



# How does philanthropy influence the diffusion of knowledge? Impacts from donations on scientific publications and patents in STEM

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## Abstract

Interest in philanthropy has witnessed a resurgence in recent decades, paralleled by a steep increase in the creation of individual fortunes. Originally being a more conspicuous phenomenon in Anglo-Saxon countries, philanthropy has become increasingly salient in traditional welfare states. However, the economic implications of philanthropy basically remain unknown. Here, we examine whether donations to research at higher education institutes (HEIs) in Sweden affect their knowledge output, as reflected in scientific publications and patent applications. The analysis is confined to the STEM-disciplines (science, technology, engineering, and mathematics) for the period 2001 to 2015. We have access to data on the respective HEIs' total research funding for STEM divided into donations, corporations, public block grants, and other public sources. In the analysis, we compare the effects of different research funding on knowledge output relative to their base funding. Implementing numerous controls, we find that patent applications are positively associated with a higher regional share of donations, whereas no such effects are detected for scientific publications. This is indicative of philanthropy being positively related to growth, since contemporary microeconomic models assign a critical role to innovation in promoting growth and societal prosperity.

**Keywords** Philanthropy · Donations · STEM research · Knowledge production · Patent applications · Scientific publications

**JEL Classification** D64 · I23 · L31 · O33

## 1 Introduction

Does philanthropy, the act of privately giving to public causes (Brown & Ferris, 2007; Clayton et al., 2021), influence knowledge output and, ultimately, economic outcomes, or is it simply a sign of country-specific ethical values and social norms? Both views are represented in literature, where, for example, Acs (2013) takes the former standpoint, while

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Bekker (2016) argues for the latter. In the former case, there is a rationale for policies to encourage and incentivize philanthropic acts.

The different perceptions seem to be associated with how societies are organized. In Anglo-Saxon countries in particular, philanthropy is an important complement to public funding. It is considered to have a collective or social good character, e.g., related to research, education, culture, or other social purposes. By addressing various societal needs, it has been argued that philanthropy links the business sector with other parts of society (Bruni & Zamagni, 2013), thereby contributing with knowledge and additional resources. For example, Feldman and Graddy-Reed (2014) argue that philanthropy could be viewed as a type of long-term societal venture capital where private initiatives may complement and invigorate traditional governmental solutions.

This perspective contrasts with that of continental European tax-based welfare states, where the government provides the overwhelming share of funding and provision of social services and education. Neither incentives nor norms have fostered a contemporary philanthropic culture. Accordingly, wealthy individuals have not been expected to share their fortunes with society through donations (Helgesson, 2004). However, during recent decades, a change in individuals' attitudes towards philanthropy has also been observed in typical welfare states (Wijkström & Einarsson, 2018).<sup>1</sup> The resurgence of Swedish philanthropic activities seems to be driven by the creation of new fortunes originating in entrepreneurial endeavors, a general shift towards acceptance of privately funded measures, and entrepreneurs being influenced by role models such as Bill Gates and Warren Buffet. Studies on Swedish philanthropists suggest that they are primarily motivated to promote change, advance knowledge, and address issues neglected by public funding. Just substituting for public funding might lead to lower engagement among philanthropists.<sup>2</sup>

Here, we seek to analyze the real effects of philanthropy in Sweden by examining whether donations to universities' STEM departments contribute to regional knowledge output, measured by either academic achievements (scientific articles) and/or the commercialization of knowledge, i.e., innovations approximated by patent applications. Admittedly, patent applications do not capture the full spectrum of innovation, but they are widely used in the innovation literature, a practice we adhere to (Sampat, 2018).<sup>3</sup>

To examine these issues, we first distinguish between different types of university research funding, i.e., private (divided between philanthropic and corporate) and public (divided between governmental base funding and governmental research councils, including EU-funding). Thereafter, we investigate whether knowledge output varies depending on the type of funding. As donations often originate from wealth accumulated through entrepreneurial endeavors, such funding tends to be directed toward applied research and closer to the commercialization of knowledge, i.e., innovation, even though this does not necessarily exclude scientific publications. On the other hand, public funds primarily target basic

<sup>1</sup> See Sect. 2 for further discussions of the Swedish case.

<sup>2</sup> For example, Helgesson (2004) reports that donations have been recaptured as donors realize that their funding will replace previous public funding. See also Braunerhjelm and Palmberg (2017) for discussion.

<sup>3</sup> See Sect. 5.1 for a more elaborated discussion of using patent applications as an indicator of innovations.

research, which, correspondingly, does not exclude patenting (Acs & Braunerhjelm, 2005; Azoulay et al., 2011; Clayton et al., 2021).

Thus, we differentiate between governmental, corporate, and nonprofit sources (donations) of universities' research funding, broken down at the regional level. The data comprise all Swedish higher education institutes (HEI) offering education in STEM (science, technology, engineering, and mathematics) between 2001 and 2015. The data are unique since we can identify funding and knowledge output at each HEI and region's academic field level. Thus, we focus on the relationship between different sources of research funding and knowledge output, categorized on scientific articles and patent applications. Additionally, we control for factors such as academic discipline, knowledge variables at the regional and HEI levels, business sector research, and spatial correlation.

Although the research literature on philanthropy is extensive, empirical analyses on its economic impact is extremely rare, and relevant data are often lacking.<sup>4</sup> Still, philanthropy merits study not merely as a social phenomenon but also as a potential driver of economic development, particularly given efforts to stimulate philanthropic activity in several countries.<sup>5</sup> As endogenous growth proponents argue, investments in knowledge and innovations are the cornerstones of economic growth (Aghion & Howitt, 1992; Romer, 1986, 1990). If philanthropy contributes new knowledge that potentially affects societal development, this might justify measures to stimulate and encourage such activities.

To the best of our knowledge, the closest comparable analysis to the current study was conducted by Acs and Braunerhjelm (2005). They found a weak correlation between regional growth and donations. However, their study was limited by less accurate data, both regarding the proxy used for regional growth and donations to research, and without the possibility to control for other sources of research funding. The present analysis uses data that are considerably more precise and are much more disaggregated. Moreover, our aim is not to establish a direct relationship between growth and donations but rather to examine whether philanthropy influences the forces that are supposed to be the backbone of the endogenous growth model (Romer, 1990), i.e., knowledge diffusion and innovation.

We contribute new knowledge regarding the role and impact of philanthropy on regions' knowledge base and its potential for economic development. First, the analysis uses a transparent, widely used economic model as its point of departure, i.e., the knowledge production function, which links to the endogenous, or knowledge-based, growth model. Second, we separate between different sources of university funding for research; hence, we can distinguish between the effects associated with each type of research funding. Third, based on detailed micro-level and regionalized data, we present evidence that philanthropic donations significantly affect knowledge output, although the effects differ between scientific publications and innovations in both magnitude and timing. Fourth, we control for within-regional effects related to human capital endowment and for between-regional effects by accounting for spatial autocorrelation. Finally, our findings have implications for policies directed towards philanthropy targeting research at HEIs, both at the regional and national levels.

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<sup>4</sup>For comprehensive overviews of different aspects of philanthropy, see Bruni and Zamagni (2013) and Taylor et al. (2014). A survey on corporate philanthropy is presented by Gautier and Pache (2015). Sengupta and Rossi (2023) find that the universities' funding portfolios influence their knowledge output.

<sup>5</sup>This is not only with respect to tax deduction possibilities (e.g., in the UK and US) but also by other means, e.g., matching private donations with governmental funds (e.g., in Norway and Finland).

## 2 Some institutional descriptives: Swedish philanthropy and higher education institutes (HEIs)

### 2.1 Informal and formal institutions

Typically, the welfare state has been less supportive of privately funded social goods and services, as reflected in both informal and formal institutions. Rather, welfare services have, to a greater extent, been provided by the government and financed through taxes. This strategy functioned well as long as there was room to increase taxation due to clearly defined national boundaries and legal jurisdictions, and the overall tax pressure remained relatively modest. However, tax rates in most European welfare states now hover at approximately 40–50 percent of GDP, while production factors have become considerably more mobile.

The combination of high tax rates and an increasingly globalized tax environment limit the scope for additional expansion of the tax-funded welfare state. Simultaneously, emerging societal challenges, such as demographic development, further accentuate the difficulties the welfare state faces in funding and providing high-quality welfare services. One explanation for the resurgence in philanthropy in several economies, including welfare states, may thus be inadequate or inefficiently deployed governmental resources (Anheier, 2018a, 2018b). This view indicates that the potentially beneficial societal effects of philanthropy refer to the constraints associated with a universal welfare state—increasing needs and dwindling tax bases—but also new and cost-efficient ways of addressing existing problems. If societal externalities can be linked to philanthropy, there is a rationale for policies to encourage and incentivize philanthropic acts.

Differences in the structure and extent of philanthropy, defined as private donations to public causes (Brown & Ferris, 2007; Clayton et al., 2021), across countries and regions can be attributed to divergences in informal and formal institutions (Acs, 2013; Bekker, 2016). As shown by Fehr and Schmidt (2006), using experiments, giving and altruism are strongly influenced by the norms and social context in which individuals operate. Hence, philanthropy can be argued to constitute part of a nation's social contract, rather than being driven solely by its perceived benefits to society. However, pinning down the drivers of philanthropy is highly challenging, even at a regional level. Finding data on philanthropic activities is the first hurdle. Moreover, its effects must be disentangled from other impetus likely to influence societal development and economic performance.

### 2.2 The Swedish context: philanthropy and taxes

The role and interest in philanthropy have shifted over time and seem inversely related to the scope and ambition of the welfare state. In the latter part of the nineteenth century, philanthropy was prominent in Swedish society, paralleled by a strong entrepreneurial era that saw the birth of many of Sweden's still dominant and innovative firms (e.g., Ericsson, Sandvik, Scania, and SKF). Many of the larger and active foundations today were also established during that era. Interest in and positive societal attitudes towards philanthropic activities declined in the wake of an expanding welfare state and the corresponding increase

in taxes, culminating around 1990 (Henrekson & Stenkula, 2015). However, foundations—under certain conditions—maintained preferential tax treatment (see discussion below). Since 1850, the majority of donations have been directed toward research and education.

In the last decades, philanthropic activities have experienced a renaissance, and institutional conditions have improved. Presently, the framework conditions for Swedish philanthropy are ranked relatively high internationally. For example, the Global Philanthropy Environment Index 2022 (IUPUI Indiana University Lilly Family School of Philanthropy, 2022) assigns Sweden 4.63 points on a scale of 1 to 5, where 5 corresponds to an institutional environment that stimulates philanthropic activity.<sup>6</sup> That is, in an international comparison, Sweden provides an institutional framework regarded as relatively conducive to philanthropy. However, a restrictive tax system regarding philanthropy and donations (4.0) and the socio-economic environment (4.0) somewhat lower the country's overall grade.

Taxes constitute a particularly important formal institution, influencing the extent and structure of philanthropic activities. Even though Swedish foundations have received preferential tax treatment since at least the beginning of the nineteenth century, the current tax environment dates back to legislation passed in 1942. Tax exemptions are conferred to foundations that, on average, donate 80 percent of their revenue (e.g., dividends, interest income, etc.) to “qualified public purposes” over a moving five-year period.<sup>7</sup> Additionally, 90 percent of a foundation's activities must be directed toward the purpose declared in its statutes.<sup>8</sup> Traditionally, the purposes entitled to tax exemption were—with a few exceptions—education and research. Only recently (2014) was the concept of public purpose extended to encompass cultural, social, and religious causes. Hence, Swedish tax regulations have shaped how philanthropy was organized (donations through foundations) and for a considerable time the targeted causes (research and education), which meant that universities and educational institutions became the dominant recipients of donations.

Foundations receiving preferential tax treatment must be registered with the county government.<sup>9</sup> Over the period examined in this study (2001–2015), the number of foundations ranged from 17,500 to 19,400, of which approximately 6000 were inactive. The overall volume of donations from foundations has oscillated between 0.2 and 0.3 percent of GDP throughout the period (Braunerhjelm och Palmberg 2020; Statistics Sweden, 2017), which is approximately one-tenth of the volume donated annually in the U.S. (IUPUI Indiana University Lilly Family School of Philanthropy, 2018). Despite the larger metropolitan areas hosting most of the foundations and receiving a substantial share of donations in absolute terms, normalized by the size of the region, the principal recipients are Jönköping, a smaller region in the southern part of Sweden, followed by Stockholm (the capital region) and Kronoberg (another small, southern region). The concentration of resources in foundations is also noteworthy; the top ten percent of foundations account for roughly 75 percent of all donations, even though donations are distributed to all regions (Statistics Sweden, 2017).

<sup>6</sup>For comparison, the regional average for Northern Europe is 4.72, the global average is 3.63, and 4.76 for the U.S. See for example the Philanthropy Europe Association website ([philea.eu](http://philea.eu)) for country-specific information about the European foundation sector.

<sup>7</sup>There is also a possibility for private persons to deduct 25 percent of their donations from their taxes up to a ceiling of approximately \$1200 U.S., i.e., maximum \$300 U.S. Such donations primarily fall into the category of charity as defined in Sect. 3.

<sup>8</sup>See chapter seven, Swedish income law (SFS nr: 1999:1229).

<sup>9</sup>There are 21 county governments in Sweden.

## 2.3 Financing of academic research and doctoral education in Sweden

Sweden has 47 HEIs offering higher education, of which 34 are government-run and 13 are private. Chalmers University of Technology, Jönköping University, and the Stockholm School of Economics are the three largest and most well-known private HEIs. The first two are organized as foundations, and the third as an association.

The overall structure of Swedish HEIs comprises larger universities in the major urban hubs (Stockholm, Gothenburg, and Malmö), together with two older and established universities—Lund University (founded 1666) and Uppsala University (founded 1477)—and several smaller, newer regional universities and colleges. To a significant degree, the latter universities were established as part of a major expansion of higher education during the 1990s (Swedish Higher Education Authority, 2017).

In Sweden, about 75 percent of university research funding is provided by the government, either as block grants (appropriations) for research and doctoral education or as external funding in the form of grants to researchers from research councils such as the Swedish Research Council, Formas, and Forte. The Swedish HEIs also receive public funding from municipalities and county councils, public research foundations, and from the EU and other foreign organizations.

Public funding has changed considerably over the last decades, both in terms of size and organization. During the period we investigate, total public funding has increased by at least 34 percent, with increases of 26 percent for appropriations and 77 percent for research councils. Similarly, funding from Swedish non-profit organizations has increased significantly (76 percent) during the same period, whereas corporate funding to research has decreased slightly to about 4 percent of total funding. Taken together, the donations to research and research education amounted to 4.9 billion Swedish krona, which corresponds to 12 percent of HEI's total income for research and doctoral education and 24 percent of HEI's research grants (Swedish Higher Education Authority, 2019). Our interpretation of the evolution of research funding is that there is no indication of private funding crowding out public funding. Rather, both public and private funding have increased over the period we are examining.<sup>10</sup>

We illustrate the role of foundations by presenting facts about the Wallenberg Foundations, which are the largest in both the market value of their capital and the volume of donations.<sup>11</sup> The Wallenberg Foundations collectively encompass all foundations initiated by the Wallenberg family or established in memory of family members. Since 1917, the foundations have, in total, donated more than 50 billion SEK to research and higher education. At the beginning of the Foundation's activities, the priority was to create premises for research and education. The emphasis has then gradually shifted to financing advanced equipment needed for research, and to long-term grants for basic research of the highest international standard. This is combined with funding allocated to strategic causes, such as

<sup>10</sup>The data refers to 2007–2017, i.e., it does not exactly overlap with the investigated time period. However, the expansion of the public funding expanded primarily 2008 and 2012 (Governmental Bill 2008/09:50 and 2012/13:30). EU funding has also increased during that period and accounts for roughly 4 percent of total funding, which corresponds to an increase of 38 percent since 2007 (Table 10, Swedish Higher Education Authority 2019). The overall trend is that the largest and long-term EU projects consist of partnerships, missions and very large cooperation projects (Lindberg et al., 2025; Mattsson 2025).

<sup>11</sup>The Wallenberg foundations, The Kempe Foundation, and the Kamprad Family Foundation are the largest (Swedish Higher Education Authority, 2021).

research areas, laboratories, and research infrastructure, which together comprise the largest share of donations.

### 3 Previous research and hypotheses

#### 3.1 Definition of philanthropy

When analyzing philanthropy as a phenomenon, we first need a useful definition. “Philanthropy” literally means “love for mankind,” which is obviously hard to operationalize in quantitative analysis.<sup>12</sup> Philanthropy, it could be argued, contributes means that extend society’s opportunity set. Prominent examples of philanthropy promoting such effects include donations to universities that target research projects and programs that could increase an economy’s knowledge base and extend its innovation potential (Acs, 2013; Braunerhjelm & Skogh, 2004; Murray, 2013).<sup>13</sup> We define philanthropy as:

Philanthropy refers to long-term structured donations of assets directed toward qualified public purposes such as research, education, culture, healthcare, and similar social causes.

Philanthropy is thus a way of building public goods through private funding, a definition that aligns with that of Acs (2013), Brown and Ferris (2007), and Clayton et al. (2021). It is distinguished from charity, which usually remedies immediate circumstances, such as starvation, or alleviating the consequences of a natural disaster (Anheier & Leat, 2006).

#### 3.2 Philanthropy, HEIs, and knowledge output

A few studies have looked at the risk profiles and time horizons of philanthropic activities. They conclude that philanthropy generally tends to be more long-term and less risk-averse compared to both government and corporate research outlays. The latter two forms of funding frequently set requirements related to some kinds of output within a given time limit (Buckland et al., 2013; Veugelers et al., 2022). The less risk-averse nature of philanthropic findings could be advantageous when funding complex, innovative, and risky societal projects with longer-term time horizons. Hence, philanthropy may be better positioned to explore new and innovative solutions to complex social problems. Additionally, diffusion of new knowledge may be more efficient when research donations target HEIs, having fewer proprietary claims.<sup>14</sup>

Feldman and Graddy-Reed (2014) extend the argument and suggest that philanthropy should be viewed as a type of long-term societal venture capital. As early as 1965, the

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<sup>12</sup> See for example Sulek (2010) and Taylor et al. (2014) for thorough discussions on the definitions and delineation of philanthropy.

<sup>13</sup> See also Falck et al. (2011, 2018) regarding the societal effects of donations targeting culture.

<sup>14</sup> Regarding ownership of ideas, Sweden has a “professors’ privilege” system meaning that the individual researchers own the right to develop and exploit their findings, which contrasts with the US Bayh-Dole system (introduced 1980), where universities are the owners of ideas stemming from federally funded research (Astebro et al., 2019). See for example Blume-Kohout (2023) for a discussion of the American system.

U.S. Senate stated that philanthropy is “uniquely qualified to initiate thought and action, experiment with new and untried ventures, dissent from prevailing attitudes, and act quickly and flexibly” (Treasury Department Report on Private Foundations, 1965, p. 5). This is the rationale for encouraging philanthropy through tax incentives, and the extensive definitions of the causes entitled to preferential tax treatment in the U.S. Acs and Phillips (2002) argue that philanthropy has been instrumental in shaping the economic success of the American capitalistic model, but present no empirical analysis to support their claim.<sup>15</sup> The impact and role of philanthropy, however, are not uncontroversial.<sup>16</sup>

### 3.3 Philanthropy and publications

Previous research on philanthropy and knowledge output, and on the extent to which the outcomes of such funding activities differ across funding types, is extremely scarce. Toepler and Feldman’s study (2003) is an exception, although they do not define the type of outcome. Based on questionnaires directed towards researchers, they claim that considerable differences prevail between funding from governmental sources and foundations, as perceived by the respondents. The former are reported to be more risk-averse, inflexible, and bureaucratic. Foundations, on the other hand, seem to embark from different norms, being more inclined to take risks and less constrained in their decision-making, which may reflect the background of their founders. Moreover, the respondents claimed that foundations were considerably less likely to fund basic research and more oriented towards applied research. However, Topler and Feldman did not elaborate on the exact type and disclosure of new knowledge output.

We build on these perceived differences associated with the types of funding as reported by Toepler and Feldman (2003) and suggested by Acs and Braunerhjelm (2005). Thus, we examine whether philanthropy complements governmental funding of research at Swedish HEIs, distinguishing between scientific articles and patent applications, thereby potentially contributing to a more diversified research portfolio and enlarged knowledge output (America, 1995; Muscio et al., 2013; Sachs, 2000). Given that philanthropic funding does not replace other sources of revenue, a general positive effect on research can be expected, as the overall quantity of resources available for research increases. At least, it should not negatively influence knowledge output originating from research.

Azoulay et al. (2011) claim that the conditions and stipulations of research funding affect scientific creativity. Based on a comparative analysis of research programs, they found that private funding for the Howard Hughes Medical Institute, where few strings were attached to how research should be conducted, bolstered scientific creativity and generated more breakthrough knowledge, as evidenced by a higher proportion of publications in top-ranked journals. However, in a Swedish context, such unconditional funding is primarily provided through governmental base research funding or block grant funding, where universities themselves largely decide how to use and allocate the funds. The share of research funding

<sup>15</sup> One of the objectives of the current analysis refers to Acs and Phillips (2002) but is more modest: That is, to detect a relationship between philanthropy and knowledge output where the latter is claimed to be instrumental for economic development.

<sup>16</sup> Scholars from several disciplines, such as political science and sociology, have stressed its potentially adverse effects and the need for appropriate institutions surrounding philanthropy (McGoe, 2016; Reich, 2018).

that HEIs receive from other public sources, e.g., research councils, is mainly allocated through competition with other research groups. Overall, public sources of funding are primarily directed towards basic research, where publication opportunities are more common than in targeted, applied research.

Large Swedish foundations, being the most important donors, frequently provide a mix of grants and donations to HEIs directly as well as to individual researchers or small research groups. Donations often involve substantial sums used to fund laboratories, demonstration facilities, and buildings, as well as broad research areas within, for example, technology (e.g., AI), medicine (e.g., mapping proteins), or measures to abate climate change. In addition, grants to individuals and groups of researchers often support a mix of applied and theoretical research, in which both publications and patents may be outcomes. This leads us to the following hypothesis:

**H1** *The positive association between research funding of HEIs and scientific publications is smaller for donations than for governmental funding.*

### 3.4 Philanthropy and patent applications

Another channel of knowledge output, associated with applied research, is manifested in patents or patent applications. Adhering to previous contributions, we associate patent applications with innovations, a widely used measure of innovation activity (Criscuolo & Verspagen, 2008; Griliches, 1967; Hall et al., 2000; Jaffe, 1986; Sampat, 2018). It should, however, be noted that the use of patent applications as a proxy for innovation is not uncontroversial. Jaffe and Lerner (2004) argue that related non-innovation activities, such as institutional and legal changes, also drive patenting activity. Moreover, there may be innovations that are not patented or that are impossible to patent, e.g., business models.<sup>17</sup> Nevertheless, we consider patent applications the best available measure of innovation and use them to test our second hypothesis.

Toepler and Feldman (2003) argue that private donations can provide direct links to organizations and firms outside the receiving organization. This may extend the network of academia, e.g., towards firms, entrepreneurs, and venture capitalists, and hence can also affect the culture and the attitudes in the receiving institution, and facilitate the commercialization of ideas.<sup>18</sup> If research funded by philanthropy is more applied than that funded by governmental sources, which seems to be the case in Sweden (Acs & Braunerhjelm, 2005), we expect it to be manifested in more innovations. Moreover, even though donations span a wide range of causes, an individual philanthropist might target specific issues, e.g., a disease, the preservation of a particular species, or the abatement of pollution in a specific region, where results may be applicable in the short term.<sup>19</sup> Governmental base funding and

<sup>17</sup> Patents may also be used for strategic purposes (Haeussler et al., 2014). A more general criticism is that patents are claimed to be noisy and subjective perceptions of inventions (Ashton, 2020).

<sup>18</sup> This latter effect has been emphasized by the former chancellor of Helsinki University as one of the major effects during two rounds of fundraising where the Finnish government allowed tax deductions for donations and matched private donations by a factor of two to three additional Euro (Braunerhjelm and Palmberg, 2020).

<sup>19</sup> Tobias register (the Swedish registry for blood stem cell donors, <https://tobiasregistret.se/en/>) and the Baltic Waters (environment, <https://balticwaters.org>) are two interesting Swedish examples.

scientific councils contrast with this, tending to be more directed toward mainstream and basic research areas.

Swedish foundations also tend to stress knowledge output of a more applicable nature to address societal problems. For instance, the original purpose of Sweden's largest private funder of research, the Knut and Alice Wallenberg Foundation, was to support scientific research and promote trade and development of forestry and other industries in the country. Due to legal requirements brought in a decade later, the purpose was changed to "to benefit Sweden by supporting Swedish basic research and education, mainly in medicine, technology, and the natural sciences." Similarly, with the recently established (2011) Kamprad Foundation, the purpose is "to support, stimulate and award education and research such that entrepreneurship, environment, competence, health and social development are promoted." Such advances "should benefit the many people."<sup>20</sup> The applied aspect is present in both examples. We thus set out to test the following hypotheses:

**H2** *The positive association between research funding of HEIs and patent applications (innovation) is stronger for donations than for governmental funding.*

Altogether, the scant evidence on the effect of different sources of research funding thus suggests that, in relative terms, governmental funding is more conducive to knowledge output in the form of scientific publications. Philanthropic donations, on the other hand, are expected to be associated with applied research that is more likely to generate innovation.

One strand of research has stressed the regional dimension of philanthropy. Feldman and Zoller (2012, p. 12) refer to successful entrepreneurs turned philanthropists as "regional champions," i.e., individuals who "live and work in a region and take responsibility for the stewardship of the place." Through their engagement, these agents of change are claimed to be pivotal in improving regional conditions for growth and prosperity. Often, they have a long-term perspective, implying that they tend to move from the entrepreneurial role to that of philanthropists with the ambition of building a more prosperous region. Stanford University, founded in 1885 by Leland Stanford after the death of his only child, is probably an unmatched example of a regional philanthropic project in which the rate of social return has been unusually high (Acs & Braunerhjelm, 2005). Also, in Sweden, some studies provide descriptive evidence of strong regional preferences in philanthropy, targeting knowledge-enhancing causes at existing HEIs, or the establishment of new HEIs (Braunerhjelm & Palmberg, 2017; Sjögren, 2004). Accordingly, we will undertake the analysis at the regional level.

## 4 Model and empirical strategy

We examine two key output variables that capture different aspects of knowledge output: academic publications and patent applications. The former is a measure of knowledge output primarily targeting the academic community but may contribute to more applied purposes in the long run. The latter refers to converting knowledge into innovations with potential appli-

<sup>20</sup> Authors' translation. See <https://kaw.wallenberg.org/stiftelsen/stiftelsens-grundande-1917> and <https://fami.ljenkampradsstiftelse.se/wp-content/uploads/2015/02/Stadgar.pdf>.

cations predominantly outside academia. Both types of knowledge are considered decisive for economic development and economic growth.

#### 4.1 Model

Griliches (1967), inspired by Solow’s growth model (1956, 1957) and the fact that most of its explanatory power resided in an exogenous “technical residual,” developed the knowledge production function, which relates knowledge input to knowledge output.<sup>21</sup> A version of the knowledge production function is applied in the empirical analysis, in which output—defined as either academic publications or patent applications ( $P$ )—is modelled as a function of productivity-adjusted funding ( $PK$ ), and human capital ( $H$ ):

$$\ln(P) = \ln(A) + \alpha \ln(PK) + \beta \ln(H) \tag{1}$$

Productivity-adjusted funding includes capital from four different sources: private nonprofit organizations ( $N$ ), corporations ( $C$ ), government base funding ( $B$ ), and other government sources ( $P$ ), and is specified as,

$$PK = \gamma_N K_N + \gamma_C K_C + \gamma_P K_P + K_B$$

$$\Leftrightarrow PK = K(1+z), \quad \text{where } z = (\gamma_N - 1) \frac{K_N}{K} + (\gamma_C - 1) \frac{K_C}{K} + (\gamma_P - 1) \frac{K_P}{K} \tag{2}$$

where government base funding is normalized to unity and  $K = K_N + K_C + K_B + K_P$ . The coefficients  $\gamma_x$  measure the contribution of the  $x$ -category of funding source to the productivity-adjusted funding capital relative to government base funding. Using the approximation  $\ln(1+z) \approx z$  for small values of  $z$ , and adding subscripts for region or HEI ( $r$ ), academic field ( $s$ ), and time ( $t$ ), we arrive at the empirical equation,

$$\ln P_{r,s,t} = \ln A + \alpha \ln K_{r,s,t} + \alpha_N \frac{K_{N,r,s,t}}{K_{r,s,t}} + \alpha_C \frac{K_{C,r,s,t}}{K_{r,s,t}} + \alpha_P \frac{K_{P,r,s,t}}{K_{r,s,t}} + \beta \ln H_{r,t} \tag{3}$$

where  $\alpha_x = \alpha(\gamma_x - 1)$  for funding source  $x$ . The coefficients in Eq. (3) will be estimated using a negative binomial model, an appropriate model given the over-dispersed count data (see, e.g., Long & Freese, 2003).

#### 5 Data

All data were gathered from official sources, including the European Patent Office (PATSTAT, 2020), Statistics Sweden (SCB, 2018, 2020), the Swedish Research Council (SRC, 2020), and the Swedish Agency for Growth Policy Analysis (2020). The period covers 2001–2015 for the independent variables, while the period for the dependent variables is 2003–2015 since we are elaborating with lags in the empirical analyses. Moreover, the

<sup>21</sup>This refers to different levels of analyses. See Fritsch (2002) and Varga and Horáth (2015) for applications at the regional level. See also for example Lehmann and Menter (2016) for a discussion and analysis of the role of universities in shaping regional wealth.

empirical analyses target the regional level and the respective HEI, depending on which type of knowledge output is considered, i.e., publications or patent applications. We focus on the STEM disciplines, categorized into the following four broad fields: (1) *biology, biotech, chemistry, and medicine*, (2) *engineering*, (3) *information technology (IT) and computer science*, and (4) *mathematics, physics, and geological sciences* (“other”).<sup>22</sup>

The respective HEI is the central unit in the analysis of different sources of funding and the publication of research. Out of Sweden’s 47 HEIs, 27 are included in our analysis (See Table 7 in the Appendix for an overview). Those excluded are not active in the STEM fields. Publication data were obtained through the Swedish Research Council (SRC, 2020) but required tedious work to ensure they matched correctly with researchers, disciplines, and HEIs.

When analyzing patenting activity, we use the geographical unit functional labor market region (FA-region), as defined by the Swedish Agency for Growth Policy Analysis (2020).<sup>23</sup> This is because our data does not allow for a strict delineation between university-based patent applications and those originating from firms. However, there are numerous interconnections and cooperation between HEIs and local businesses, which should generate local knowledge flows (Ponds et al., 2009). Corporate-funded research at HEIs, often organized as joint research endeavors, is less frequently disclosed in journals, and corporations are often applicants and owners of patents arising from such funding (Bikard et al., 2018).

## 5.1 Dependent variables

The first dependent variable is the *number of academic publications* (SRC, 2020) registered in Web-of-Science, measured as an annual, forward-looking, four-year rolling average of the number of publications produced by authors at Swedish universities. If a publication is co-authored, it is shared equally among the universities to which the authors are affiliated. We use this variable to test our first hypothesis, i.e., how the composition of universities’ funding relates to academic research output.

The second dependent variable refers to all *submitted patent applications* registered by the Swedish Patent Office during 2003–2015 (PATSTAT, 2020). The classification of patents into our four broad fields is based on the International Patent Classification (IPC) system at the four-character level. If a patent falls into multiple categories, the four-character level categorization with the most occurrences is used.

## 5.2 Independent variables

The independent variables are classified into four categories, with our key variable being *research funding*. In addition, we implement three groups of control variables: *human capital*, *regional accessibility*, and *dummy variables* (see Table 8 in the Appendix for a detailed description of the variables).

<sup>22</sup>To illustrate how our analysis is structured, a single observation in our patent analysis might for instance be: FA-Region 72 recorded two patent applications in the IT/computer science subject area in 2004.

<sup>23</sup>The definition of an FA-region is continuously revised, as regional boundaries are based on labor mobility, which changes over time. We use the regional delineation which was valid during 2005–2015, which divides Sweden into 72 regions.

### 5.2.1 Research funding variables

We use both absolute and relative measures of research funding. Total research funding is measured as the combined amount of all funding from private and government sources to a particular subject area and HEI in a specific year. This variable is used in the analysis of academic publications. As official university funding data are collected only every second year, we interpolate missing years by taking the average funding levels for the preceding and following years. In analyzing regional patent applications, we include the regions that host an HEI, even though corporate R&D occurs in considerably more regions. The total research funding variables are measured in millions of Swedish crowns and expressed as the inverse hyperbolic sine transform in our regression analysis.<sup>24</sup>

In addition to the absolute levels of research funding, we also use variables that indicate the share of each type of funding relative to the relevant total funding variable (the shares range from zero to one). This allows us to examine how the composition of research funding influences knowledge output. Hence, we use five measures of research funding in the analysis: Government HEI base funding, government HEI non-base funding, corporate HEI funding, nonprofit HEI funding, and regional corporate research funding (used only in the patenting analysis).

The distribution of corporate research funding is attributed to a particular region and industry based on employment patterns of research personnel (research-educated employees and SNI classification). The reason is that the original SCB corporate R&D data are survey-based and do not allow reliable allocation to a particular combination of region and industry, where the latter is linked to patent classes. The following research funding shares are used in the analysis (where shares are either expressed in relation to total funding of HEIs or total regional research funding, including corporate research funding outside funding of HEIs).

- Share of government base university research funding, which comprises so-called block grants from the government, i.e., pre-allocated government funding to each HEI.
- Share of other public university research funding, e.g., grants from the National Research Council or the European Union, for which researchers apply.
- Share of corporate university research funding, i.e., funding from private firms to university research.
- Share of nonprofit university research funding, i.e., funding from private nonprofit organizations to university research. This category primarily includes foundations, the main provider of philanthropic donations in Sweden (see Sect. 3 for further discussion). Funding is either donated to specific research fields or applied for by researchers within those fields, depending on the statutes of the respective foundation.
- Share of corporate R&D funding of total regional research funding. The category comprises private corporate R&D expenditure used for research and development within the firm (i.e., it does not overlap with corporate-funded university research). This variable is only used in the analysis of patent applications.

<sup>24</sup>The inverse hyperbolic sine transformation is a way of taking logarithms of variables which contain zeros (see e.g., Bellemare and Wichman, 2020).

## 5.2.2 Control variables

The first group of control variables includes two *human capital variables*. In our analysis of HEI publication output, we control for the *level of research intensity* at each HEI, measured as the share of full professors among all research and teaching staff. This can also be seen as an indicator of research quality, whereas total funding captures the quantity of research activities at the HEIs.<sup>25</sup> In the analysis of patent applications, we proxy the *regional human capital level* with the share of the regional population with at least a three-year post-secondary degree.<sup>26</sup> These variables are included since we expect highly educated employees to impose both a quantitative impact on knowledge output (relatively more researchers) and a qualitative effect (higher education levels, higher absorption capacity). Both human capital variables are expressed using the inverse hyperbolic sine transformation.

The second category of control variables includes two *accessibility variables* assumed to capture spillovers from nearby regions. Proximity implies increased access to knowledge-intensive activities that may spill over through several channels (Roche et al., 2022). Such effects will be accounted for by controlling for a weighted measure of publications in each academic field to a given region based on geographical proximity.<sup>27</sup> We control for patent applications in each academic field in geographically close regions in a similar way. These two variables are expressed as inverse hyperbolic sine transforms.

Finally, we use dummy variables to control for time-specific effects (annual dummies), academic fields, and patent categories. Patenting and academic publication are also quite unevenly distributed across regions. Even though dummies can be expected to capture most field-specific effects, one should be aware that non-observable factors, such as academic leadership and/or peer effects, might influence the results.

Note that the knowledge production function relates to input factors in the production of new knowledge, and the inherent assumption is that causality goes from factors of production to new knowledge. When we use this framework in the current analysis, especially for academic publications, there is a risk that causality may run both ways, since research performance is one of the main determinants of attracting research funding. By using a lag structure of two to four years for all independent variables in the estimation of Eq. (3) we lower the risk of simultaneous causality even though it cannot be ruled out completely. In addition, the number of publications is measured as a forward-looking four-year moving average, further reducing the risk of simultaneous causality.

<sup>25</sup> An alternative would be to include all staff involved in research, i.e., professors, associate professors, lecturers, PhD students, etc. Unfortunately, we do not have data at such detailed level that we can identify how, for an example, much time an associate professor devotes to research. Contracts also vary across universities. However, we have data on full-time professors and full-time PhD students. The correlation between the two is extremely high, 0.95 in 2024 according to data from The Swedish Higher Education Authority (2026). We have strong reasons to believe that this also holds for other faculty positions involved in research. Hence, we conclude that the share of professors is a good proxy for the overall amount, as well as the quality, of research.

<sup>26</sup> Note that we do not implement both the regional human capital variable and the regional corporate R&D variable in the same regressions since these are highly correlated (0.86) and may introduce multicollinearity.

<sup>27</sup> I.e., each region has a measure of total publication or patent flow from all other regions. The contribution decreases non-linearly with travel time, such that far-away regions contribute little to this measure.

### 5.3 Descriptives

Table 1 presents a summary of descriptive statistics for observations used in our regression analysis, and Table 9 in the Appendix contains mean values for the variables over time. The upper part of Table 1 refers to our analysis of academic publication activity (hypothesis 1), while the lower part refers to our analysis of patents (hypothesis 2). As can be seen in Table 1, the average number of academic publications per field, year, and HEI is roughly 385. The range, however, is broad. For instance, in the medical, chemical, and biotech fields, the Karolinska Institute reached a peak in 2014 with 5700 publications. The table further reveals that, on average, the total amount of funding is 200 million SEK annually per HEI/region, field, and year, with a maximum of 4876 million SEK (Karolinska Institute, 2015). Government funding is the primary type of funding for Swedish universities (on average, 88 percent), where government base funding accounts for 35 percent and other types of government funding account for the remaining 53 percent of total funding. Nonprofit organizations contribute, on average, 6.1 percent of total university research funding, while the corresponding share for corporations is 5.3 percent.

Regarding regional patent applications, Table 1 shows that the average number of applications is 14, ranging from 0 to 462, with the maximum value occurring in the Stockholm region in 2003. Similarly, the distribution of annual research funding to HEIs is also quite dispersed. Note that the mean value of regional corporate funding is roughly three and a half

**Table 1** Descriptive statistics for observations used in the regression analysis (divided on HEI/FA-region, year, and field)

	N	Mean	Sd	Min	p25	p50	p75	Max
Variable: publication analysis								
Publications (number)	1044	385.7	850.8	0	15.28	54.61	326.5	5700
Total funding (mSEK)	1403	200.3	449.4	0.500	10.50	36.00	185	4876
Human capital	1403	13.32	6.099	2.200	7.600	12.80	18.60	26.90
Publication spillover	1403	14.37	47.95	0	0	1.157	6.195	434.5
Share of total funding								
Base govt. funding	1403	0.354	0.239	0	0.227	0.368	0.519	1
Other govt. funding	1403	0.532	0.255	0	0.361	0.487	0.639	1
Corporate funding	1403	0.0532	0.0698	0	0	0.0329	0.0779	0.556
Nonprofit funding	1403	0.0607	0.0846	0	0	0.0452	0.0863	1
Variable: patent analysis (HEI regions only)								
Patent applications (number)	1273	13.60	43.39	0	0	2	9	462
Total HEI funding (mSEK)	1273	220.7	747.2	0.500	7	23	67	8550
Corporate R&D funding (mSEK)	1273	813.6	2213	8.881	81.34	151.5	329.4	16,667
Human capital	1273	10.02	1.32	7.46	9.14	9.80	10.56	14.37
Patenting spillover	1273	1.099	2.504	0	0.0469	0.229	0.884	27.87
Share of total funding								
Base govt. funding	1273	0.359	0.248	0	0.167	0.376	0.538	1
Other govt. funding	1273	0.533	0.263	0	0.354	0.486	0.667	1
Corporate funding	1273	0.0549	0.0720	0	0	0.0345	0.0822	0.526
Nonprofit funding	1273	0.0534	0.0813	0	0	0.0376	0.0805	1

The descriptive statistics include data for dependent variables for 2003–2015 and independent variables for 2001–2015

times as large as the research funding received by HEIs. The share of donations (nonprofit funding) to HEIs is, on average, close to 5.5 percent of total research funding.

The correlation matrix (see Table 10 in the Appendix) shows a particularly strong correlation between government base funding and other government funding in panel a) ( $-0.89$ ), whereas the correlation remains negative when considering FA-regions in panel b), albeit at a considerably lower level ( $-0.42$ ). Regarding correlations between funding shares, we expect these to be negative in general, due to the sum-to-one constraint. We should also expect this negative relationship to be strongest for the two dominant funding sources in panel a), i.e., base government funding and other government funding. In general, this expectation is confirmed, with the major exception being the (weakly) positive correlation between corporate and non-profit research funding. Similarly, as expected, panels (a) and (b) show a strong, positive correlation between the total funding variables and human capital.

## 6 Results

### 6.1 Philanthropy and publications

Table 2 shows our first set of regression results, where the estimations are separated by two lag structures (2- and 4-years) and the influence of neighboring universities (accessibility). Relative to governmental base funding for universities, we find that the impact of donations from nonprofit organizations is consistently insignificant across regressions, irrespective of lag structure or the inclusion of accessibility measures. The same results hold for governmental funding, excluding base funding, while private corporate funding of university research is negative and highly significant across the four regression specifications.<sup>28</sup> The latter probably reflects that corporations are less interested in disclosing research findings openly in scientific publications. It is also likely to mirror that a considerable share of donations goes to funding research infrastructure (e.g., laboratories and test facilities). Altogether, only corporate funding is significantly different from basic research funding. The results show that the marginal impact of governmental university base funding is at least as high as private donations for knowledge production defined as scientific publications.

Regarding the control variables, the overall level of funding and human capital, where the latter is defined as the density of university professors at each HEI, exert a positive and strongly significant impact on the number of academic publications. The regional accessibility variable is also positive and significant, highlighting the role of knowledge spillovers from universities in neighboring regions, even though the coefficient suggests a modest effect. Moreover, its inclusion has only a marginal effect on the coefficients of the other funding variables. Finally, the medical, chemical, and biotech fields seem more productive than other academic fields, i.e., there are disciplinary-specific effects that can be expected, as seen in publication cultures, norms, and the number of scientific journals.

Overall, the results imply that we cannot distinguish how different sources of funding influence scientific publications, except for funding from corporations, which negatively impacts the number of publications. Moreover, knowledge spillover effects, as indicated

<sup>28</sup> Development expenditures are included when we refer to corporations' research, i.e., the 'D' in R&D.

**Table 2** Regression results, dependent variable: academic publications

	2-year lag		4-year lag	
	(1)	(2)	(3)	(4)
University funding shares				
Nonprofit organizations	0.39 (0.24)	0.36 (0.24)	0.12 (0.23)	0.06 (0.23)
Government excl. base funding	0.02 (0.11)	-0.02 (0.11)	0.03 (0.10)	-0.04 (0.11)
Corporations	-1.41*** (0.40)	-1.43*** (0.41)	-1.45*** (0.31)	-1.52*** (0.32)
Total funding, logarithm	0.60*** (0.02)	0.60*** (0.02)	0.59*** (0.02)	0.60*** (0.02)
Human capital, logarithm	1.63*** (0.08)	1.64*** (0.08)	1.51*** (0.07)	1.50*** (0.08)
Accessibility	-	0.001** (0.0003)	-	0.001*** (0.0003)
Academic field dummies				
Engineering	0.21*** (0.07)	0.20*** (0.07)	0.28*** (0.06)	0.27*** (0.06)
Medical, chemical, biotech	1.36*** (0.05)	1.32*** (0.05)	1.48*** (0.05)	1.41*** (0.05)
Other	0.38*** (0.06)	0.38*** (0.06)	0.44*** (0.06)	0.43*** (0.06)
Constant	-3.02*** (0.21)	-3.04*** (0.21)	-2.48*** (0.19)	-2.49*** (0.19)
Observations	1009	1009	980	980

\*\*\*, \*\*, and \* denote statistical significance at the 1-, 5- and 10-percent level, respectively. Robust standard errors are in parentheses. Dummy variables for years are included in all models. Government university base funding constitutes the base category of university funding shares, and IT is the base category for academic fields. See Fig. 1 for a graphical analysis of the coefficients for nonprofit organizations and Table 5 for an analysis of the relative productivity of funding

by the density of university professors within the given HEI and by the impact of HEIs in neighboring regions, seem important for the output of scientific articles.

## 6.2 Philanthropy, university research, and regional patenting

The set of regression results using our second knowledge output variable, patent applications, shows that corporate funding, both directly to the HEIs and at the overall regional level, is highly significant irrespective of the estimation specification (see Table 3). This finding is expected because corporations account for the dominant share of regional research expenditure directed toward innovations. The remaining variables of interest, except for total HEI funding and academic field dummies, fail to attain significance.<sup>29</sup> The results prevail as we implement different lag structures.

As described in the data section, the regional distribution of firms' research expenditures is based on the distribution of their R&D staff (i.e., human capital) since there is no data allocating corporations' R&D-expenditures to regions. That implies a strong correlation

<sup>29</sup>How successful HEIs are in generating patents and patent applications also depends on their ability to organize various tech transfer activities. This aspect however falls outside the scope of the current paper. See Caldera and Debande (2010) for further discussion.

**Table 3** Regression results, dependent variable: regional patent applications

	2-year lag		4-year lag	
	(1)	(2)	(3)	(4)
University funding shares				
Nonprofit organizations	0.22 (0.27)	0.22 (0.27)	-0.24 (0.36)	-0.24 (0.35)
Government excl. base funding	0.11 (0.09)	0.11 (0.09)	0.06 (0.10)	0.06 (0.10)
Corporations	0.60*** (0.20)	0.58*** (0.20)	0.64*** (0.21)	0.64*** (0.22)
Total HEI funding	0.06*** (0.01)	0.06*** (0.02)	0.05*** (0.02)	0.05** (0.02)
Total corporate R&D expenditure	0.30*** (0.02)	0.30*** (0.02)	0.34*** (0.02)	0.34*** (0.02)
Accessibility		0.006 (0.03)		-0.003 (0.03)
Academic field dummies				
Engineering	0.96*** (0.05)	0.96*** (0.06)	1.10*** (0.06)	1.10*** (0.07)
Medical, chemical, biotech	0.15** (0.07)	0.15** (0.07)	0.26*** (0.08)	0.26*** (0.08)
Other	0.30*** (0.06)	0.30*** (0.06)	0.39*** (0.07)	0.39*** (0.07)
Constant	-1.91*** (0.13)	-1.91*** (0.13)	-2.49*** (0.14)	-2.49*** (0.14)
Observations	1073	1073	893	893

\*\*\*, \*\*, and \* denote statistical significance at the 1-, 5- and 10-percent level, respectively. Robust standard errors are in parentheses. Dummy variables for years are included in all models. Government university base funding constitutes the base category of university funding shares, and “Information technology” is the base category for academic fields

between our inferred research expenditure and the human capital variable (correlation coefficient 0.86). However, a human capital variable may be better suited to capture a region’s capacity to absorb and exploit internal and external spillovers. In some regions, corporate research expenditures are concentrated to one or a few firms, with uncertain regional trickle-down effects. Hence, we rerun the regressions, replacing total corporate funding with regional access to human capital (individuals with three or more years of tertiary education).

As expected, the human capital variable is positive and strongly significant, and the overall results are basically unchanged (see Table 11 in the Appendix). Hence, the regional human capital variable seems a somewhat better choice for capturing the effects of intra- and inter-regional knowledge spillovers. Both other governmental funding and funding from nonprofit organizations remain insignificant, except in specification 1, where other governmental funding becomes weakly significant.

It is not surprising that corporate funding tends to dominate regional patenting, since corporations account for most of the research expenditure. However, it might be the composition of research expenditures that affects regional patent applications. That is, the mix of basic research conducted by universities paired with more applied research undertaken or initiated by corporations and nonprofit foundations might prove decisive for regional patenting. To assess such effects, we re-ran the regressions, pooling all research funding in

a region. Hence, shares are now expressed as a percentage of total research expenditure in a region, while controlling for the total level of funding.

As is apparent from the estimations (Table 4), universities' share of philanthropic funding now becomes a relatively strong predictor of innovative regional activity measured as patent applications—the effect being significantly larger than the governmental base funding in all four specifications. The share of corporate funding to HEIs, the share of the business sectors' research expenditures, and the total level of research funding within a region remain significant, while the impact of governmental funding outside university base funding cannot be significantly distinguished from the HEIs' base funding. Finally, the spatial spillover variable now becomes significant, while engineering remains prominent among the academic field variables, with considerably larger coefficients and highly significant.<sup>30</sup>

**Table 4** Regression results, dependent variable: regional patent applications

	2-year lag		4-year lag	
	(1)	(2)	(3)	(4)
University funding shares				
Nonprofit organizations	17.25*** (2.03)	16.64*** (2.05)	17.73*** (2.46)	16.99*** (2.49)
Government excl. base funding	1.02 (0.70)	0.77 (0.71)	0.30 (0.83)	0.01 (0.85)
Corporations	5.27*** (1.31)	5.38*** (1.31)	3.25* (1.71)	3.35* (1.72)
Corporate R&D funding share	3.96*** (0.53)	3.75*** (0.54)	3.56*** (0.63)	3.33*** (0.64)
Total research funding	0.28*** (0.01)	0.29*** (0.01)	0.29*** (0.01)	0.30*** (0.01)
Accessibility		0.07** (0.03)		0.08** (0.03)
Academic field dummies				
Engineering	1.00*** (0.06)	0.93*** (0.06)	1.16*** (0.07)	1.08*** (0.08)
Medical, chemical, biotech	0.02 (0.08)	0.01 (0.08)	0.09 (0.10)	0.08 (0.10)
Other	0.30*** (0.07)	0.30*** (0.07)	0.40*** (0.08)	0.39*** (0.08)
Constant	-4.49*** (0.54)	-4.34*** (0.54)	-4.56*** (0.64)	-4.38*** (0.64)
Observations	1073	1073	893	893

\*\*\*, \*\*, and \* denote statistical significance at the 1-, 5- and 10-percent level, respectively. Robust standard errors are in parentheses. Dummy variables for years are included in all models. Government university base funding constitutes the base category of university funding shares, and "Information technology" is the base category for academic fields. See Fig. 2 for a graphical analysis of the coefficients for nonprofit organizations and Table 6 for an analysis of the relative productivity of funding

<sup>30</sup> Because of multicollinearity issues, we have not included the human capital variable in the estimations. However, including the human capital does not affect the results in any major way (see footnote 26). Results are available upon request.

Overall, the results are quite stable over the period we are considering. Only minor changes can be observed in the estimates as we extend the lag period for our explanatory variables from two to four years.

The empirical analyses include four STEM categories, and they may exhibit different trends in publication and patenting. Therefore, Tables 2 and 4 are re-estimated to allow separate time trends for the STEM categories. Funding from nonprofit organizations becomes moderately significant using the two-year lag specification in the publication analyses, and the STEM-category “Other” becomes insignificant in the two-year lag specification in the patent analysis. The remaining results are essentially unchanged, as reported in Tables 12 and 13 in the Appendix.<sup>31</sup>

To summarize, when implementing shares of funding to HEIs and controlling for total levels and accessibility effects, we find that only the share of corporate research funding to HEIs impacts patenting significantly (Table 3). When interpreting the results, it is important to note that the lack of statistical significance between the share of funding from a particular source and the outcome variable does not mean that the funding category lacks an impact on outcomes. Rather, it should be interpreted as not significantly different in its impact from other forms of funding. However, as we pool all research sources in a region, i.e., adding research funds available to HEIs and research by corporations, we find that donations from nonprofit organizations to HEIs are strongly associated with regional patenting (Table 4). These findings suggest that the composition of research funding is vital for regional patenting.

## 7 Relative productivity of different funding categories

The estimated coefficients from the negative binomial regressions in Tables 2 and 4 enable us to derive the underlying structural parameters of the knowledge production function, i.e., to calculate the relative publication/patent productivities ( $\gamma$  in Eq. 2). Tables 5 and 6 present the estimated relative publication and patent productivities, respectively.

Corporations’ funding share is the only significant funding variable in Table 2, and, according to the derived productivity in Table 5, one extra dollar of corporate funding to a HEI is between  $-1.4$  and  $-1.5$  times as productive as one extra dollar of university base funds in producing publications. This likely reflects that the prime objective of corporations’

**Table 5** Estimated relative publication productivities from Table 2

	2-year lag		4-year lag	
	(1)	(2)	(3)	(4)
University funding shares				
Nonprofit organizations	1.6	1.6	1.2	1.1
Government excl. base funding	1.0	1.0	1.0	0.9
Corporations	-1.4***	-1.4***	-1.5*	-1.5*

\*\*\*, \*\*, and \* denote statistical significance at the 1-, 5- and 10-percent level, respectively

<sup>31</sup>We have also elaborated with other specifications for our funding variables and also analyzed interaction effects between different sources of funding. No clear interaction effects could be discerned. It should be noted, though, that these estimations are not comparable to our preferred approach presented above, and results should be interpreted cautiously. Results are available upon request.

**Table 6** Estimated relative patent productivities from Table 4

	2-year lag		4-year lag	
	(1)	(2)	(3)	(4)
University funding shares				
Nonprofit organizations	62.0***	58.8***	62.1***	58.4***
Government excl. base funding	4.6	3.7	2.0	1.0
Corporations	19.6***	19.7***	12.2*	12.3*
Corporate R&D	15.0***	14.0***	13.3***	12.2***

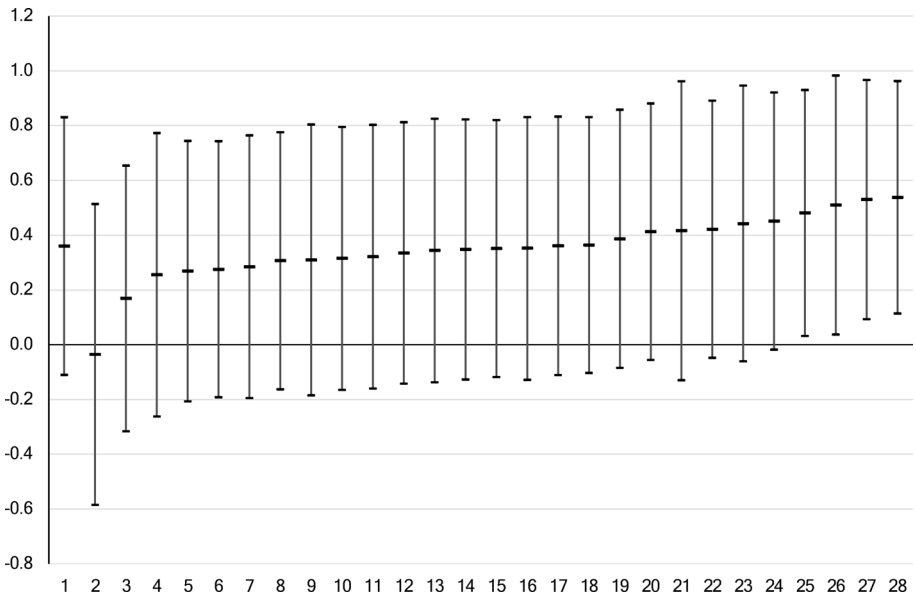
\*\*\*, \*\*, and \* denote statistical significance at the 1-, 5- and 10-percent level, respectively

research funding may not be to disclose results in scientific journals (Bikard et al., 2018). In a similar fashion, Table 6 suggests that corporate funding to universities is between twelve and 20 times more productive than university base funding for generating patent applications. Also, funding from non-profit organizations has substantial effects compared to university base funding. Patent applications are the first step in attaining intellectual property rights; hence, disclosure is unavoidable. However, it does not guarantee that a patent will eventually be granted, and applying for a patent carries risk. Thus, some corporations might prefer to shield their findings through other means related to their corporate structure and strategies. This suggests that innovations captured by patent applications tend to be underestimated.

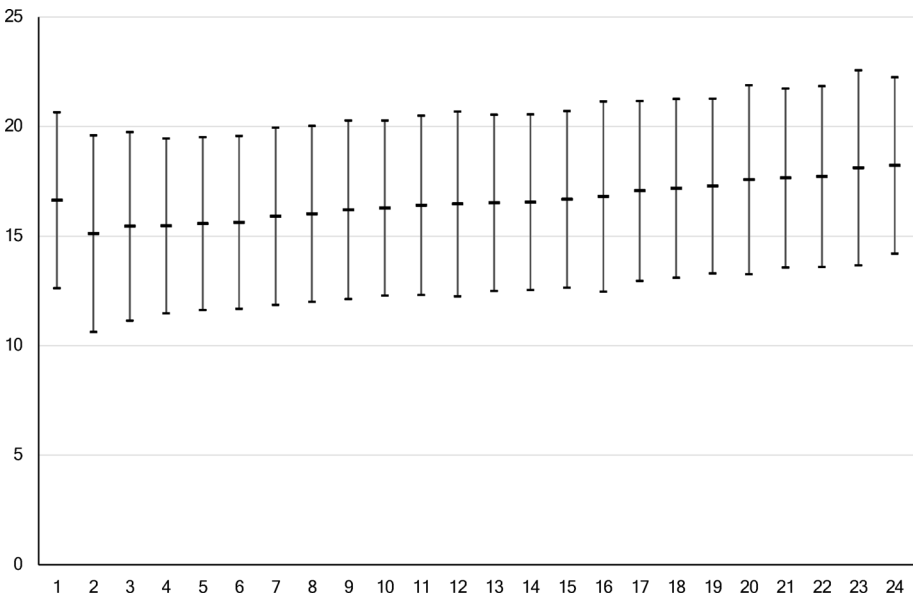
### 8 Robustness tests

Our results may be driven by individual universities or regions and, hence, do not capture a general effect of philanthropy on knowledge production. Therefore, we perform two tests, based on regression specification (2) in Tables 2 and 4 to assess how robust our findings are regarding the relationship between philanthropic funding and knowledge output. First, we sequentially exclude individual universities, followed by a similar analysis for FA-regions, to examine the impact of our primary variables of interest, i.e., scientific publications and patent applications. Starting with publications as the dependent variable, Fig. 1 shows the estimated coefficient for nonprofit organizations’ university funding shares, along with 95-percent confidence intervals, while excluding one university at a time. The leftmost bar shows the overall estimate, while the remaining bars are sorted from the smallest to the largest point estimate. The estimated coefficient is robust to excluding individual universities from the regressions. It is, however, slightly lower when excluding Mälardalen University (the bar next to the far left) and slightly higher when excluding the Swedish University of Agricultural Sciences (the bar farthest to the right). The effect of nonprofit organizations’ university funding remains statistically insignificant throughout the regressions.

The result from doing the same type of analysis for patents, but excluding one FA-region at a time, is shown in Fig. 2, along with 95-percent confidence intervals. The leftmost bar contains the overall estimate, while the remaining bars show the estimated coefficient for nonprofit organizations, excluding individual FA-regions, sorted from the smallest point



**Fig. 1** Robustness—result of exclusion of individual HEIs on coefficient estimates for nonprofit funding share



**Fig. 2** Robustness—result of exclusion of individual FA-regions on coefficient estimates for nonprofit funding share

estimate. Again, the estimate seems robust across the regressions, and we conclude that the estimated effect of philanthropy on innovation is relatively insensitive to differences between regions and universities; hence, we capture a general effect in our regression analysis.<sup>32</sup>

## 9 Discussion and conclusions

Although organized philanthropy has been around for several centuries, a resurgence in philanthropic activity has been observed in recent decades. Several factors, such as individual wealth creation, rising social needs, scarce resources, an increasingly globalized tax environment, and role models, interact to explain this development. The research issue we address in the present analysis focuses on the effect of philanthropy, which in a Swedish context primarily implies donations from nonprofit foundations, on knowledge output measured in terms of either scientific publications or patent applications.

Thus, we seek to identify mechanisms through which philanthropy might have societal effects, i.e., whether it complements other sources of university research funding, thereby contributing to a more diverse knowledge base of an economy. More precisely, we examine the impact of different research funding categories for universities in the STEM fields during 2001–2015 on knowledge output defined as scientific publications and patents. If different output effects can be associated with different sources of funding, it indicates complementarity and that societal value may be attached to philanthropy that has not yet been recognized. Donations directed toward research that generates new knowledge then have bearing on the growth potential of an economy, in accordance with contemporary economic growth models stressing the role of continuous knowledge upgrading and innovation. A minuscule share of previous research, referred to above, also suggests that growth effects of philanthropy are likely, yet the evidence is feeble and indicative. The current paper does not aim to fill that gap, i.e., establish a link between philanthropy and growth, rather it focuses on the first step in the growth process, i.e., research expenditure and knowledge production (Romer, 1986; Agion and Howitt, 1992; America, 1995; Sachs, 2000; Barro, 2001).

Our results reveal that, relative to governmental base funding of Swedish universities, there is no significant difference in the impact of research funding sources on scientific publications, except for funding from corporations (negative). That is in line with our first hypothesis. When we reran the regressions replacing publications with patent applications, we found that the share of funding provided by corporations was positively associated with regional patenting. Contrary to our expectations, the relationship between the share of donations from nonprofit organizations was insignificant, while most controls were significant and had the expected signs. However, as we continue evaluating the effect of different funding sources in relation to total research funding, where the private business sector is incorporated, we found that the share of donations and the share of HEIs' research fund-

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<sup>32</sup>We also performed similar tests for the remaining variables, and the results are rather stable for these as well.

ing provided by corporations were strongly associated with patent applications. Hence, our second hypothesis receives partial support. The composition of research funding thus seems important for innovative activities as approximated by patent applications. Moreover, the total share of corporations' regional research funding and the total level of HEIs' research funds both exhibited positive relationships with regional patenting activity.

Hence, we conclude that philanthropic funding seems to complement governmental funding by being more inclined to undertake applied research that generates patent applications. This is in accordance with the motives expressed by philanthropists at the individual level, i.e., to contribute to something primarily not covered by public funding. We contend that this effect captures the importance of the composition of total research funding in promoting research that is turned into innovations as reflected in patent applications. Hence, diversity in research funding, representing different knowledge bases, seems vital for generating ideas that can be turned into innovations. This has been alleged in previous research, i.e., heterogeneity supports innovative outcomes (Parrotta et al., 2014).

To our knowledge, this is the first study implementing data that is disaggregated enough to estimate how philanthropy influences various categories of knowledge output. We find that philanthropy directed toward HEIs has the potential to enlarge the knowledge base, thereby complementing traditional sources of research funding, primarily affecting applied research, as evidenced by its impact on patent applications. These findings align with the results presented by Muscio et al. (2013) looking at governmental and corporate research funding. Additionally, philanthropic funding may generate other important knowledge-related impetus, such as extended networks involving other research nodes, access to new potential funders, a higher propensity for researchers to work with industry, and tapping into novel innovative environments that might lead to new research ideas (Bozeman & Gaughan, 2007; Muscio et al., 2016).

We believe that the results can be generalized to other disciplines, at least regarding publications, and to some extent also to innovation, albeit not always substantiated in a patent application (e.g., business models, new organizational structures and production processes, etc.). To validate this assertion would obviously require an extended analysis based on a broader set of data. Furthermore, similar effects could be expected in other countries, as suggested by Toepler and Feldman (2003) and indicated by Muscio et al. (2013). However, a notable difference compared to most other countries is that faculty at Swedish universities own the results of their research, i.e., they are subject to the so-called "professors' privilege". Inspired by the US, many European countries have adopted some version of the US Bayh-Dole regime, under which universities own the outcomes of publicly funded research. The outcomes of these different regimes for innovation are not obvious; a professor's privilege system might increase faculty members' motivation to engage in innovation, whereas a Bayh-Dole system might generate more professional support organizations to transfer and commercialize research. The outcome is also associated with how conducive society at large is to entrepreneurial endeavors. Hence, *à priori* hypotheses are difficult to underpin; one has to resort to empirical analyses.<sup>33</sup>

<sup>33</sup> Presently, most European countries have a similar system, hoping to increase the rate of patents and innovations. However, evaluations find that the effects are modest or even non-existent (Astebro, 2016).

The results entail some obvious strategic implications for HEIs, as well as policy inferences at the regional and national levels. First, for HEIs that aim to produce scientific articles and innovations, it seems important to have a diversified research funding portfolio, clearly separating between public and other sources of funding. Moreover, to attract philanthropic funding, universities should establish a reputation for being entrepreneurial and innovative (Lundqvist & Williams-Middleton, 2023). Second, at the regional level, close interaction between the business sector and HEIs is important for facilitating and further promoting knowledge dissemination and the conversion of research into innovation. Virtuous cycles may be initiated by regional policies that encourage businesses to cooperate and capitalize on the presence of innovative universities. This corroborates previous contributions (Ponds et al., 2009; Varga & Erdős, 2019). Third, at the national level, there is a reason to consider additional policy measures to encourage donations to HEIs, i.e., not only through foundations. Policies could attempt to balance the level of tax deduction possibilities for donations to research and/or to match private donations with governmental funding up to a certain threshold over a given period. Moreover, it seems less likely that funding from philanthropists would replace reductions in public funding. We also find no evidence of crowding-out effects, since public funding has increased in real terms.

However, our results have several limitations. First, our research design rests on the implementation of a relatively large set of confounding factors and on some standard robustness tests. Thus, we cannot claim that we provide causal evidence. However, we argue that our results are strongly indicative of research output being affected by the type of research funding. Second, more research is required to further pin down this relationship. To accomplish that, more disaggregated data would be needed, preferably embracing more disciplines and universities, also in other countries as mentioned above. For instance, we do not have access to the agreements between the respective universities and corporations; hence, we cannot tie a specific contribution from a given corporation to a patent. A similar limitation applies to the respective donations to HEIs. Moreover, we cannot tell whether the HEI or the corporation applies for the patent, only that research initiated by corporate funding to HEIs positively influences regional patenting.

Furthermore, the policy suggestions are based on the prevalence of a link between philanthropy, knowledge output, and economic growth. We have only explored the first sequence in this chain, i.e., the link between philanthropy and knowledge output. Since there is consensus that knowledge is imperative for growth, the entire chain should be analyzed, and the extent to which there are more effective means of achieving growth beyond donations should be considered. That, however, is a subject for future research.

## Appendix

See Tables 7, 8, 9, 10, 11, 12 and 13.

**Table 7** List of HEIs included in the analysis, whereof two are private (Chalmers university of Technology and Jönköping University)

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Blekinge Institute of Technology
Chalmers University of Technology
Gothenburg University
Dalarna University
University West
University of Borås
University of Gävle
Halmstad University
Jönköping University
Kristianstad University
University of Skövde
Karlstad University
Karolinska Institute
KTH Royal Institute of Technology in Stockholm
Linköping University
Linnaeus University
Luleå University of Technology
Lund University
Malmö University
Mid Sweden University
Mälardalen University
Stockholm University
Swedish University of Agricultural Sciences
Södertörn University
Umeå University
Uppsala University
Örebro University

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**Table 8** Description of variables

	Description	Level
<b>Dependent variables</b>		
Academic publications (2005–2015) (Swedish Research Council, 2020)	Number of publications (4-year moving average, year range denotes the first year in moving average, i.e., the 2005 observation denotes the 2005–2008 observation). Multi-university publications are divided based on authorship	4-yr moving avg., HEI, academic field
Patent applications (2003–2015) (PATSTAT, 2020)	Patent applications by Swedish applicants registered by the Swedish patent authority (PRV)	Year, region, academic field
<b>Independent variables</b>		
<b>University funding shares</b>		
Nonprofit organizations (2001–2015) (Statistics Sweden, 2020)	Funding for university research by nonprofit organizations as a share of total research funding or HEI funding (patent analysis) or HEI research funding (publication analysis)	Year, region/HEI, academic field
Governmental base funding (2001–2015) (Statistics Sweden, 2020)	Governmental base funding for university research as a share of HEIs total funding (publication analysis) or as a share of total regional research funding (HEIs and private research in the patent analysis)	Year, region/HEI, academic field
Government excl. base funding (2001–2015) (Statistics Sweden, 2020)	Non-base governmental funding for university research as a share of total research funding or HEI funding (patent analysis) or university research funding (publication analysis)	Year, region/HEI, academic field
Corporate funding (2001–2015) (Statistics Sweden, 2020)	Funding for university research by corporations as a share of total research funding or HEI funding (patent analysis) or university research funding (publication analysis)	Year, region/HEI, academic field
Corporate R&D funding, share (2001–2015) (Statistics Sweden, 2020)	Private R&D spending (imputed based on research employment) as a share of total research spending. Used in the knowledge production function for patent applications	Year, region, academic field
Corporate R&D funding, sum (2001–2015) (Statistics Sweden, 2020).*	Sum of total regional R&D spending (imputed based on researcher employment). Used as control in some model specifications	
Total research (2001–2015 for patent analysis, 2001–2015 for publication analysis).*	The sum of all research spending (for patent analysis) or research funding (for publication analysis) of universities, corporations, and government	Year, region/HEI, academic field
Human capital (2001–2015, (Statistics Sweden, 2020).*	Number of individuals between 16 and 74 years old with at least three years of post-secondary education	Year, region/HEI
Regional accessibility*	Measure of proximity of innovation or publication activity in other regions, based on travel time between regions. Measures geographical proximity of patenting (patent analysis) or university publication activity (publication analysis), discounted by travel time	Year, region/HEI, academic field
Field dummies**	Field dummies are separated into the STEM-disciplines	Field

**Table 8** (continued)

	Description	Level
HEI dummies	Dummy variable for each HEI used in the analysis of academic publishing activity	HEI
Year dummies	The time dummy is included in all estimations and accounts for yearly effects	Year

\*The variable has been altered through an inverse hyperbolic sine transformation procedure, which is a way of “taking logs” of variables that contain zeros (see, e.g., Bellemare & Wichman, 2020). \*\* To the original STEM-disciplines we have added medical and health sciences as well as some subcategories of agricultural, veterinary sciences and agricultural biotechnology (to maintain consistency with older Swedish classification schemes used prior to 2013). Patents are categorized into four broad categories: IT-, electronics and telecommunications, engineering, medicine & biology and “other” (I.e. patents not covered by the three previous categories). The categorization of patents is based on the International Patent Classification (IPC) standard

**Table 9** Means over time

a) Variable: publication analysis										
Year	Publications (no)	Accessibility	Total HEI funding (mSEK)	Base govt. funding (mSEK)	Other govt. funding (mSEK)	Corporate funding (mSEK)	Nonprofit funding (mSEK)	Human capital (prof./staff ratio)		
2001	N/A	N/A	155	55	70	13	17	12		
2002	N/A	N/A	152	55	68	12	17	12		
2003	N/A	N/A	163	59	73	13	18	12		
2004	N/A	N/A	153	55	69	12	17	12		
2005	330	16	161	58	73	12	18	13		
2006	314	16	161	58	74	12	17	13		
2007	334	16	170	61	80	12	17	13		
2008	344	17	185	65	88	12	19	14		
2009	381	18	210	72	103	13	22	14		
2010	387	19	211	75	102	12	22	14		
2011	432	16	237	85	113	13	25	14		
2012	408	23	233	85	111	12	25	14		
2013	431	24	257	95	121	13	29	14		
2014	435	24	265	95	125	14	31	14		
2015	451	24	285	100	135	15	35	14		

b) Variable: patent analysis (HEI regions only)										
Year	Patents (no)	Accessibility	Total HEI funding (mSEK)	Base govt. HEI funding (mSEK)	Other govt. HEI funding (mSEK)	Corporate HEI funding (mSEK)	Nonprofit HEI funding (mSEK)	Corporate R&D expenditure (mSEK)	Human capital (n:o ind.)*	
2001	N/A	N/A	167	60	75	14	18	797	37,155	
2002	N/A	N/A	166	60	75	13	18	761	36,578	
2003	26	2.2	179	65	80	14	20	771	37,707	
2004	21	1.8	166	60	75	13	18	706	35,979	
2005	10	0.9	176	63	80	13	20	723	36,834	

**Table 9** (continued)

b) Variable: patent analysis (HEI regions only)										
Year	Patents (no)	Accessibility	Total HEI funding (mSEK)	Base govt. HEI funding (mSEK)	Other govt. HEI funding (mSEK)	Corporate HEI funding (mSEK)	Nonprofit HEI funding (mSEK)	Corporate R&D expenditure (mSEK)	Human capital (n:o ind.)*	
2006	10	0.9	179	64	82	13	19	734	36,706	
2007	9	0.8	190	69	89	14	19	775	37,845	
2008	9	0.7	206	73	99	14	21	798	38,565	
2009	10	0.7	233	80	114	14	24	853	40,620	
2010	10	0.8	236	83	114	14	24	836	41,148	
2011	8	0.6	263	95	126	15	27	891	43,898	
2012	8	0.6	257	94	122	14	28	829	41,911	
2013	8	0.6	280	103	132	14	31	857	42,979	
2014	9	0.6	289	104	136	15	34	896	43,515	
2015	8	0.6	315	110	150	17	39	981	45,553	

\*Here described as the number of highly educated individuals per FA-region on average, in the main descriptive table in the paper, expressed as a share of the highly educated population (i.e., 3 years or more of post-secondary education)

**Table 10** Correlation matrix

a) Correlation matrix divided by HEI-region, year, and field

Publication analysis	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Publications (weighted, logarithm)	1.00							
(2) Nonprofit organizations, share	0.12	1.00						
(3) Government base funding, share	0.18	-0.06	1.00					
(4) Government excl. base funding, share	-0.21	-0.30	-0.89	1.00				
(5) Corporations, share	-0.01	0.09	-0.07	-0.23	1.00			
(6) Total HEI funding, logarithm	0.57	0.24	0.22	-0.34	0.20	1.00		
(7) Human capital, logarithm	0.52	0.20	0.41	-0.48	0.10	0.72	1.00	
(8) Accessibility (weighted, logarithm)	0.21	-0.06	-0.22	0.27	-0.15	-0.21	-0.24	1.00

b) Correlation matrix divided by FA-region, year, and field

Patent analysis	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Patents, logarithm	1.00								
(2) Nonprofit organizations, share	0.14	1.00							
(3) Government base funding, share	-0.14	0.09	1.00						
(4) Government excl. base funding, share	-0.10	-0.25	-0.42	1.00					
(5) Corporations, share	0.32	0.07	-0.01	-0.25	1.00				
(6) Total HEI funding, logarithm	0.50	0.22	0.51	-0.28	0.19	1.00			
(7) Total corporate R&D expenditure, logarithm	0.76	0.17	-0.10	-0.15	0.18	0.67	1.00		
(8) Human capital, logarithm	0.63	0.19	0.10	-0.13	0.07	0.76	0.86	1.00	
(9) Accessibility (weighted, logarithm)	0.34	0.00	-0.40	0.20	0.25	-0.25	0.09	-0.15	1.00

**Table 11** Regression results, dependent variable: regional patent applications, controlling for human capital

	2-year lag		4-year lag	
	(1)	(2)	(3)	(4)
University funding shares				
Nonprofit organizations	0.25 (0.27)	0.21 (0.27)	-0.20 (0.34)	-0.24 (0.35)
Government excl. base funding	0.17** (0.08)	0.12 (0.09)	0.13 (0.09)	0.08 (0.09)
Corporations	0.79*** (0.19)	0.65*** (0.20)	0.90*** (0.21)	0.74*** (0.21)
Total HEI funding	0.06*** (0.02)	0.06*** (0.02)	0.03* (0.02)	0.04** (0.02)
Human capital, logarithm	0.44*** (0.03)	0.43*** (0.03)	0.51*** (0.04)	0.50*** (0.04)
Accessibility		0.06** (0.03)		0.08*** (0.03)
Academic field dummies				
Engineering	1.19*** (0.06)	1.13*** (0.06)	1.33*** (0.07)	1.26*** (0.07)
Medical, chemical, biotech	0.04 (0.07)	0.03 (0.07)	0.13 (0.08)	0.12 (0.08)
Other	0.37*** (0.06)	0.36*** (0.06)	0.44*** (0.07)	0.43*** (0.08)
Constant	-4.82*** (0.31)	-4.79*** (0.31)	-5.87*** (0.36)	-5.83*** (0.37)
Observations	1073	1073	893	893

\*\*\*, \*\*, and \* denote statistical significance at the 1-, 5- and 10-percent level, respectively. Robust standard errors are in parentheses. Dummy variables for years are included in all models. Government university base funding constitutes the base category of university funding shares, and “Information technology” is the base category for academic fields

**Table 12** Regression results, dependent variable: academic publications, controlling for academic field-specific time trends

	2-year lag		4-year lag	
	(1)	(2)	(3)	(4)
University funding shares				
Nonprofit organizations	0.49** (0.23)	0.46** (0.23)	0.15 (0.22)	0.09 (0.22)
Government excl. base funding	0.03 (0.10)	-0.01 (0.11)	0.03 (0.10)	-0.04 (0.10)
Corporations	-1.56*** (0.40)	-1.58*** (0.40)	-1.57*** (0.31)	-1.64*** (0.31)
Total funding, logarithm	0.61*** (0.02)	0.62*** (0.02)	0.59*** (0.02)	0.60*** (0.02)
Human capital, logarithm	1.59*** (0.08)	1.60*** (0.08)	1.49*** (0.07)	1.49*** (0.08)
Accessibility		0.001*** (0.0003)		0.001*** (0.0003)
Academic field dummies				
Engineering	0.53*** (0.20)	0.53*** (0.20)	0.47** (0.20)	0.46** (0.20)
Medical, chemical, biotech	1.48*** (0.15)	1.45*** (0.15)	1.51*** (0.17)	1.47*** (0.17)
Other	0.61*** (0.16)	0.60*** (0.16)	0.60*** (0.16)	0.55*** (0.16)
Constant	-2.89*** (0.22)	-2.90*** (0.22)	-2.27*** (0.21)	-2.27*** (0.22)
Observations	1009	1009	980	980

\*\*\*, \*\*, and \* denote statistical significance at the 1-, 5- and 10-percent level, respectively. Robust standard errors are in parentheses. Dummy variables for years are included in all models. Government university base funding constitutes the base category of university funding shares, and “Information technology” is the base category for academic fields. Full results are available upon request

**Table 13** Regression results, dependent variable: regional patent applications, controlling for academic field-specific time trends

	2-year lag		4-year lag	
	(1)	(2)	(3)	(4)
University funding shares				
Nonprofit organizations	17.73*** (2.07)	17.09*** (2.09)	18.10*** (2.51)	17.42*** (2.53)
Government excl. base funding	0.97 (0.70)	0.70 (0.71)	0.30 (0.82)	0.04 (0.83)
Corporations	4.92*** (1.32)	4.98*** (1.33)	3.06* (1.80)	3.13* (1.81)
Corporate R&D funding share	3.95*** (0.52)	3.71*** (0.54)	3.63*** (0.62)	3.42*** (0.63)
Total research funding	0.28*** (0.01)	0.29*** (0.01)	0.29*** (0.01)	0.30*** (0.01)
Accessibility		0.07*** (0.03)		0.07** (0.03)
Academic field dummies				
Engineering	0.60*** (0.15)	0.51*** (0.15)	1.33*** (0.24)	1.25*** (0.24)
Medical, chemical, biotech	-0.18 (0.18)	-0.20 (0.18)	0.30 (0.26)	0.28 (0.26)
Other	0.11 (0.16)	0.11 (0.16)	0.75*** (0.26)	0.73*** (0.25)
Constant	-4.22*** (0.55)	-4.05*** (0.55)	-4.82*** (0.66)	-4.64*** (0.67)
Observations	1073	1073	893	893

\*\*\*, \*\*, and \* denote statistical significance at the 1-, 5- and 10-percent level, respectively. Robust standard errors are in parentheses. Dummy variables for years are included in all models. Government university base funding constitutes the base category of university funding shares, and “Information technology” is the base category for academic fields. Full results are available upon request

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**Data availability** All data were gathered from official sources and are available from the European Patent Office (PATSTAT, 2020), Statistics Sweden (SCB, 2018, 2020), the Swedish Research Council (SRC, 2020), and the Swedish Agency for Growth Policy Analysis (2020).

## Declarations

**Conflict of interest** The authors declare no competing interests.

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