022).

Table 4
The EU27 Countries' Relative Performance Scores for GERD and Its Components for 2020 and 2000-2020.

		Performance 2000-2020				Performance 2020			
		GERD	BERD	HERD	GOVERD	GERD	BERD	HERD	GOVERD
	EU27	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
High Income	Luxembourg	0.00	0.00	192.31	166.67	35.68	30.30	44.68	100.00
	Ireland	62.50	80.99	46.15	66.67	41.08	53.03	51.06	14.81
	Denmark	134.38	101.65	507.69	0.00	138.38	123.48	223.40	33.33
	Sweden	9.37	31.40	46.15	114.29	164.32	175.76	165.96	59.26
	Netherlands	98.96	115.70	38.46	47.62	98.38	100.76	123.40	48.15
	Finland	15.63	42.98	107.69	33.33	133.51	133.33	144.68	81.48
	Austria	185.42	140.50	130.77	147.62	148.65	153.03	146.81	88.89
Upper Middle	Germany	122.92	104.96	130.77	147.62	144.32	143.94	112.77	166.67
	Belgium	211.46	166.12	176.92	180.95	164.86	178.03	123.40	114.81
	France	73.96	90.91	69.23	52.38	101.62	102.27	93.62	103.70
	Italy	103.13	106.61	38.46	95.24	57.84	55.30	68.09	74.07
	Spain	102.08	95.87	84.62	142.86	50.81	43.18	70.21	92.59
	Cyprus	111.46	97.52	192.31	66.67	20.54	12.88	57.45	22.22
Lower Middle	Malta	89.58	100.00	69.23	71.43	10.27	15.91	42.55	0.00
	Slovenia	129.17	136.36	23.08	66.67	90.81	103.03	46.81	111.11
	Estonia	170.83	139.67	223.08	109.52	71.35	58.33	119.15	66.67
	Czechia	138.54	114.88	207.69	119.05	82.16	75.76	82.98	125.93
	Portugal	136.46	127.27	238.46	47.62	60.00	51.52	114.89	29.63
	Lithuania	107.29	105.79	169.23	57.14	37.84	26.52	82.98	66.67
	Slovakia	76.04	76.86	138.46	100.00	24.32	21.97	42.55	66.67
Low Income	Greece	143.75	115.70	169.23	185.71	55.14	36.36	91.49	118.52
	Latvia	73.96	72.73	153.85	104.76	12.43	0.00	68.09	48.15
	Hungary	133.33	143.80	15.38	66.67	62.16	78.03	36.17	59.26
	Poland	125.00	123.97	223.08	4.76	49.73	50.76	95.74	11.11
	Croatia	80.21	86.78	61.54	109.52	43.24	30.30	78.72	92.59
	Romania	57.29	72.73	0.00	128.57	0.00	5.30	0.00	55.56
	Bulgaria	84.38	109.09	0.00	33.33	21.08	28.03	2.13	81.48

Source: Eurostat (2022).

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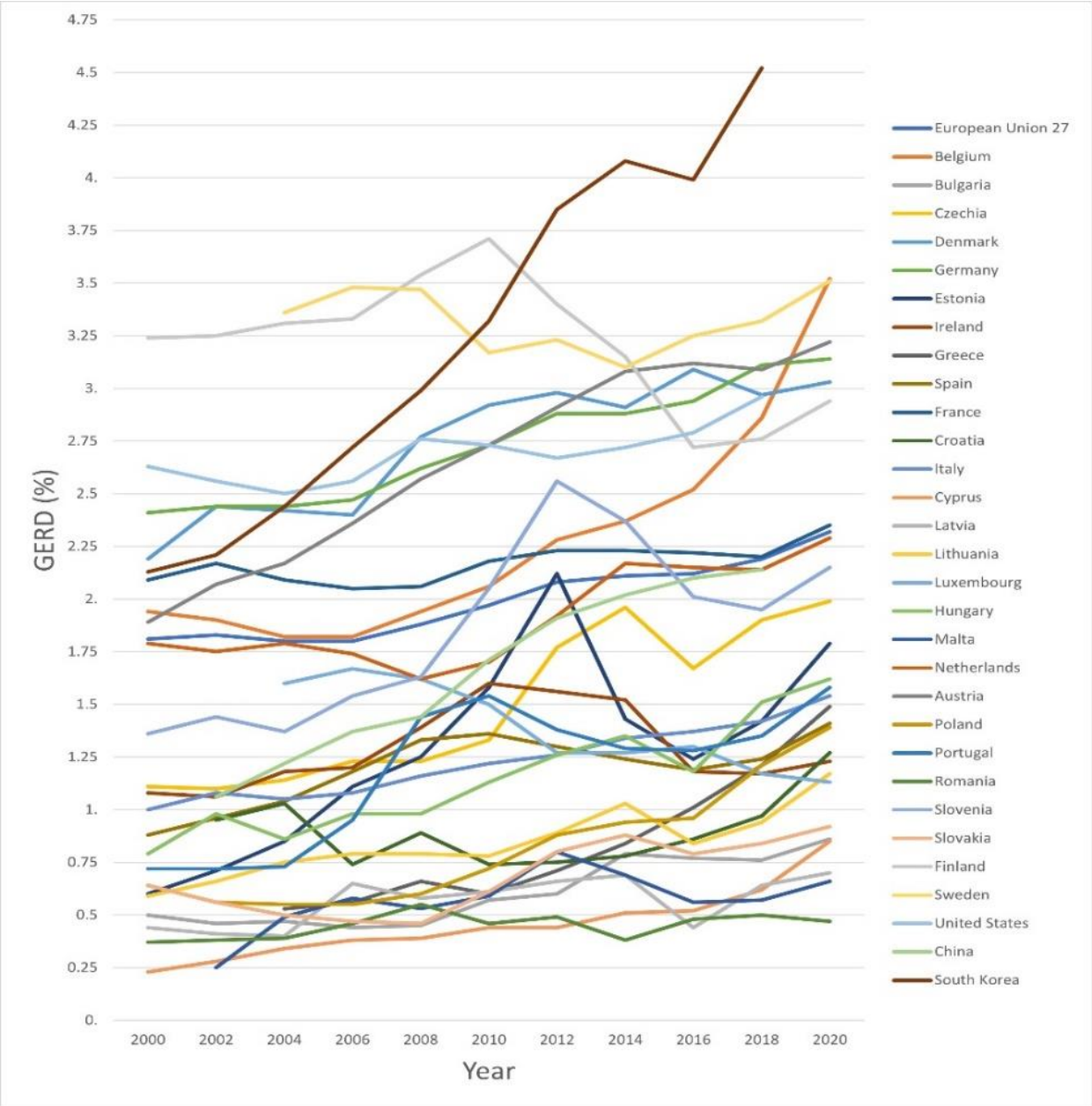


Figure 1
Gross domestic expenditure on R&D as a percentage of GDP for countries between 2000 and 2020
Source: Eurostat (2022)

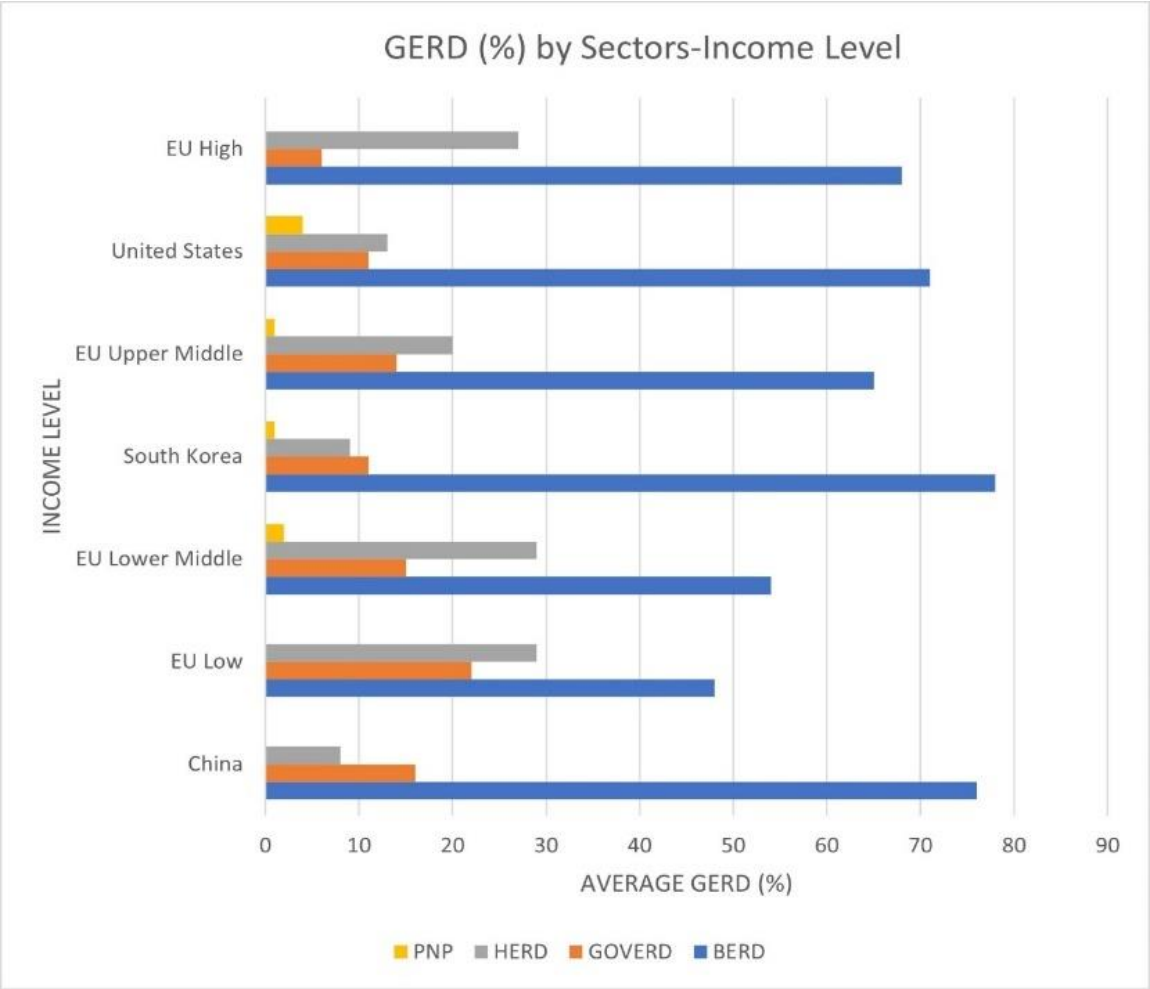


Figure 2
Sectoral Distribution of GERD as a Percentage of GDP between 2000 and 2020 for Income Groups
Source: Eurostat (2022)

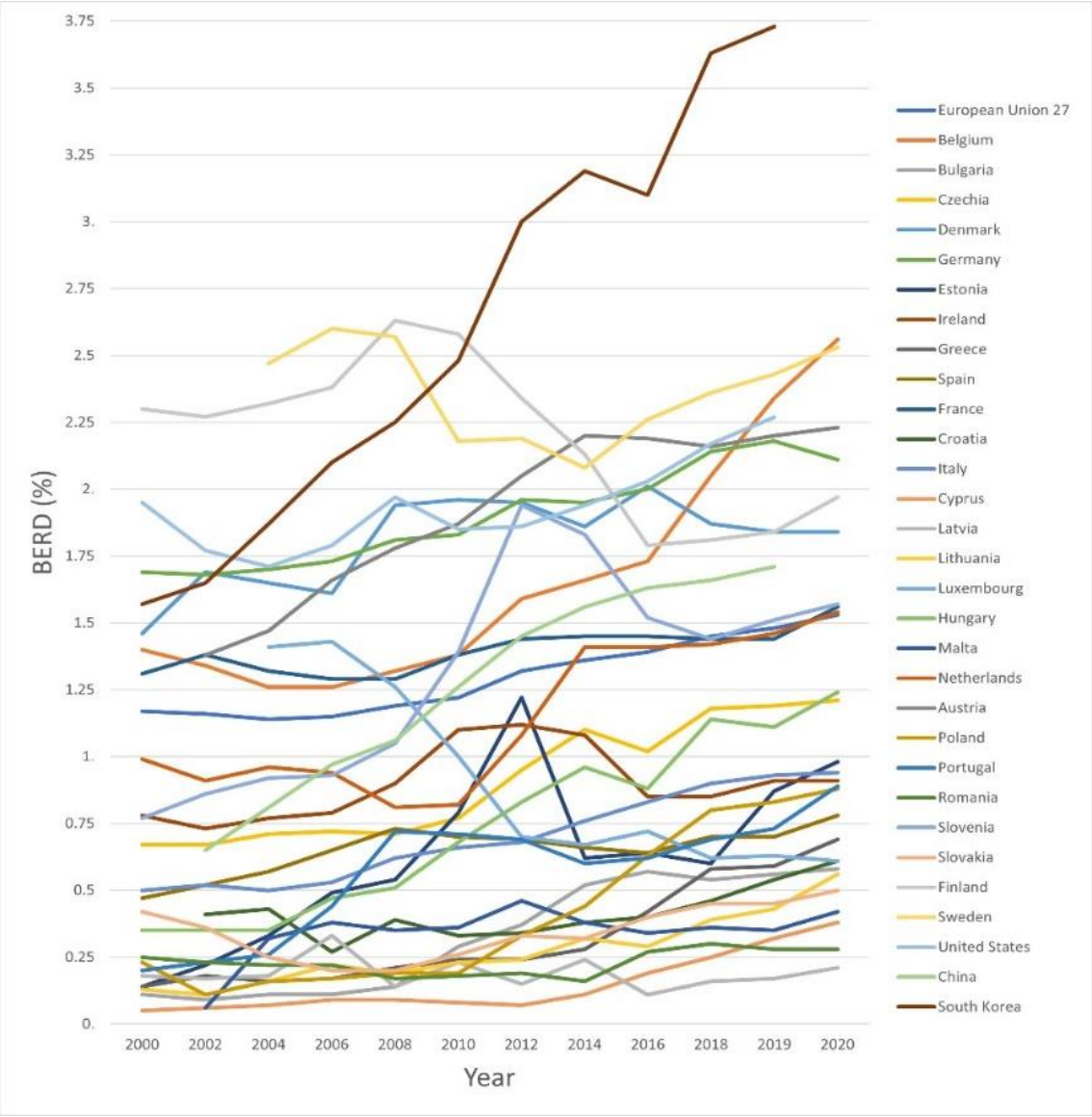
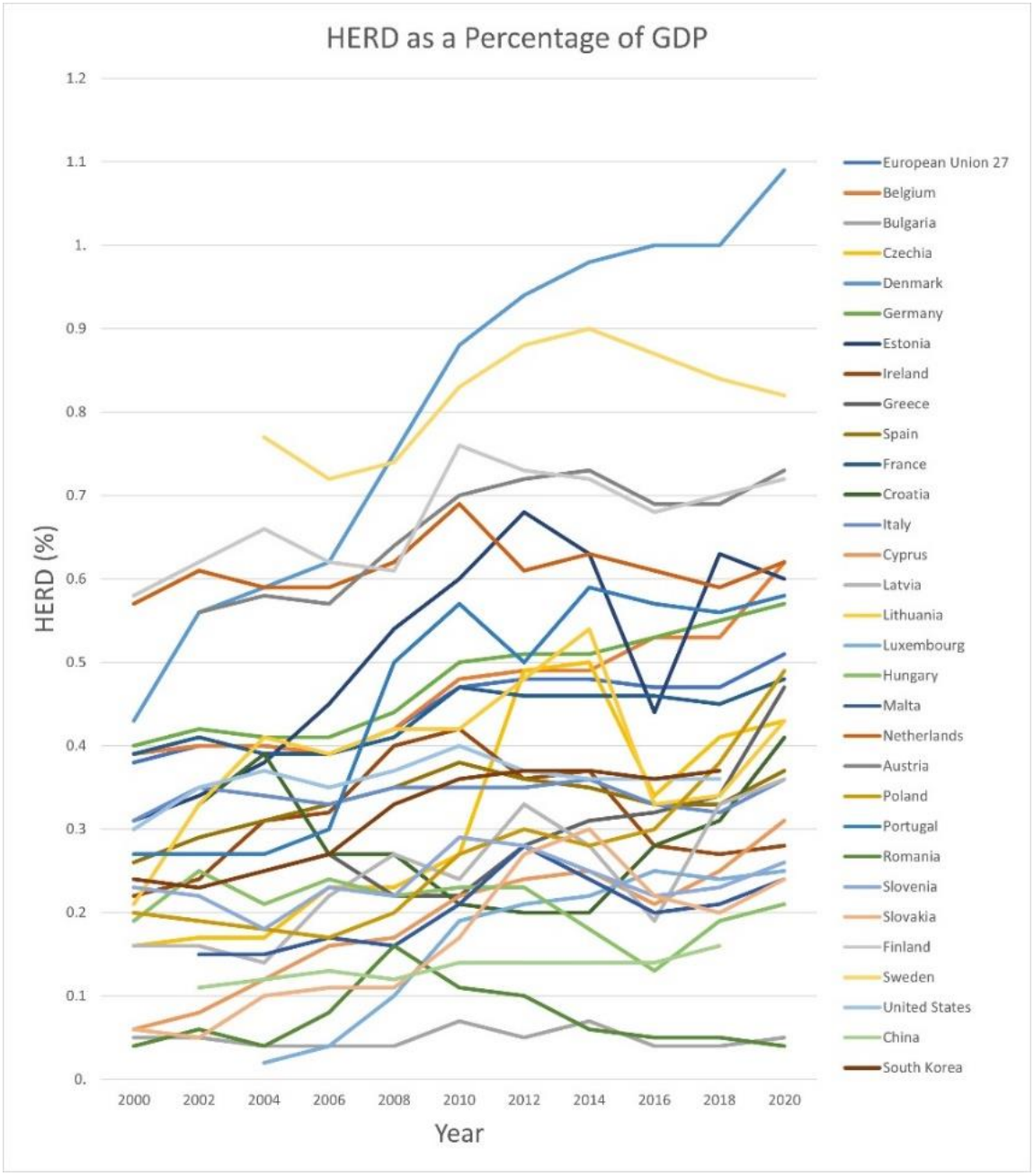


Figure 3
Business Enterprise Expenditure on R&D as a Percentage of GDP for Countries Between 2000 and 2020
Source: Eurostat (2022)



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Higher Education Expenditure on R&D as a Percentage of GDP for Countries Between 2000 and 2020
Source: Eurostat (2022)

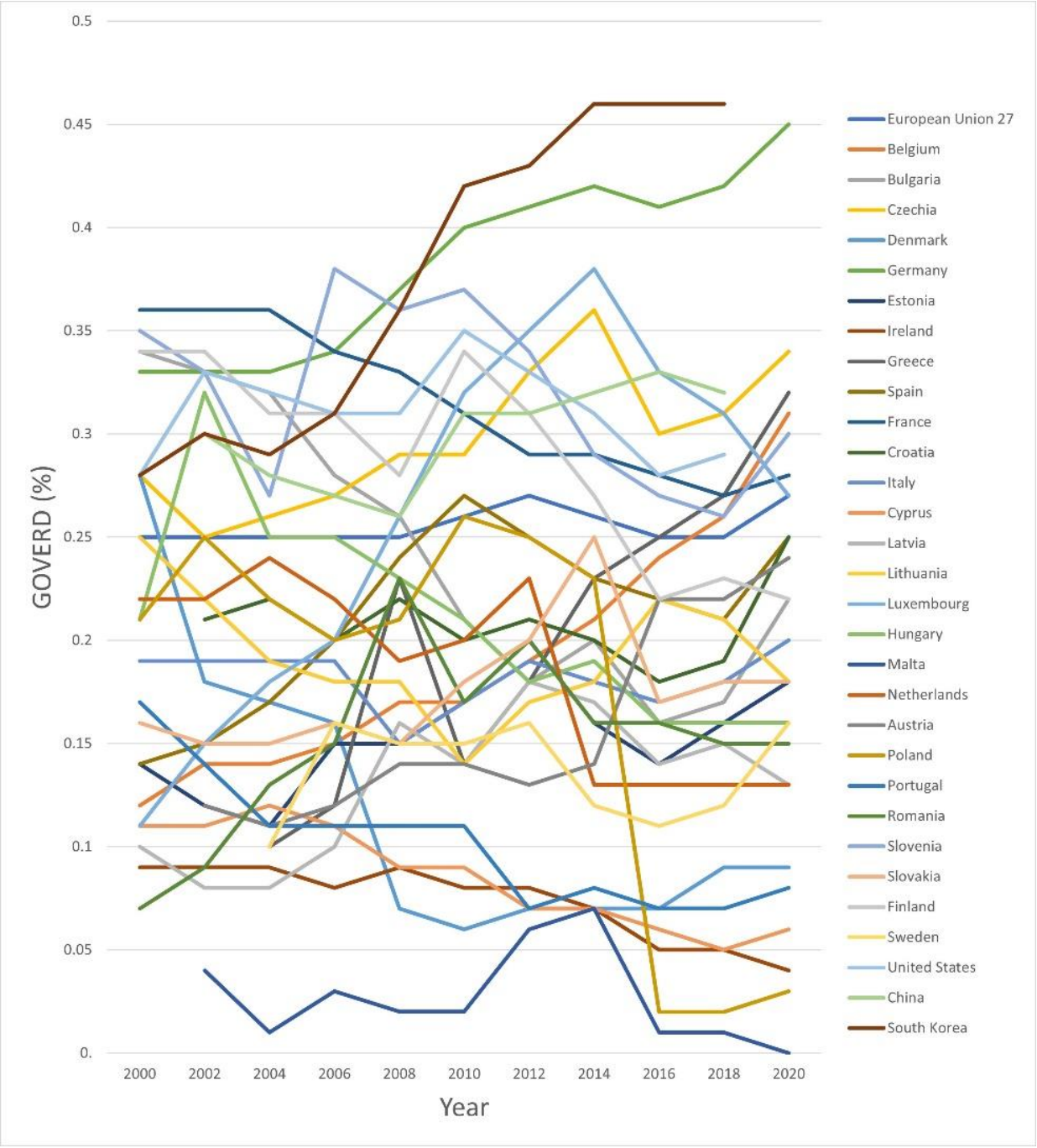

Figure 5
Government Expenditure on R&D as a Percentage of GDP for Countries Between 2000 and 2020
Source: Eurostat (2022)