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Funding sources and university patenting: an analysis of European higher education institutions

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Abstract
Although European universities account for no more than 10% of all patents, examining their patenting patterns remains relevant, given their contribution to breakthrough innovations and European technological competitiveness. We examine the role of university funding sources in patenting, addressing three key research gaps: (i) the reliance on limited, country-specific samples rather than pan-European data in most patenting-funding studies; (ii) the scarcity of evidence on the impact of the funding sources on patent quantity and quality; and (iii) the lack of precise estimates of interactions between university patenting, funding sources, and regional systems. We fill these gaps thanks to a micro-level database of almost 2,900 higher education institutions (HEIs) in 31 European countries and 295 within-country regions (2011–2019), containing detailed information on their activity as direct patent applicants and various institutional characteristics, including financial records. We show that universities with a greater share of third-party funds (research grants, contracts) apply for more patents and have better quality patents than those that rely mainly on core funding, i.e. national/regional allocations. The HEIs that do patent have more than twice the share of third-party revenues. This indicates that the very marked core-periphery pattern of university patenting in Europe is related both to the amount of university funding and to its sources. Additionally, we find that regional economic systems influence the way in which the funding sources relate to university patenting. The positive relationship between patenting and third-party funding is strongest in the wealthy regions, less so in developed areas, and negligible in the poorest regions.

Keywords Patents · Higher Education Institutions · University · Funding · Knowledge

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Introduction

Patenting has long been used to proxy for innovation and new knowledge creation, not only by firms but also by research institutions, including universities (Yang et al., 2021; Hvide & Jones, 2018; EPO, 2024). Recent data show that academic patents constitute approximately 10% of all European patent applications (EPO, 2024, p.11). Additionally, European university patenting[1] is extremely concentrated, with higher education institutions (HEIs) from just five Western European countries accounting for three-quarters of all applications and grants, while over 70% of institutions are inactive patent applicants (Parteka et al., 2024) and just 5% of universities account for half of all patent applications (EPO, 2024).

Despite the modest share of HEIs in overall patenting, investigating university patenting patterns remains highly relevant, given the critical role of university research in many breakthrough innovations such as vaccines (for instance, universities and public research organizations constitute 42% of patent applicants in COVID-19 vaccine field[2]), the 3D printer, laser technologies and artificial intelligence (EPO, 2024). Patents generated in the higher education sector are important instruments for transferring knowledge and technology from academia to the market (EPO, 2024; Perkmann et al., 2013), and are an important part of the so-called 'third mission' (Compagnucci & Spigarelli, 2020; Guerzoni et al., 2014; Baldini et al., 2006). For policy relevance, understanding how university funding sources relate to market-oriented innovation is important and timely, particularly given current EU efforts to close the innovation gap with the United States and China (EC, 2024; Draghi, 2024, EPO, 2024; EUA, 2025).

A rich literature has investigated determinants of university patenting (see Sect. 2), but one aspect, namely the role of universities' revenue sources, has remained underexplored in a pan-European perspective. The role of financial resources has been analysed mainly in terms of universities' aggregate budgets (Jain et al., 2020; Ejermo & Källström, 2016; Azagra-Caro et al., 2006). The purpose of this paper, instead, is to assess the sources of university funding as a determinant of patenting by European HEIs operating in different regional contexts. We use cross-country and cross-institutional variation in European universities' budget sources (ETER, 2019) to examine the relationship between patenting outcomes and financial sources, whilst controlling for other documented determinants of patenting success. We formulate two main research questions: (1) How does the composition of European universities' funding relate to their patenting success? (2) Is the relationship between university patenting and funding sources dependent on the characteristics of the regional innovation system?

In our analysis, we focus on the distinction between core and third-party funding given their divergent objectives (Yu et al., 2022; Guerzoni et al., 2014; Angori et al., 2023). Core funding typically finances the general operating budget of the higher education institution, while third-party funding is usually earmarked for specific activities, units, or researchers

[1] We use the term "university patents" to refer to direct patent applications in which at least one of the applicants was classified as HEI. Patents are allocated to HEIs using applicant shares.

[2] https://www.wipo.int/en/web/patent-analytics/exploring-covid-19-vaccine-patents (date of access: 1 April, 2026).

(Lepori, 2023), and thus potentially more supportive of patent-oriented work. European countries differ in the importance of academic third-party funding while top-ranked universities have a much higher share of third-party funds (up to 40% and above of total revenues, compared to median share of 7% - ETER, 2019, p. 3). In our sample, patenting HEIs have, on average, more than twice the share of third-party revenues in their total budgets (see Sect. 3 for details), so the heterogeneity in universities' budget sources can be another, not yet explored, source of the unsatisfactory innovation performance of many European HEIs (Parteka et al., 2024). This is relevant as European universities have undergone substantial changes in research funding sources since the 1980 s (Cesaroni & Piccaluga, 2002). HEIs responded to restrictive, performance-based public funding policies (Yu et al., 2022; Jain et al., 2020), demands to implement their third mission by engaging with industry (Guerzoni et al., 2014; Baldini et al., 2006; Rizzo & Ramaciotti, 2014) and joint company-university patenting (Wolszczak-Derlacz, 2025).

We address the following research gaps. First, most studies on the patenting-funding nexus, including those on revenue composition, are country-specific (e.g. Gulbrandsen & Smeby, 2005 on Norway; Lawson, 2013 on the UK; Hottenrott & Thorwarth, 2011 and Graf & Menter, 2022 on Germany; Rizzo & Ramaciotti, 2014 on Italy). In particular, studies on the relationship between industry funds and patenting rely on single-country samples of researchers or engineers (Hottenrott & Thorwarth, 2011; Lawson, 2013; Gulbrandsen & Smeby, 2005). This is an important limitation because European HEIs are not only highly stratified (Lepori, 2022; Triventi, 2013; Shavit, 2007; Van der Wende, 2008), but they also operate in a highly heterogeneous setting. There is no uniform higher education system (HES) model in Europe[3], and the country-specific solutions stem from historical and political contexts (Garritzmann, 2024). National HESs differ in funding schemes, access, and institutional types. In most of the European countries the central level is the most important public funder of higher education (ETER, 2019) but in federal states like Germany, Switzerland, or Belgium the regional level dominates (Garritzmann, 2024, p. 8; OECD, 2025).[4]

Secondly, we lack precise estimates of the interaction between the funding of university patenting and regional conditions. Academic patenting is more prevalent in industrialised regions where universities make a significant contribution to local innovation systems (EPO, 2024). While university patenting can be influenced by regional economic conditions (Bilbao-Osorio & Rodriguez-Pose, 2004; Baldini et al., 2006; Baldini, 2009; Rizzo & Ramaciotti, 2014), the interaction between this factor and the sources of university funding remains unclear. A third research gap concerns the lack of empirical investigation into whether the sources of university funding affects the quantity and *quality* of patents. This distinction is necessary because the literature (Acosta et al., 2012; Graf & Menter, 2022;

[3] Some degree of homogeneity in European HES is achieved through cross-border initiatives such as the European Research Area (ERA) and the Bologna Process. Source: https://ehea.info/page-three-cycle-system, accessed 17.01.2026.

[4] Additionally, private higher education funding typically plays a minor role in Europe (except in the UK - OECD, 2025). HEIs in continental countries like Germany, Poland, and Nordic states offer low or no tuition fees in public institutions for EU students, the UK stands out with higher fees while France has low public university costs but selective Grandes Écoles. Important differences concern also institution types. For instance, Germany distinguishes research universities from practical Fachhochschulen, France pairs broad universities with elite schools, the UK features concise degrees and global academic leaders. The Nordic system is characterised by equity and high attainment.

Hottenrott & Thorwarth, 2011; Whalley & Hicks, 2014) identifies different significant factors at the individual, university, and regional levels in shaping the two outcomes.

Our contribution is based on a detailed, university-level dataset on about 2900 HEIs from 295 NUTS-2[5] regions in 31 countries, between 2011 and 2019. We combine information on universities' patent applications recorded in the PATSTAT Global with several characteristics of HEIs using new PATSTAT-ETER crosswalk. To the best of our knowledge, no study has used such a large, international sample to analyse the link between university patenting, funding sources, and regional innovation systems in Europe, at the same time analysing not only the number of university patent applications but also their impact (assessed by patent citations).

The rest of the paper is structured as follows. Section 2 reviews the literature; Sect. 3 describes the dataset and the key stylised facts on European HEIs' patenting, and Sect. 4 presents our results. Section 5 concludes. In the Appendix, we include additional materials, while a replication package[6] allows to reproduce the findings.

Determinants of university patenting – review of the literature

The rich micro-level literature on academic patenting reveals a set of its basic institutional determinants[7], such as university type and research orientation (HEIs with technical/engineering orientation patent more – Lee, 2021; Parteka et al., 2024), size (Baldini et al., 2006; Jain et al., 2020; Lee, 2021), employment structure (Graf & Menter, 2022), collaboration with firms (Wolszczak-Derlacz, 2025; Nugent et al., 2022; Rizzo & Ramaciotti, 2014), the presence of high quality technology transfer office (EPO, 2024; Abbas et al., 2018; Olaya-Escobar et al., 2020; Caviggioli et al., 2023), or institution age and experience (Jain et al., 2020). Many of these factors are interconnected with Europe's stratified higher education system (Lepori, 2022; Triventi, 2013; Van der Wende, 2008). Global university rankings mirror academic patenting rankings, recalling the "European paradox" problem (Van der Wende, 2008), and there is a self-enforcement mechanism between prestige (rankings), research outcomes (including patenting), funding acquisition and university-industry relationships (Czarnecki & Sauer, 2025; Torres-Olave et al., 2020). Higher-ranked institutions share such characteristics with intensively patenting HEIs as research focus (Taylor et al., 2016) or specialisation in disciplines (STEM, medicine) that attract funding and drive top universities (Taylor, 2016).

As to our main topic, namely the role of funding, some studies unsurprisingly find that richer HEIs engage more in patenting (Jain et al., 2020; Azagra-Caro et al., 2006; Parteka et al., 2024). This is another documented aspect of stratification (generally reflecting the 'vertical order' of institutions - Bloch & Mitterle, 2017): ranking positions of top European universities such as Cambridge, Oxford, UCL, Manchester, and Imperial College, followed

[5] NUTS stand for Nomenclature of territorial units for statistics. NUTS divides each EU country into three hierarchical levels: NUTS 1 (major socio-economic regions), NUTS 2 (basic regions for regional policies), and NUTS 3 (small regions for specific diagnoses).

[6] The replication package is available for download in the institutionalrepository: https://doi.org/10.34808/pz38-p306.

[7] The rich literature has also studied the role of national legislation and IP policy reforms (the Bayh-Dole Act in the U.S.: Link & Hasselt, 2019; or the so-called "professor's privilege" in some European countries: Hvide & Jones, 2018; Cesaroni & Piccaluga, 2002; Ejermo & Källström, 2016; EPO, 2024).

by ETH Zurich, Edinburgh and KU Leuven, are associated with large budgets (ETER, 2019, p.3). However, the literature suggests that not only the level of funding but also its sources is relevant. Studies on the relationship between public funding (which often dominates European universities' financial resources – ETER, 2019) and university patenting performance have found positive effects (Rizzo & Ramaciotti, 2014; Yu et al., 2022).[8] Yu et al. (2022) argue that researchers enjoy greater flexibility in allocating private funds to their ideas, investing in riskier, innovative projects, than in the case of public funds.

External funding, in particular industrial funding, was found to increase the probability of patenting by faculty members in Norway (Gulbrandsen & Smeby, 2005) and the UK (Lawson, 2013), and the quality of patenting in Germany[9] (Hottenrott & Thorwarth, 2011). Nugent et al. (2022) compared two Australian funding programs showing that government grants requiring industry collaboration resulted in more patent activity. Lawson (2013) shows that only large industrial grants have a positive effect on academic patenting, while small grants boost the number and citations of academic patents, regardless of funding source.

However, the interregional differences in technology transfer may diminish (Lissoni et al., 2013) or even reverse the positive effect of third-party funding on patenting, as in the example of Italy. For example, HEIs in the northern regions of Italy display better patenting performance than those in the South, reflecting Italy's well-known pattern of uneven regional development (Baldini et al., 2006; Baldini, 2009; Rizzo & Ramaciotti, 2014). Bilbao-Osorio and Rodriguez-Pose (2004) find that private R&D funds have a stronger impact on patenting in non-peripheral than peripheral EU regions. Generally, at sub-national level, academic patents are characterised by strong regional concentration in well-developed European regions (Acosta et al., 2012; Parteka et al., 2024), and the good economic performance of highly developed regions can stimulate patenting by HEIs (Caviggioli et al., 2023). We build upon this literature and while investigating the link between funding and university patenting, we will take the regional economic context into account.

Data and stylised facts

The dataset

We draw on a new dataset designated KC-HEI (described in detail in Parteka et al., 2024), which contains institution-level patenting indicators for HEIs in 31 European countries, identified in PATSTAT Global from 1980 onwards. Here, we restrict the sample period to 2011–2019 due to the limited availability of institution-level data from ETER (European Tertiary Education Register; Lepori et al., 2023).[10] We merge university-level patent records,

[8] By contrast, Krieger (2024) summarizes several studies on the German Excellence Initiative, a selective public funding program for universities between 2006 and 2017 and did not find the effect of government funding on patenting.

[9] Graf and Menter (2022) found mixed results concerning the impact of third-party funding on patent quality in German HEIs.

[10] We use linear interpolation of the data. Outliers – defined as values below the 1 st and above the 99th percentile – are replaced with the values at those percentiles.

ETER variables and the data on scientific publications indexed in the Web of Science (from RISIS-OrgReg[11]) using the PATSTAT-ETER crosswalk (Płatkowski et al., 2024).[12]

Unlike the recent EPO (2024) report on academic patenting, we extend the analysis beyond patents filed at EPO only, which could result in significant home bias, and consider European university patent applications filed with the world's top five intellectual property offices, the so-called "IP5" (namely: EPO, USPTO, CPO, JPO, KPO)[13]. Together, the IP5 account for 85% of global patent applications (WIPO, 2024). We focus on direct university patents, i.e. applications filed in the name of the university itself or its knowledge transfer office, identified with the use of an applicant identifier provided by PATSTAT. We identified 107,501 university patent applications to the IP5, them summing them over HEIs. In case of multiple applicants, patents are allocated to universities by fractional apportionment (FA) according to the applicant's share, so that patent applications resulting from university-industry collaboration are (partly) taken into account.[14] In the main analysis, we use patent applications; the data on patents granted is used in the robustness checks. Additionally, we analyse forward patent citations from the OECD Patent Quality Indicators database (version: August 2023) available at the OECD STI Micro-data Lab[15], as a proxy for patent quality, capturing their technological and economic value (Squicciarini et al., 2013).

ETER is our source of data on HEIs' individual characteristics, such as foundation year, number of students ISCED 5–7 (total and in STEM fields[16]), academic staff (FTE)[17], HEI type (general universities versus universities of applied science[18]) and the financial variables crucial to our analysis: universities' total budgets (revenues) and their sources. Current revenues are split into core budget, third party-funding[19] and other[20]: student fees and unclassified revenues. Core budget consists mainly of allocations from either national or regional governments and is defined as "funding available for the operations of the whole institution, which is not earmarked for specific activities and whose internal allocation

[11] Register of Research and Higher Education Organizations (https://www.risis2.eu/orgreg-data/).

[12] PATSTAT-ETER crosswalk is available at: https://doi.org/10.34808/h4h3-2k20. Parteka et al. (2024) point to a series of problems related to the proper identification of HEIs in the global patent data and develop a complex procedure for linking university applicants identified in PATSTAT with external datasets on universities' characteristics such as ETER (Lepori et al., 2023).

[13] European Patent Office, United States Patent and Trademark Office, China Patent Office (China National Intellectual Property Administration), Japan Patent Office, and Korean Intellectual Property Office.

[14] We do not capture instances in which patents result from industry-science collaboration and university researchers are among the inventors but only a company appears as the applicant.

[15] Available at: https://www.oecd.org/en/data/datasets/intellectual-property-statistics.html. The quality indicators of all IP5 patents are not available. We use EPO quality indicators in the main analysis and USPTO indicators as a robustness check.

[16] Science, Technology, Engineering, Mathematics. We use the share of students in the following fields: 05, 06 and 07 – Lepori (2023, p.119).

[17] We consider full-time equivalent academic staff (FTE), but in some countries, e.g. Italy, data are reported in headcounts (HC).

[18] The division is based on the ETER metrics standardized university category as institutions with the right to award doctorates (Lepori, 2013, p. 63–64). We designate ETER's "university" category as "general university" to avoid confusion with HEI.

[19] The data on subcategories of third-party funds is available only for 17 countries, showing the following distribution: 43% public third-party funding, 21% private, 18% from abroad, and 27% unclassified funds.

[20] Other funding sources (student fees and unclassified revenues) will be treated as a reference category in the empirical analysis.

can be decided freely by the institution itself" (Lepori, 2023, p. 93). Third-party funding, instead, is "earmarked for specific activities and institutional units" and includes grants from national and international funding agencies for research, funds from charities and non-profit organisations for specific research and educational purposes, contracts from public bodies and private companies for research and services, as well as fees or payments from companies for educational or research services (Lepori, 2023, p. 94).

Regional statistics come from Eurostat. The main characteristic is GDP per capita at NUTS2 level, but in the robustness section, we use other regional variables: (1) tertiary educational attainment (ages 25–64), (2) tertiary education participation rate, (3) employment in high-technology manufacturing (% of total), (4) employment in knowledge-intensive services (% of total), (5) employment in scientific and technical activities (% of total), (6) employment in education (% of total), and (7) higher education sector intramural R&D expenditure (euros per inhabitant).

The final sample used in this paper consists of 2886 European HEIs (785 directly patenting and 2101 inactive in direct patenting[21]) in 31 countries[22] and 295 NUTS2 regions, observed in 2011–2019. The number of institutions observed (by type and by country) is given in Table A1 in the Appendix. In some of the models estimated, the number of HEIs/countries drops due to the unavailability of some variables in ETER.[23] The Appendix also reports the summary statistics of the variables for the entire sample (Table A2), the two subsamples of patenting and non-patenting HEIs (Table A3), and mean values by country (Table A4).

Even though our approach builds upon the rich literature using patent data to analyse innovation in the higher education system (e.g. Lissoni et al., 2013; Rizzo & Ramaciotti, 2014; Gulbrandsen & Smeby, 2005; Cesaroni & Piccaluga, 2002; Parteka et al., 2024; EPO, 2024)[24], when measuring academic patents we faced three key challenges (see Parteka et al., 2024 for details). Firstly, not all university-generated patents can be captured, particularly when inventors patent independently (Ejermo & Källström, 2016; EPO, 2024; Lissoni et al., 2013). We identify direct university patents through applicant names, which aligns with our focus on institutionally channelled funding and ensures cross-country comparability. Secondly, matching PATSTAT patents to ETER universities required us to address fragmented identifiers : we created a unique crosswalk, successfully matching 87% of entities. Thirdly, patent counts may not reflect quality; we address this issue by using patent citations as a quality proxy (Squicciarini et al., 2013), with both measures highly correlated (0.757).

[21] Inactive (i.e. non-patenting) universities are identified as European HEIs present in the official register (i.e. ETER - Lepori, 2023) that are not found among applicants in PATSTAT Global (Autumn 2022) and not present in RISIS Patent and OrgReg in 2011–2019– see Parteka et al. (2024, p. 17) for details.

[22] AUT, BEL, BGR, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IRL, ISL, ITA, LTU, LUX, LVA, MLT, NLD, NOR, POL, PRT, ROU, SVK, SVN, SWE.

[23] Financial statistics (total revenues, core revenues and third-party funding) are not available for HEIs in BGR, ESP, GRC, HRV, SVN, and the data on third-party funding is missing for CZE.

[24] Significantly less research has been devoted to university patent quality as measured, for instance, by patent citations or other indicators (e.g. Acosta et al., 2012; Hottenrott & Thorwarth, 2011; Graf & Menter, 2022; Guerzoni et al., 2014).

Table 1 The share of directly patenting[1] institutions - all HEIs and specific types (2011–2019)

	all HEIs		STEM[2] only		general universities[3] only		excluding applied science universities		excluding small HEIs < 500 students	
	number	%	number	%	number	%	number	%	number	%
patenting [1]	785	27	743	46	693	43	668	30	770	32
non-patenting	2101	73	875	54	930	57	1591	70	1621	68

Source: Authors' own calculations based on PATSTAT Global (Autumn 2022) and ETER

[1] HEIs appearing as applicant in at least one IP5 patent application; [2] identified as HEIs with students in STEM disciplines; [3] HEI types identified using ETER

Stylised facts – patterns of direct university patenting in Europe

Patent applications and patent quality

Strikingly, of the 2886 European universities in our sample, 73% were inactive as direct patent applicants; just a fourth, that is, appeared among applicants to the IP5 for at least one patent (Table 1). Within technically-oriented or STEM institutions, the distribution is more balanced, but even so, 54% made no patent applications. Excluding universities of applied science and small units (fewer than 500 students) does not change the general tendency, and two-thirds of HEIs are still inactive.

Turning to the country ranking of university direct patenting (Figure A1 in Appendix), we find striking differences within Europe: HEIs in the top five patenting-countries (U.K., Germany, France, Switzerland and Belgium) account for 71% of all patent applications and 73% of patent citations. Figure 1 illustrates very strong geographical concentration, showing that the most active universities are located in the economic core, and peripheral regions exhibit weak academic patenting. Figure 2 depicts the key characteristics of regional systems in Europe: the wealthier NUTS2 regions, gauged by GDP per capita (in red), are mostly in Switzerland, Luxembourg, Belgium (Brussels), the southern region of Ireland, Inner London and the Czech Republic (Prague). The shares of employment in knowledge-intensive services are highest in the NUTS2 regions that comprise highly developed metropolitan and capital areas, notably Ireland, Germany, France, the United Kingdom, the Netherlands, and the Nordic countries (Fig. 2B).

Key features of patenting and non-patenting universities

European HEIs are highly heterogeneous (for a complete set of summary statistics, see Tables A2–A4 in the Appendix). Figure 3 depicts the key differences between patenting and non-patenting institutions in our sample: on average, the patenting ones have nearly three times the share of students in STEM disciplines (0.13 vs. 0.36), are considerably larger (number of students over six times as large), have lighter teaching loads (i.e., lower student/academic teacher ratios), and much better publication records (five times more Web of Science papers per academic staff member annually). Institutional stratification is evident:

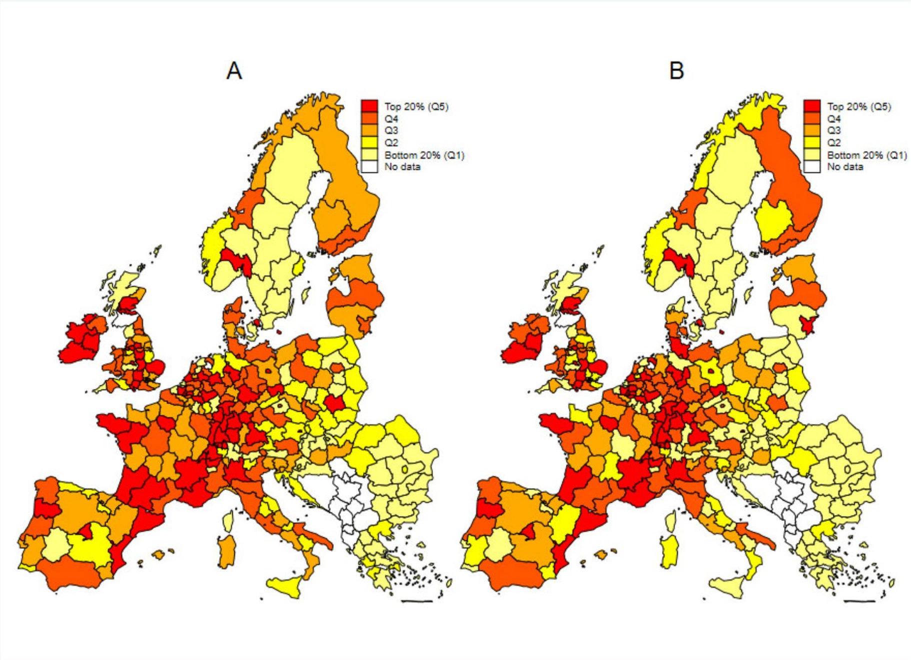

Fig. 1 Regional distribution of patenting by European HEIs. (**A** – patent applications, **B** – patent quality: citations), total 2011–2019. Note: Sample of 2,886 HEIs in 31 European countries (2011–2019); Iceland is not shown on the graph. Values for Sweden are likely to be underestimated due to professor's privilege. IP5 patents are allocated to HEIs using fractional apportionment (FA) by the applicant's share. Patent quality measured as the number of forward citations of EPO patents (in 5-year period), normalised by the maximum number of citations in the corresponding technological field. *Legend:* Regions are divided into five groups according to university patent distribution: quintiles e.g. the top class in red corresponds to the top 20% of regions. Source: Authors' own elaboration using PATSTAT Global (Autumn 2022) and OECD Patent Quality Indicators database

while over 42% of patenting HEIs are ranked in ARWU (6% in top 100), a small proportion of non-patenting HEIs is ranked (0.52%, and only 0.06% in top 100).[25]

Average values in a sample of 2,886 HEIs from 31 European countries (2011–2019), divided into patenting and non-patenting HEIs. *Based on the shares of core funding (third-party funding) in the total budget (total revenues) of each HEI, expressed here as a ratio of 0–1. ETER data provides breakdowns of HEI revenues into: core budget, third-party funding, and other (student fees and unclassified funds). ** based on HEI-year specific ARWU rankings.

Source: authors' own elaboration using PATSTAT Global (Autumn 2022), ETER and OrgReg.

[25] 12% of all HEIs in our dataset appeared at least once in ARWU rankings (2011–2019), with 329 (i.e. 95%) patenting. ARWU-ranked universities have on average 30 times more patent applications annually than unranked institutions (including non-patenting HEIs). Among patenting institutions only, ARWU-ranked HEIs patent 4.5 times more than unranked ones. Out of top 10 European HEIs with the highest number of IP5 patent applications in the analysed period, 5 are listed among top 100 universities in the ARWU ranking. See Table A26 in the Appendix. The correlations between ARWU ranking, patenting outcomes and our explanatory variables are reported in Table A27 in the Appendix.

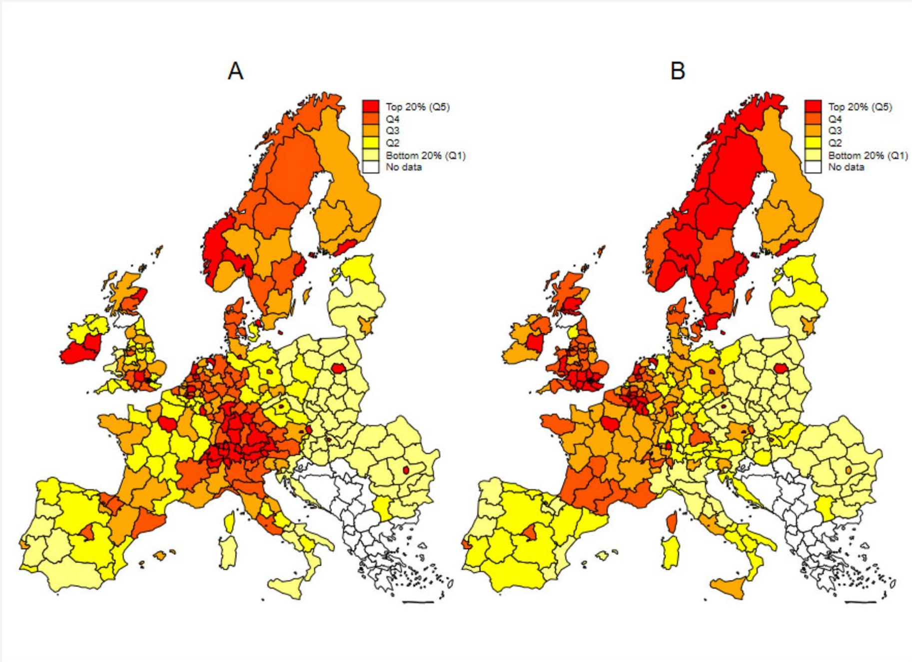

Fig. 2 Key features of regional systems in Europe (**A** – mean GDP per inhabitant in thousands of euros (PPS) in 2011–2019; **B** – employment in knowledge-intensive services, % of total employment, mean 2011–2019). Legend: Regions are divided into five groups according to university patent distribution:; quintiles e.g. the top class in red corresponds to the top 20% of regions. Source: Authors' own elaboration using regional data from Eurostat

Patenting and financial records

As to the specific focus of our analysis, i.e. the financial records, Fig. 3 shows that patenting HEIs are not only richer (0.17 vs. 0.15 million EUR per academic staff in patenting and non-patenting HEIs, respectively), but also have a considerably greater share of third-party revenues in their total revenues (0.18 vs. 0.08). In general, European countries exhibit significant geographical diversity in the financing of HEIs, with strong differences in total resources and their sources.

On average, the wealthiest institutions in our sample are located in Britain, the Netherlands, and Austria, with the largest total revenues in proportion to staff. By comparison, HEIs from Latvia, Romania, Slovakia or Poland operate with budgets 2–3 times smaller (Table 2, column 1). Micro-level data reveals high differences in wealth of European HEIs, even in the same countries. For example, the ratio of the highest to lowest budgets per academic staff member in the UK in 2029 was 5 (that is, the richest HEI in UK had a five-fold higher budget per academic staff member than the poorest). The shares of core budget and third-party funding also vary substantially between countries (Table 2, columns 2 and 3).[26] Czechia, Slovakia, and Finland show the highest share of core funding, Britain and Ireland

[26] In Figure A2 in the Appendix we additionally show cross-country and within-country variation.

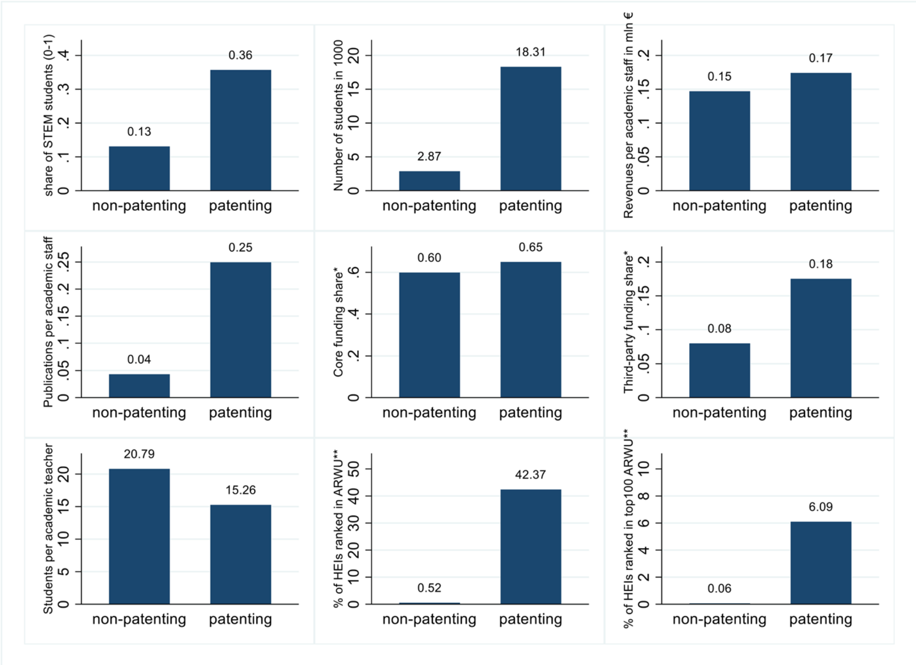

Fig. 3 Comparison of patenting and non-patenting HEIs in Europe – key features

the lowest. When it comes to third-party funding, HEIs in Ireland, and Luxembourg have the highest shares (nearly ¼ of total budget).

Do these financial features affect university patenting? At the aggregate level, we observe a correlation between the number of patent applications and the sources of the universities' funding. In particular, countries with larger shares of third-party funding also show more HEI patent applications (Fig. 4). However, numerous other factors, related to institutional stratification, are at work here (see Sect. 2), so we move on to the detailed, institution-level analysis.

Empirical analysis

The basic analysis

Our dataset allows us to relate (without implying causal claims) alternative indicators of HEIs' patenting activity (such as patent counts and patent citations) to a broad set of characteristics in terms of size, academic tradition, technical orientation, research efficiency (publication output), and regional and national conditions.[27]

First, we estimate the following equation:

[27] Table A5 reports the correlation coefficients between the explanatory variables (they are low, so the problem of collinearity is not severe).

Table 2 Differences in HEIs' revenues by country

country	Revenues per academic staff (millions of PPS euro) (1)	Core budget (share of total revenues) (2)	Third-party funding (share of total revenues) (3)
AUT	0.20	0.79	0.14
BEL	0.12	0.70	0.12
CHE	0.16	0.80	0.13
CYP	0.14	0.67	0.08
CZE	0.14	0.92	n.a.
DEU	0.15	0.51	0.12
DNK	0.15	0.78	0.06
EST	0.18	0.69	0.16
FIN	0.12	0.90	0.17
FRA	0.18	0.81	0.07
GBR	0.23	0.28	0.12
HUN	0.17	0.60	0.15
IRL	0.17	0.32	0.24
ISL	0.17	0.51	0.03
ITA	0.17	0.62	0.10
LTU	0.08	0.46	0.21
LUX	0.15	0.79	0.21
LVA	0.07	0.74	0.05
MLT	0.07	0.86	0.01
NLD	0.21	0.66	0.11
NOR	0.17	0.81	0.09
POL	0.09	0.82	0.04
PRT	0.11	0.72	0.08
ROU	0.10	0.54	0.22
SVK	0.09	0.92	0.05
SWE	0.18	0.75	0.23

mean values of university-level data, by country, 2011–2019

Source: Authors' own calculations using ETER data

$$\begin{gathered} Y_{irct} = a + \beta_1 Age_i + \beta_2 GenUniv_i + \beta_3 STEM_{it} + \beta_4 Stud_{it} + \\ \beta_5 Stud\_acad_{it} + \beta_6 Publ\_acad_{it} + \beta_7 Rev\_acad_{it} + \\ \beta_8 Core\_budget_{it} + \beta_9 Third\_party_{it} + D_r + D_t + \in_{irct} \end{gathered} \tag{1}$$

where *i* refers to the university located in region *r* (NUTS2) and country *c*, while *t* denotes time (year). The dependent variable, *y*, is either the number of university patent applications (IP5, FA) or an indicator of patent quality (forward citations). The set of independent variables includes the university's age (Age_i), calculated as 2020 minus the foundation year; institution type ($GenUniv_i$ stands for general university based on ETER); the proportion of students in STEM disciplines ($STEM_{it}$); number of students as proxy for institution size ($Stud_{it}$); student/academic staff ratio ($Stud\_acad_{it}$) as proxy for teaching load; scientific publications per academic staff member ($Publ\_acad_{it}$), reflecting research orientation. Our key variables of interest are financial: revenue per academic staff (Rev_acad_{it}); and two indicators of funding sources, namely the shares of core funding ($Core\_budget_{it}$) and third-party funding ($Third\_party_{it}$) in HEIs' revenues. In all specifications, we include region (D_r) and time (D_t) effects to control for local differences and time trends.

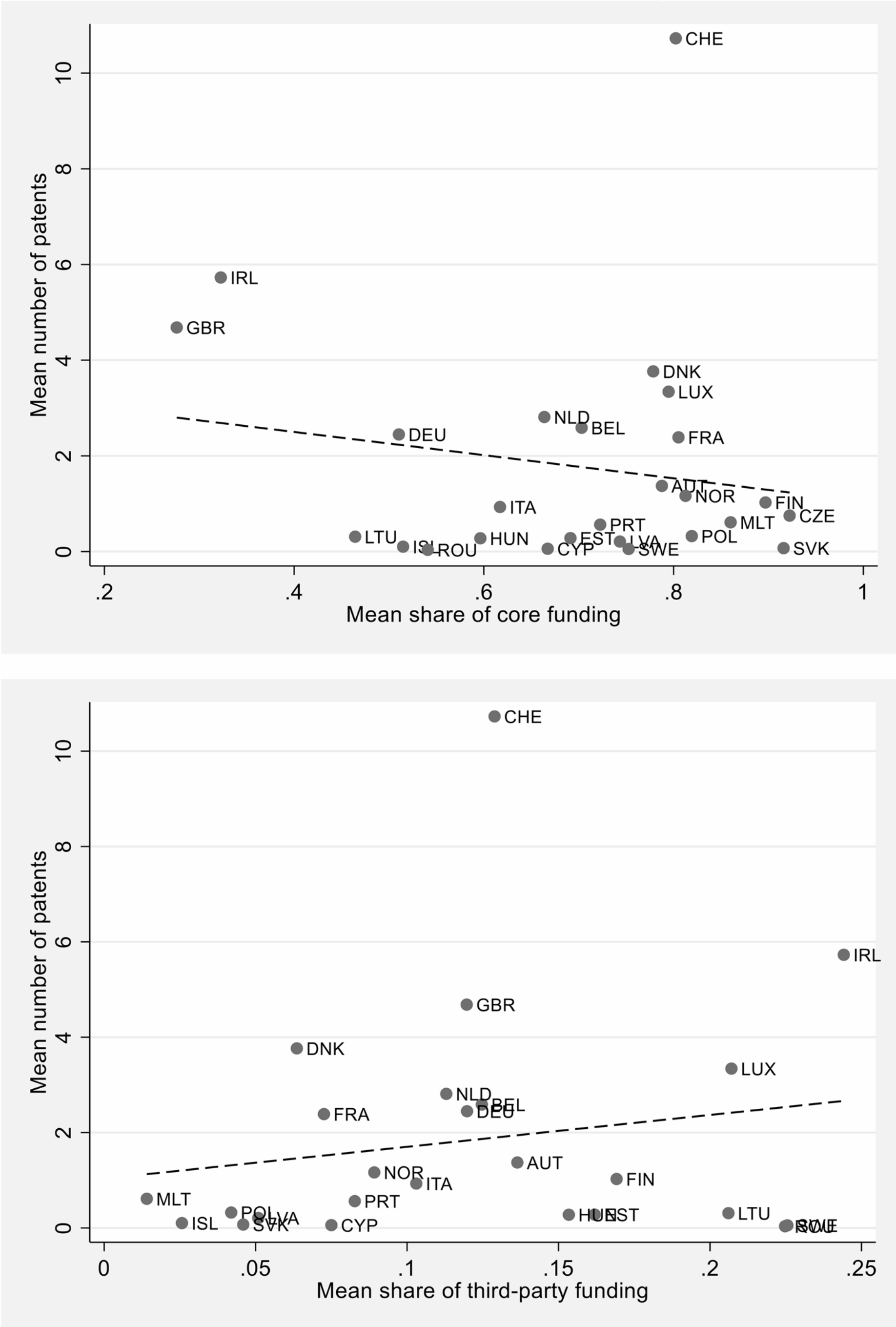

Fig. 4 Country-level correlation between universities' patenting and funding sources. Note: Mean national values. Source: authors' elaboration using PATSTAT Global (Autumn 2022) and ETER

Table 3 Basic estimation results – determinants of direct patent applications and patent citations by HEIs

	Dependent variable: number of patent applications to IP5 patent offices			Dependent variable: forward citations of EPO patents #		
	(1)	(2)	(3)	(4)	(5)	(6)
Age_i	0.010***	0.013***	0.013***	0.008***	0.011***	0.011***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
$GenUniv_i$	0.23	1.526***	0.930***	0.122	1.349***	0.886***
	[0.158]	[0.243]	[0.261]	[0.181]	[0.284]	[0.306]
$STEM_{it}$	6.020***	6.167***	6.023***	6.083***	6.861***	6.770***
	[0.277]	[0.411]	[0.433]	[0.317]	[0.479]	[0.509]
$Stud_{it}$	0.227***	0.228***	0.231***	0.149***	0.145***	0.145***
	[0.008]	[0.010]	[0.011]	[0.009]	[0.012]	[0.013]
$Stud\_acad_{it}$	−0.055***	−0.074***	−0.070***	−0.040***	−0.053***	−0.045***
	[0.004]	[0.008]	[0.009]	[0.005]	[0.009]	[0.010]
Pub_acad_{it}		10.467***	7.644***		7.232***	5.063***
		[0.672]	[0.740]		[0.783]	[0.870]
Rev_acad_{it}		1.35	2.819**		0.038	0.956
		[1.258]	[1.362]		[1.466]	[1.601]
$Core\_budget_{it}$			−1.102***			−0.475
			[0.399]			[0.469]
$Third\_party_{it}$			9.383***			8.028***
			[0.865]			[1.017]
N	14,833	9639	9018	14,833	9639	9018
R2	0.37	0.42	0.44	0.24	0.27	0.28
Number of Countries	31	26	25	31	26	25

All specifications include region- and time-fixed effects. Standard errors in brackets, * $p<0.10$, ** $p<0.05$, *** $p<0.01$

The institution-level estimation results with number of university patents as dependent variable (Table 3[28], columns 1–3) confirm the descriptive statistics in Fig. 4: older, larger universities with a higher proportion of STEM students, lower student/teacher ratios and better publication records tend to have more patent applications. These results are in line with documented stratification of the higher education system (Lepori, 2022; Triventi, 2013; Van der Wende, 2008; Bloch & Mitterle, 2017).

Source: authors' calculations using PATSTAT Global (Autumn 2022), OrgReg and ETER.

Patenting is significantly correlated with a lower share of core funding and a higher share of third-party revenues (column 3). Analogous estimations using a proxy for patent quality i.e. forward citations of EPO patents are similar (column 6), so we find that the institutional funding sources is correlated to the number and the quality of patent applications filed by HEIs in a comparable manner. To evaluate the relative importance of each explanatory variable (differing in scale) in predicting the dependent variable, we have taken the fully specified model (Column 3 in Table 3) and computed standardised regression coefficients. The results (available upon request) show that our key variable of interest, i.e. the share of third-party funding in university budgets, is among the key four institutional characteristics determining the patenting output (along with institution size, age, and STEM orientation).

[28] Full results in Table A6 and Table A7 in the Appendix.

Extended analysis – the role of regional systems

Following the literature (Lissoni et al., 2013; Rizzo & Ramaciotti, 2014; Bilbao-Osorio and Rodriguez-Pose, 2004) and the observed correlation between regional economic conditions and university patenting (Figs. 2 and 3), we further investigate how university location and the regional economy affects the relationship between financing sources and patenting. We now include NUTS2-level GDP per capita instead of the regional dummies and also consider its interaction with the funding sources variables:

$$\begin{gathered} y_{irct} = \alpha + \beta_1 Age_i + \beta_2 GenUniv_i + \beta_3 STEM_{it} + \beta_4 Stud_{it} + \\ \beta_5 Stud\_acad_{it} + \beta_6 Publ\_acad_{it} + \beta_7 Rev\_acad_{it} + \beta_8 Core\_budget_{it} + \\ \beta_9 GDPpc_{rt} + \beta_{10} Core\_budget_{it} \times GDPpc_{rt} + D_c + D_t + \epsilon_{irct} \end{gathered} \tag{2}$$

$$\begin{gathered} y_{irct} = \alpha + \beta_1 Age_i + \beta_2 GenUniv_i + \beta_3 STEM_{it} + \beta_4 Stud_{it} + \\ \beta_5 Stud\_acad_{it} + \beta_6 Publ\_acad_{it} + \beta_7 Rev\_acad_{it} + \beta_8 Third\_party_{it} \\ + \beta_9 GDPpc_{rt} + \beta_{10} Third\_party_{it} \times GDPpc_{rt} + D_c + D_t + \epsilon_{irct} \end{gathered} \tag{3}$$

Figure 5 illustrates this interaction through marginal plots: the horizontal axis represents the proportion of core or third-party funding, the vertical axis the predicted patent volume (upper panel) or forward citation count (lower panel). The three curves correspond to HEIs located in regions with low, medium, and high GDP per capita.[29]

A larger core budget share corresponds to fewer patents and forward citations, and the decline is greater among universities in the wealthier regions (steeper slope for the high GDP line). The two outcomes (number of applications and patent quality) converge as core budget share increases. The relationship between third-party funding share and patenting also differs by region, opposite of that for core funding: as the share of external funding increases, universities in medium- and high-income regions make more patent applications and receive more forward citations. For universities in low-income regions, however, increased third-party funding does not significantly affect either patent quantity or quality. These results underscore the importance of university location in the relationship between funding sources and patenting. Major third-party (external) funding appears to relate positively to patent applications and patent citations in medium- and high-income regions but shows little association in low-income regions.

Extensions and robustness

To validate our results, we ran a number of robustness checks (see Appendix). First, we estimated equations with lagged financial variables, to account for potential delayed effects on patent/citation outcomes. Tables A9 and A10 confirm our main findings. We then replaced regional GDP per capita with other NUTS2-level regional variables related to tertiary education, employment in high-tech, scientific or technical activities, and R&D expenditure. All of these variables show statistically significant positive correlations with university patent applications/patent citations (Tables A11 and A12). Next, we tested our results using forward citations relating to USPTO rather than EPO (Table A13), again confirming our basic specifications.

[29] The determination of low, medium and high GDP per capita is according to the distribution of income across European regions: low indicates the tenth percentile, medium the median, high the ninetieth percentile.

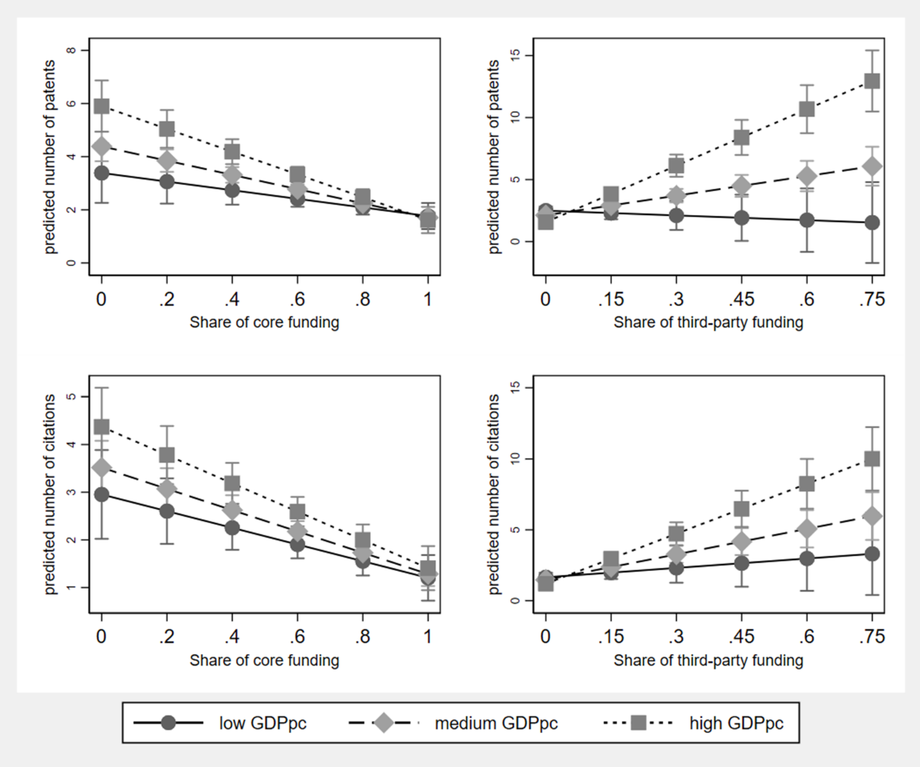

Fig. 5 Regional systems and university funding sources – patenting relationships: marginal plots from Eqs. (2) and (3). Note: Full estimation results are reported in Table A8 in the Appendix. Source: Authors' calculations using PATSTAT Global (Autumn 2022), ETER, OrgReg, OECD/STI Micro-data and Eurostat data

To address potential biases produced by professors' privilege in Sweden and Italy, we added dummy variables for them. Our findings confirm the lower counts of patents and forward citations there (Tables A14 and A15), presumably because professors' privilege facilitates indirect patenting, and academics apply for patents independently rather than through their institutions.

We further validated our analysis by running regressions for patents granted only (rather than all applications), as shown in Table A16. This did not affect our conclusions regarding the impact of institutional characteristics on HEI patenting. Moreover, the estimations run on distinct subsamples – general universities, STEM universities, samples excluding universities of applied sciences, and samples excluding small institutions – did not significantly alter our benchmark results (Tables A17-A24).

Additionally, we have explored mechanisms linking universities' patenting activity and regional economic performance, including industry-university partnerships, regional innovation ecosystems, and accumulated research capacity. Table A25 reports correlation coefficients between university patenting and various regional characteristics. Both patent applications and citations are positively correlated with employment in high-tech and scientific/technical activities, R&D expenditure, and tertiary education.

Finally, we run the estimations only for patenting HEIs (Tables A28 and A29), as well as we delated Swiss institutions as potential outliers in terms of patenting (see Fig. 4 and Tables A30 and A31) – the main results hold.

Conclusions and policy implications

Still, cross-country empirical studies on university patenting remain scarce. We present novel empirical evidence based on scrutinising over 107,000 university patent applications to the IP5 patent offices used to derive large, micro-level dataset of nearly 2,900 universities in 31 European countries and 295 NUTS2 regions (2011–2019). Our research contributes to the literature on the determinants of market-oriented innovation in higher education by specifying the relationship between universities' funding sources and the quantity and quality of their patenting, conditional on regional economic conditions.

Our baseline results, consistent with previous research based on single-country samples (Gulbrandsen & Smeby, 2005; Lawson, 2013; Hottenrott & Thorwarth, 2011), indicate the positive relationship between third-party funding and university patenting. Consequently, our findings support the view that alternative funding sources (such as grants and contracts) effectively stimulate applied, innovative, and commercially relevant research (Angori et al., 2023; Yu et al., 2022). The absence of a positive relationship between core funding and patenting (observed also by Krieger, 2024) may reflect its general-purpose nature, allowing universities to distribute funds across various institutional needs beyond patent-generating applied research.

We have additionally shown that, on a European-wide basis the interaction between regional systems and universities' funding sources produces distinct patenting patterns. This supports the view that regional mechanisms are important drivers of universities' research performance (Acosta et al., 2012; Lissoni et al., 2013; Bilbao-Osorio & Rodriguez-Pose, 2004; Baldini et al., 2006; Baldini, 2009; Caviggioli et al., 2023; Rizzo & Ramaciotti, 2014; Ejermo & Källström, 2016). For instance, our findings are in line with studies of smaller samples, such as Bilbao-Osorio and Rodriguez-Pose (2004), whose analysis of NUTS2 regions in nine European countries showed that regional socio-economic factors influence the capacity to transform R&D into innovation, or Rizzo and Ramaciotti (2014), who document location-specific patterns of patenting by Italian universities.

Important policy implications follow. First of all, there must be support for regional innovation networks, as universities operate as part of local systems and are closely dependent on them, while the strong core-periphery pattern in European university patenting should heighten our awareness of the risk of regional disparities (Bilbao-Osorio & Rodriguez-Pose, 2004). The public action for stimulating HEIs' patenting needs to be region-specific to avoid a vicious circle in which the periphery is left behind. Secondly, policy should encourage universities to diversify and increase their external research funding to enhance innovation outputs but different support mechanisms are needed for universities in low-income regions. Also, it should be borne in mind that core funding remains essential for most, if not all, public universities to conduct applied research, and is particularly important for universities in less developed regions where it enables them to participate in the local education and innovation system (EPO, 2024). Patenting is only one of the outputs of university research (Lee, 2021; Gulbrandsen & Smeby, 2005; Yu et al., 2022; Whalley & Hicks, 2014; Hottenrott & Thorwarth, 2011; Jain et al., 2020).

This paper demonstrates, lastly, that large-scale, micro-level, empirical studies on university patenting are feasible. Our dataset confirms the association between the stratified prestige hierarchy of European higher education institutions and their patent output. There still remain a number of extensions that future cross-country studies could address, such as: distinguishing between different types of patents (e.g. AI patents and those in other technological fields); evaluating the effectiveness of various models of university-industry collaboration; or the role of technology transfer offices and their impact on the commercialisation of academic inventions in Europe.

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Authors' contributions Joanna Wolszczak-Derlacz: data curation, conceptualisation, formal analysis, methodology, writing. Aleksandra Parteka: data curation, conceptualisation, funding acquisition, project administration, supervision, writing. Sabina Szymczak: data curation, investigation, formal analysis, writing. Piotr Płatkowski: data curation, resources, software, visualization.

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Declarations

Ethics approval and consent to participate Not applicable.

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

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