UK DOCTORAL GRADUATES' CONTRIBUTION TO INNOVATION (UK DGCI)

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Executive summary

This report draws upon a comprehensive dataset of UK doctoral graduates to uncover their contribution to science and innovation. The data relate to 347,838 graduates listed in the British Library's EThOS database of UK doctoral theses, who completed their studies between 2000 and 2020, covering all disciplines in all UK Higher Education Institutions. The graduates were matched to publications listed on Scopus and OpenAlex and to patents that cite these publications via Reliance on Science, following the DOC-TRACK (https://doc-track.eu/) methodology. The resulting data provides a **comprehensive and unprecedented opportunity to examine the contributions of UK doctoral graduates over time.**

Graduate population. The total number of UK dissertations grew significantly between 2000 and 2020, from approx. 12,000 to more than 20,000 graduates per year. Dissertations in STEMM (Science, Technology, Engineering, Mathematics and Medicine) fields consistently and substantially outnumber non-STEMM fields across the whole period. Still, social science graduates account for the largest share, with 24% of all UK dissertations. This is followed by medicine (excluding doctors of medicine) and engineering with 20% and 18% respectively.

Publishing trends. Publishing has become an increasingly essential part of the doctoral experience, with the share of PhD graduates who publish during their studies rising by 70% between 2000 and 2020. Publishing is more common in STEMM fields, particularly in physical sciences and medicine, with more than 65% of graduates having at least one publication during the PhD. This share is lower post-PhD, especially in engineering where

only 42.6% of graduates continue to publish. In non-STEMM fields publishing propensity during the PhD has also increased and is now above 30%. An equivalent share of non-STEMM graduates continue to publish after the PhD indicating continued engagement in research. The share of graduates' publishing post-PhD has remained relatively stable over time for both STEMM and non-STEMM graduates.

The number of publications per PhD graduate has increased, with more recent cohorts of PhDs significantly more productive than earlier cohorts across all fields. For instance, in STEMM the number of publications more than doubled from 1.6 in 2000 to 3.5 in recent cohorts. This likely reflects a greater push towards journal publication for doctoral students in all domains. It is also consistent with expansion of publication opportunities, such as the founding of new journals and increased journal indexing in databases such as Scopus during our observed time period.

Inputs to innovation. UK PhD graduates have a substantial impact on patenting. Up to 40% of STEMM graduates who publish are being subsequently cited by EPO or USPTO patents. This represents a significant contribution to innovation by PhDs in the UK and highlights the innovation potential of doctoral research. The highest shares are observed in medicine and life sciences, followed by engineering. This finding does however contrast sharply with UK PhD graduates' low participation in patenting compared to other countries, which we reported elsewhere.

Gender patterns. Assigning gender as male or female based on first names[1], we document a persistent gender disparity in the number of PhD graduates in STEMM fields, where male graduates account for approximately 60% of dissertation authors, contrasting sharply with the near gender parity in non-STEMM fields. In terms of publications, there is only a small difference between male and female graduates in their propensity to publish during or after the PhD, with both almost equally as likely to share their research in publications. However, we observe a significant and growing gap in the number of papers published by male and female graduates, both during and after the PhD. We also observe a small but noticeable difference in male and female STEMM graduates' likelihood to inform future invention, with women's research less likely to be directly cited by a patent.

Regional patterns. There are substantial regional differences in STEMM vs. non-STEMM education and in the share of women in STEMM PhDs, with Northern Ireland and Scotland

[1] This methodology has many limitations, and does not take account of the gender identity of the individual.

for instance showing a higher participation of women in STEMM compared to England and Wales. There is also a substantial difference in PhD graduates' publication propensity, which is highest in London, East and South-East England and in Scotland, and lowest in Northern Ireland and Wales. The highest shares of STEMM graduates' being cited in patents can be found in areas of key economic activity, with lowest shares in more rural areas of the UK. The majority of USPTO and EPO patents citing UK PhD graduates' research are however not filed by UK but by foremost US and European companies, with UK-based patent applicants accounting for just 6.6% of citing patents. This highlights the role of UK science as a foundational source for technological developments across multiple major innovation systems.

Implications. Our findings show that publishing has become an increasingly central feature of the doctoral experience, which suggests a need for policies that support equitable access to publishing opportunities across disciplines. A substantial share of STEMM graduates' work being later cited by patents highlights the value of strengthening pathways from academic research to innovation, including measures that promote gender-equitable access to commercialisation opportunities. Regional disparities in publishing propensity and innovation potential indicate that targeted investment in research infrastructure and doctoral training may be needed to support under-represented areas.

Contribution: This project responded to a need for more extensive, longitudinal data on PhD graduates in the UK. We mobilised already available data sources to demonstrate the contributions of UK doctoral graduates across time and regions. The data and methodology can become an important tool for policy, enabling not only the monitoring of doctoral performance but also pathways post PhD. The analyses presented here already draw attention to the significant share of graduates that contribute to science and innovation after the conclusion of their PhD, thus alleviating concerns regarding the touted exodus of PhDs from research. The database compiled for this project will in future enable analyses to understand where these researchers end up and work is underway to link this data to career databases to uncover non-academic pathways. The data can moreover shed light on different aspects of inequality. Here we presented some initial findings on gender and regional disparities. In an ***Annex B*** we demonstrated further uses for the data, with analyses of disparities in AI research and doctoral funding. All these analyses and findings shed light on the innovation potential of UK PhD graduates and help inform policies aimed at increasing it.

Further readings: The data collected as part of this study formed the basis for follow-on research in conjuncture with DOC-TRACK, funded by the European Patent Office. For a comparison of UK STEMM graduates to graduates of six European countries (Austria, Germany, France, Italy, Netherlands & Spain), for an analysis of STEMM graduates' patenting and distance to the technological frontier, and future data releases see https://doc-track.eu/.

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Thank you

The Innovation & Research Caucus

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