RESEARCH ARTICLE

# Domestic researchers with longer careers generate higher average citation impact but it does not increase over time

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## ABSTRACT

Information about the relative strengths of scholars is needed for the efficient running of knowledge systems. Because academic research requires many skills, more experienced researchers might produce better research and attract more citations. This article assesses career citation impact changes 2001–2016 for domestic researchers (definition: first and last Scopus journal article in the same country) from the 12 nations with most Scopus documents. Careers are analyzed longitudinally, so that changes are not due to personnel evolution, such as researchers leaving or entering a country. The results show that long-term domestic researchers do not tend to improve their citation impact over time but tend to achieve their average citation impact by their first or second Scopus journal article. In some countries, this citation impact subsequently declines. These longer-term domestic researchers have higher citation impact than the national average in all countries, however, whereas scholars publishing only one journal article have substantially lower citation impact in all countries. The results are consistent with an efficiently functioning researcher selection system but cast slight doubt on the long-term citation impact potential of long-term domestic researchers. Research and funding policies may need to accommodate these patterns when citation impact is a relevant indicator.


## 1. INTRODUCTION

Knowledge production is central to modern economies and academic research is an important part of this. It is therefore important to ensure that human resources within universities are managed effectively, using each person's strengths to produce the highest quality research. This need has led to extensive research into academic careers, from the perspectives of institutional management and personal development (Laudel & Gläser, 2008; Sauermann & Stephan, 2013). More concretely, information about researcher career paths is important for academics, research managers, and research policy makers to inform decisions at key stages. For example, the EU has funded reports into researcher mobility (Idea Consult, Wifo, & Technopolis, 2017), the careers of doctorates have been tracked in the United States since 1957 (Cañibano, Woolley et al., 2019), and 9% of *Science* and *Nature* editorials discuss scientific careers (Waaijer, 2013). While careers are often assessed using national statistics or surveys, this does not give information about career trends in research impact. This is an important gap because many researchers have long publishing careers, and information about this aspect may inform decision-making. In particular,

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knowledge about career stages that produce high-impact research could help managers to decide how best to employ the skills of experienced researchers. With a few exceptions, reviewed in Section 2, research into citation impact or academic careers has not investigated the relationship between the two.

Long-term academic careers have traditionally been viewed as a partly linear progression. A researcher may progress through the following stages: apprentice; colleague (independent researcher); master (supervising apprentices); and elite (shaping field directions) (Laudel & Gläser, 2008). Alternatively, career trajectories can be thought of as accumulating the technical and social capital (Bozeman, Dietz, & Gaughan, 2001) necessary for increasingly effective research. While these are simplifications and ignore factors such as specialized roles (Robinson-Garcia, Costas et al., 2020), field changes, job changes, and movement between academia and the commercial sector (Garrett-Jones, Turpin, & Diment, 2010), it suggests that older researchers tend to be more capable. If this leads to higher impact research, then universities might need to ensure that senior researchers have adequate time for research rather than other tasks, such as mentoring. Nevertheless, in general, there is little systematic information about the relationship between career length and research impact, although some information is available about particular fields and countries.

The aim of this article is to compare the career-long citation impact trajectories of domestic researchers, separating them by career length. A domestic researcher is defined here as someone that is affiliated with the same country in their chronologically first and last Scopus-indexed publications, even if they spend part of their time abroad. As there are other reasonable definitions of domestic researchers, such as never collaborating internationally (Tan, Ujum et al., 2015), or just being based in a country, however temporarily, (Akhmadieva, Guryanova et al., 2020; Ponomariov & Toivanen, 2014), the definition used here is only one way of interpreting domesticity. It would also be possible to restrict the focus to domestic-only researchers that never work abroad, but this may tend to exclude the best funded researchers, who might move abroad temporarily for collaborative projects, or the best overall researchers, who attract international sabbaticals or job offers. The unfortunate limitation of keeping these people is that midcareer citation patterns might be due to periods spent abroad (e.g., increased citation impact due to working abroad with higher quality infrastructure and support). Although, from a pragmatic perspective, it would be more useful to study the career trajectories of all researchers working in a country, international moves may be associated with permanent changes in infrastructure quality (e.g., moving to a richer lab in a wealthier country) or may be a mark of success. The focus is on domestic researchers because the average citation impact of nations varies widely, and part of the variation is presumably due to differing national research infrastructure quality. While this could be taken into account by field normalizing each researcher against the publications of the country that they happen to be in at the time, this seems unreasonable for internationally mobile researchers. Thus, researchers who move to a new country (unless they return) are excluded from the study.

Although career trajectories for domestic or national researchers have been investigated for the United States (Thelwall & Fairclough, 2020), another study has used different methods with a similar goal for Australia (Gu & Blackmore, 2017), and worldwide career impact changes have been reported as part of a study of productivity (Larivière & Costas, 2016), this is apparently the first internationally comparative longitudinal career impact study using reasonably comprehensive journal article data. The focus is on the Scopus-indexed publications of domestic researchers for pragmatic reasons. Domestic researchers are operationalized as people with the same country affiliation (first affiliation, if multiple) for their first ever Scopus-indexed publication and last Scopus-indexed publication, as of January 2020. The affiliation of the first publication is assumed to be usually the country where the researcher completed their PhD, as the publication might originate from the PhD. The affiliation of the last publication is assumed to be the country where the researcher completed their career. This is a simplification because the researcher might move abroad afterwards but stop researching or publish different types of document. The choice of Scopus-indexed publications is also for pragmatic reasons because it is not possible to get useful citation data from all relevant national publications, despite the relatively wide coverage of Scopus (Mongeon & Paul-Hus, 2016). For example, Chinese researchers may produce excellent Chinese-language publications indexed in the Chinese Science Citation Index (now in the Web of Science, as is the Russian Science Citation Index, SciELO (including Spain) and the Korean Journal Index). It is not clear how regional citations should be fairly compared to other Scopus-indexed publications that are mainly in English, especially for domestically focused social sciences, arts, and humanities (e.g., national law, social policy, educational policy).

## 2. BACKGROUND

Prior research into scientific careers has tended to focus on definitions, typologies, phases, and key decision-making stages (Cañibano et al., 2019). These investigations have been typically small scale, focused on a single country and often also a single field. They are mainly based on surveys or interviews, although some have analyzed resumes (Cañibano, & Bozeman, 2009) or publications. All the background findings reported below are therefore subject to the caveat that they may not be universal, given the substantial national and field differences in academic research organizations (e.g., Angermuller, 2017; Becher & Trowler, 2001; Franzoni, Scellato, & Stephan, 2012).

Academic careers can take many paths, and publications are not always important (Dietz, 2004). Academics may be expected to change their job functions during their lifetimes in response to promotions, specialty changes, funding, and opportunities for collaboration. In addition, the nature of scientific careers has changed over time, with careers tending to be dramatically shorter and more researchers exclusively playing supporting roles, at least in the United States (Milojević, Radicchi, & Walsh, 2018). The nature of publishing can also vary between cohorts in a country. For example, younger Flemish social sciences and humanities researchers are currently more likely to publish in English (Guns, Eykens, & Engels, 2019). The likelihood for junior researchers to continue with an academic career can also be influenced by factors such as childbirth (women), a supportive partner, luck, an effective mentor (Van Balen, Van Arensbergen et al., 2012), and any preuniversity work experience (Angervall & Gustafsson, 2014). Field changes are also relatively common for physicists, but less common for those attracting many citations to their work (Zeng, Shen et al., 2019), and are also common in computer science (Chakraborty, Tammana et al., 2015).

For academic careers, the most relevant measure of age seems to be the number of years as a researcher, rather than physical age. This may be counted as the number of years from the award of a PhD (Barbezat, 2006) or the first Scopus-indexed publication (Primack, Ellwood et al., 2009), with the two correlating (Costas, Nane, & Larivière, 2015). These are sometimes called "academic age."

### 2.1. Academic or Physical Age and Citation Impact

Although total citations naturally accumulate with (academic) age, the pattern for average citations is only known in a few special cases. For information and computer scientists, productivity at the start of their academic career is a good predictor of long-term higher citation impact (Lee, 2019). For early career mathematicians, productivity is also a good indicator of early impact (Lindahl, 2018). An investigation into a thousand publishing sociology, economics, or political science authors from highly ranked U.S. institutions measured age since the award of a PhD and found that average citation impact peaked about 4–12 years after the PhD award (Sugimoto, Sugimoto et al., 2016). Most (70%) of the scholars in this sample were full professors, with careers starting from the 1950s to the 2010s. In contrast, an analysis of chemists and physicists did not find an age at which higher impact research was more likely (Sinatra, Wang et al., 2016).

Older authors seem more likely to self-cite (at least in archaeology: Hutson, 2006), which may influence their citation rates. This is presumably because older researchers have more work to cite, on average.

A few prior studies have analyzed age and citation impact within countries. In Australia, researchers (from three sampled universities) with academic ages 10–29 attract the most citations per publication (Gu & Blackmore, 2017). In the United States (using many of the same methods as the current study, but focusing on long-term researchers authoring at least five papers), average citations per publication do not tend to increase over careers, and may tail off towards the end of careers or start to decrease after about a decade (Thelwall & Fairclough, 2020). For a set of Spanish research council members, younger researchers tended to have higher productivity and citation impact indicators (Costas, van Leeuwen, & Bordons, 2010), but a study of Mexican researchers found almost the opposite (González-Brambila, & Veloso, 2007), through either different methods or international differences. Thus, there does not seem to be a simple and universal relationship between age and average citation impact. Nevertheless, on a global scale, except in the arts and humanities, the probability that a researcher's article is in the top 1% most cited seems to increase steadily during their career (Larivière & Costas, 2016).

One possible reason why older researchers may attract more citations, on average, is the Matthew effect (Merton, 1968, 1988), which suggests that articles by successful researchers tend to attract disproportionately many citations. These researchers also find it easier to attract funding, gaining an overall citation impact advantage. If this occurs in middle or late careers, it may misleadingly increase the average citation impact of the later career publications of the set of long-term researchers.

### 2.2. Academic Career Stages

Academics often progress into more senior roles with age, but there are many other career paths. Most scientific PhD students in the United States leave academia immediately by getting a nonresearch job (Sauermann & Roach, 2012). Thus, the typical publishing career in the United States is likely to be very short, perhaps encompassing 1–3 papers published over a span of 1–3 years. The current article mainly focuses on longer-term careers, however.

From the abovementioned study, publishing U.S. sociology, economics, or political science authors at more senior ranks (from assistant professor to associate professor, then full professor) wrote more articles, on average (also found for politics alone: Hesli & Lee, 2011), and older researchers wrote more books (Sugimoto et al., 2016), suggesting a shift in research type, perhaps towards summarizing prior work rather than conducting primary research. Senior researchers may also attract citations to their work because of their reputation (Merton, 1968; Petersen, Fortunato et al., 2014).

Several studies point to changes in publishing patterns with career stage, and this may have an indirect influence on average citation impact. This is because higher productivity is associated with higher citation impact in some fields (Kolesnikov, Fukumoto, & Bozeman, 2018).

The productivity of junior researchers is associated with their later-career productivity (Lee, 2019). More junior researchers may feel pressure to self-cite if they believe that citations may influence their promotion chances, as is the case in Italy (Seeber, Cattaneo et al., 2019). Also in Italy, when junior researchers are promoted to associate professor, they tend to be more productive than existing associate professors (Abramo, D'Angelo, & Rosati, 2014). In Japan, senior researchers seem to write fewer articles because they need to spend more time on administrative tasks (Kawaguchi, Kondo, & Saito, 2016). In Slovenia, researchers that become Principal Investigators on public grants tend to be more productive, presumably due to the funding, but also have longer careers (Kastrin, Klisara et al., 2018).

### 2.3. Academic Age and Collaboration

Collaboration is relevant to average citation impact because more collaborative articles tend to be more cited (Larivière, Gingras et al., 2015), especially for moderately stable collaboration partnerships (Bu, Murray et al., 2018). Coauthored papers also tend to attract a greater number of self-citations (in library and information science: Shah, Gul, & Gaur, 2015). In computer science, most (70%) collaborations do not survive past a single publication. Nevertheless, collaborations with senior researchers can build into long-term partnerships, but researchers also often collaborate with first-time authors, presumably usually PhD students (Cabanac, Hubert, & Milard, 2015). Older researchers also have larger collaboration networks (Wang, Yu et al., 2017). International researchers in Poland are more productive (Kwiek, 2020) and presumably these tend to be older, having had time to build networks. Collaboration is associated with productivity most towards the end of academic careers (Hu, Chen, & Liu, 2014), perhaps with older researchers needing help to continue or stay current.

### 2.4. Publication Productivity and Citation Impact

Researchers who write more articles tend to attract more citations per article, although there are disciplinary variations in this pattern (Larivière & Costas, 2016; Sandström & van den Besselaar, 2016). There are substantial disciplinary differences in the average rate of publishing (Larivière & Costas, 2016), which can influence analyses of the relationship between publication productivity and citation impact for sets of researchers from multiple disciplines.

### 2.5. Researcher Mobility

International mobility can help researchers by providing them with a wider network of contacts. Even temporary visits may be seen by researchers as helpful for their careers (Lawson & Shibayama, 2015). A side effect is that more successful researchers are more likely to be internationally mobile, and especially to countries with more resources, leading to brain drains from lower performing countries to countries with higher spending (e.g., Hunter, Oswald, & Charlton, 2009; Tian, 2011), and particularly to the United States (Freeman, 2015; Idea Consult, Wifo, & Technopolis, 2017). In contrast, Polish chemistry researchers are almost all trained in Poland and 10% leave, mainly to the EU and United States (Kosmulski, 2015).

Mobility may boost productivity by exposing researchers to new environments, equipment, or ideas (Tartari, Di Lorenzo, & Campbell, 2018), although this did not help one sample of Japanese life and medical scientists (Fukuzawa, 2014). Scientists returning from stays abroad sometimes bring back new ideas, but this is not always beneficial, as a study of Taiwan showed (Velema, 2012). A survey of biology, chemistry, materials, and Earth and environmental sciences researchers from 16 countries found that in most of these countries, a majority had international experience, so international mobility is the norm in these fields (Franzoni, Scellato, & Stephan, 2012). The United States had the fewest researchers with international experience in this survey.

## 3. METHODS

The research design was to operationalize long, medium, and short career durations, and then to evaluate the average citation impact of the publications of each matching researcher over the duration of their career, comparing them to the national average citation impact of the corresponding field, country, and year. Countries with a substantial publishing output were analyzed because the methods require many articles to give accurate results, given that most researchers fall outside the parameters chosen for career analysis. As a convenient cut-off, the 12 countries with over a million Scopus-indexed documents were analyzed (Table 1). Scopus journal articles 1996–2019 were used as the data source for this study because of the wide multidisciplinary and international coverage of Scopus (Mongeon & Paul-Hus, 2016). Its coverage expanded in 1996, so earlier data is not comparable. All data presented in this paper is therefore within the scope of this database. For example, a researcher who had one journal article published in Scopus, but many publications not indexed by Scopus, would be treated as having written one Scopus journal article and nothing else.

For pragmatic reasons (see below) the longest-term career that could be reliably analyzed was 16+ years. Short term was set at 6 years and medium term was chosen to be the middle point, 11 years. These are all relatively short time spans, and a minority of researchers have far longer careers. For reference, one study of Australia in 2015 found 58% of scholars (operationalized as those with at least one article in Scopus with an Australian university affiliation) to have academic ages 1–3, with 19% aged 4–9, 13% aged 10–19, and the remaining 10%

**Table 1.** Countries with over a million documents in Scopus in January 2020. The number of researcher years in the main data set is also reported. This is the number of long-term researchers times the number of years of publications examined (17), subtracting the number of years that each researcher did not publish. This is the effective sample size for the main analysis. The set of all domestic researchers (first and last Scopus publication from the country) is used for reference in some of the graphs.

| Rank | Country | Code | Documents | All domestic researchers: research years 2001–2016 | Long-term researchers: research years 2001–2016 |
|---|---|---|---|---|---|
| 1 | United States | US | 13,489,623 | 4,088,531 | 48,920 |
| 2 | China | CN | 5,196,006 | 4,807,129 | 48,728 |
| 3 | United Kingdom | UK | 3,671,193 | 880,364 | 11,281 |
| 4 | Germany | DE | 3,339,773 | 822,770 | 8,003 |
| 5 | Japan | JP | 3,208,893 | 1,281,662 | 13,524 |
| 6 | France | FR | 2,142,877 | 611,554 | 11,696 |
| 7 | Canada | CA | 1,807,804 | 541,501 | 6,495 |
| 8 | Italy | IT | 1,695,041 | 474,842 | 8,493 |
| 9 | India | IN | 1,641,393 | 1,139,602 | 15,993 |
| 10 | Australia | AU | 1,340,693 | 380,502 | 6,164 |
| 11 | Spain | ES | 1,245,266 | 649,219 | 12,119 |
| 12 | Russian Federation | RU | 1,120,501 | 468,190 | 8,792 |

being older (up to 71 academic years). Only standard journal articles (Scopus source type *Journal* and document type *Article*) were analyzed for the current study because other document types (e.g., reviews, books, and editorials) are less central to most areas of scholarship and have different citation trajectories or averages. While it would be possible, in theory, to add these document types for fields in which they are important, there is no public list of such fields, alternative document types might be relevant for some specialties but not others in a field, and mixing document types would complicate the interpretation of the results.

### 3.1. Researcher Identification

Researchers were identified through their Scopus ID. Scopus attempts to associate each publishing author with an ID such that a person has the same ID for all publications and this ID matches all their Scopus-indexed publications. This ID seems to have an accuracy of at least 98% (Aman, 2018; Kawashima & Tomizawa, 2015), which may be increasing with the availability of researcher-controlled systems, such as ORCID. Nevertheless, it is imperfect, and its accuracy seems likely to be lowest for China due to the large number of researchers, many large universities, and Latinization often merging different common Chinese names (e.g., Wei has many Chinese equivalents). Moreover, even with a high level of per-publication accuracy, 25% of Russian authors in one study had duplicate profiles (Selivanova, Kosyakov, & Guskov, 2019) and so profiles for researchers with many publications may often be incomplete.

### 3.2. Researcher Exclusion Criterion

Researchers with at least one journal article with 10 or more authors were excluded. It seems difficult to assess individual contributions to highly coauthored articles, so these were removed. The publishing authors were excluded as well as the article to avoid unfairly ignoring the best articles of a researcher. It is difficult to evaluate the collaborations of researchers in large coauthorship lists, partly because they may be from consortia with publishing agreements ensuring that people with no connection to a study become coauthors (Thelwall, 2020). For example, one CERN paper had 5,154 coauthors, and including this one paper may create thousands of extra authors, altering country profiles. Similarly, many long-term collaborations with almost identical lists of hundreds of authors for a series of papers (Thelwall, 2020) could substantially influence the results here with large numbers of additional authors for some countries. The 10-author threshold is relatively arbitrary, designed to exclude highly coauthoring researchers without excluding too many others. While the average numbers of coauthors varies substantially between countries and fields (Thelwall & Maflahi, 2020), the purpose of the threshold is to eliminate the possibility that the results are affected by highly collaborative authors who may have contributed little to their publications. The threshold 10 was used in the similar prior study of the United States (Thelwall & Fairclough, 2020), and accounts for less than 3% of articles in all broad fields (Thelwall & Maflahi, 2020). The results will therefore not be relevant for research fields that routinely collaborate more, such as in high-value large international health-related studies.

### 3.3. Researcher Career Length Measurement

The first publishing year of a researcher was operationalized as the year of the first journal article in Scopus after 1995, when a major Scopus coverage expansion took place. The last publishing year was taken to be the year of the last journal article in Scopus 1996–2019. A researcher with a first publication in 2001 or afterwards was assumed to have started publishing international journal articles in that year, although Scopus is not comprehensive. Years 1996–2000 were discarded, as a researcher might reasonably have started researching before 1996, leaving a gap of up to 5 years until their next publication. A researcher with a last publication before 2016 was assumed to have stopped publishing international journal articles in that year. The career length of a researcher was measured from the year of first Scopus-indexed journal article to the year of last (when known). Career gaps for any reason were ignored because there is no international source of information about these. For the United States, about a fifth of the long-term researchers judged to have a first publication in 2001 in fact had an earlier publication in Scopus from before 1996 (Thelwall & Fairclough, 2020), so the career lengths may be underestimated for a minority of researchers, even if ignoring non-Scopus articles. These rules were used to identify *long-term researchers* (16+-year career publishing in Scopus), *medium-term researchers* (11-year career publishing in Scopus) and *short-term researchers* (6-year career publishing in Scopus).

### 3.4. Researcher National Affiliation

Researchers were assigned to a country if their first and last journal articles listed first affiliations from the same country in Scopus; otherwise they were discarded. For researchers publishing multiple articles in the same year with different national affiliations, the first article published was used for their first affiliation and the last article published for their last affiliation. Order of publication within a year was judged by Scopus article ID. Because many researchers move internationally for a PhD and then remain in the target country for an academic career, the nationality of a researcher does not necessarily equate with their affiliation, especially at the start of their career. Affiliations after the first for each article were ignored, as multiply affiliated researchers seem to record their main affiliation first.

### 3.5. Citation Impact of a Set of Publications (MNLCS)

The citation impact of each journal article was obtained through the Mean Normalized Log Citation Score (MNLCS) calculation (Thelwall, 2017). This first log-transforms all citation counts by adding 1 and taking the natural log (i.e., $c \rightarrow ln(1 + c)$). This log transformation typically reduces the skewing for each field and year to under 3, allowing the safe use of the arithmetic mean for the log-transformed data. The log-transformed value for each article was then divided by the average of the log-normalized citation counts of all articles in each field and year to get a Normalized Log Citation Score (NLCS). Articles in multiple fields were instead divided by the average of the field averages. This procedure was used for domestic researchers publishing a single article and was calculated separately for each year and country.

### 3.6. Citation Impact of a Set of Researchers (MNLCS)

For a set of researchers, the MNLCS was calculated as above except that if a researcher had published multiple articles in the same year, then the average NLCS of those articles was used instead of averaging them separately. Averaging researcher average NLCS for a year instead of all NLCS for all qualifying papers prevents the results from being dominated by prolific researchers, because their publications are averaged rather than counted separately. The MNLCS for any set of researchers was then calculated as the arithmetic mean of the modified NLCS values. This is equivalent to calculating the MNLCS for each researcher and year separately, then averaging the researcher MNLCS values for each year (ignoring researchers who did not publish in that year). This procedure was used for domestic short-term, medium-term and longer-term researchers, as defined above, and was calculated separately for each year and country.

The MNLCS for any group of researchers is 1 if their articles have, on average (by researcher), the same number of (log transformed) citations as all other articles published in the same fields and year. Scores above 1 indicate impact above the world average and scores below 1 indicate impact below the world average. These figures can be fairly compared between years and between data sets with different balances of fields, by design. These calculations used all Scopus-indexed journal articles (22.4 million articles 2001–2016), categorized moderately accurately into 330 Scopus narrow fields (Klavans & Boyack, 2017).

The citation counts are from January 2020 for the articles published 2014–2019 and from December 2018 for the articles published 2001–2013, giving at least 3 full years of citations for each article (December 2016 having the shortest citation window). Because of the field normalization process used, it was not necessary for the articles to have the same citation window or to use data collected at the same time. Confidence intervals (95%) were calculated using the normal distribution formula ($\pm 1.96\sigma/\sqrt{n-1}$) or *t*-distribution formula, as relevant, as the log transformation greatly reduces skewing (Thelwall, 2016). Some NLCS data points are averages of multiple articles published by the same researcher in the same year, reducing variation.

### 3.7. Citation Impact Relative to National Citation Impact (MNLCS Difference)

The average citation impact of nations (e.g., MNLCS) changes over time, so MNLCS values for researchers must be compared to the national MNLCS at the year of publication to assess them. This can be achieved graphically by plotting both on the same graph, but this approach is awkward when comparing many graphs. Thus, each researcher's MNLCS value for some graphs was converted into an *MNLCS difference* value (defined here for the first time) by subtracting the national MNLCS from the MNLCS of the researchers. This gives an indicator of the citation impact of the researchers relative to the national average.

### 3.8. Researcher Age and MNLCS Difference

A researcher's (Scopus publishing) age was defined to be the number of years of publishing in Scopus, starting with their first journal article (after 1995). Thus, a researcher first publishing a Scopus-indexed journal article in 2002 would be 2 in 2003. MNLCS difference scores for researchers with the same age, country, and career length were averaged together to give a single number to represent the aggregate relative citation impact for researchers of a given age with a given career length and country affiliation. This was calculated only for the 11-year and 6-year researchers because there is only one cohort for the long-term researchers (so nothing to average). Although each cohort could be analyzed separately, the low numbers per cohort gives wide confidence intervals and messy graphs, so the aggregation of cohorts in this way adds precision to the career trends found. In contrast, while the single-year researchers could be averaged across all years, it is more informative to report values for individual years, and the sample sizes are sufficient to not need aggregating.

## 4. RESULTS

The graphs (Figures 1–4) illustrate the average citation impact of the four groups of researchers: long-term, medium-term, short-term, and single-article. The sample sizes and exact values of all data points in the graph are available in the online supplement (https://doi.org/10.6084/m9.figshare.13537178).

Long-term researchers (at least 16 years publishing journal articles in Scopus, starting in 2001) do not experience a clear increase in the average impact of their research over time (Figure 1). The first and last dates (2001, 2016) should be interpreted cautiously, as they are based on larger


**Figure 1.** Average citation impact of long-term researchers with a first Scopus journal article in 2001 and at least one Scopus article in 2016–19, both with the same country affiliation. Researchers ever collaborating with more than nine coauthors are excluded. The black reference line without error bars is for all researchers with a first and last article from the same country and no collaborations involving more than nine researchers (i.e., the same parameters as the orange line except the specified start and end years).


**Figure 2.** Average citation impact relative to the national average for researchers with an 11-year publishing career: first Scopus journal article in 2001–06 and last Scopus article in 2011–16, both with the same country affiliation. Researchers ever collaborating with more than nine coauthors are excluded.

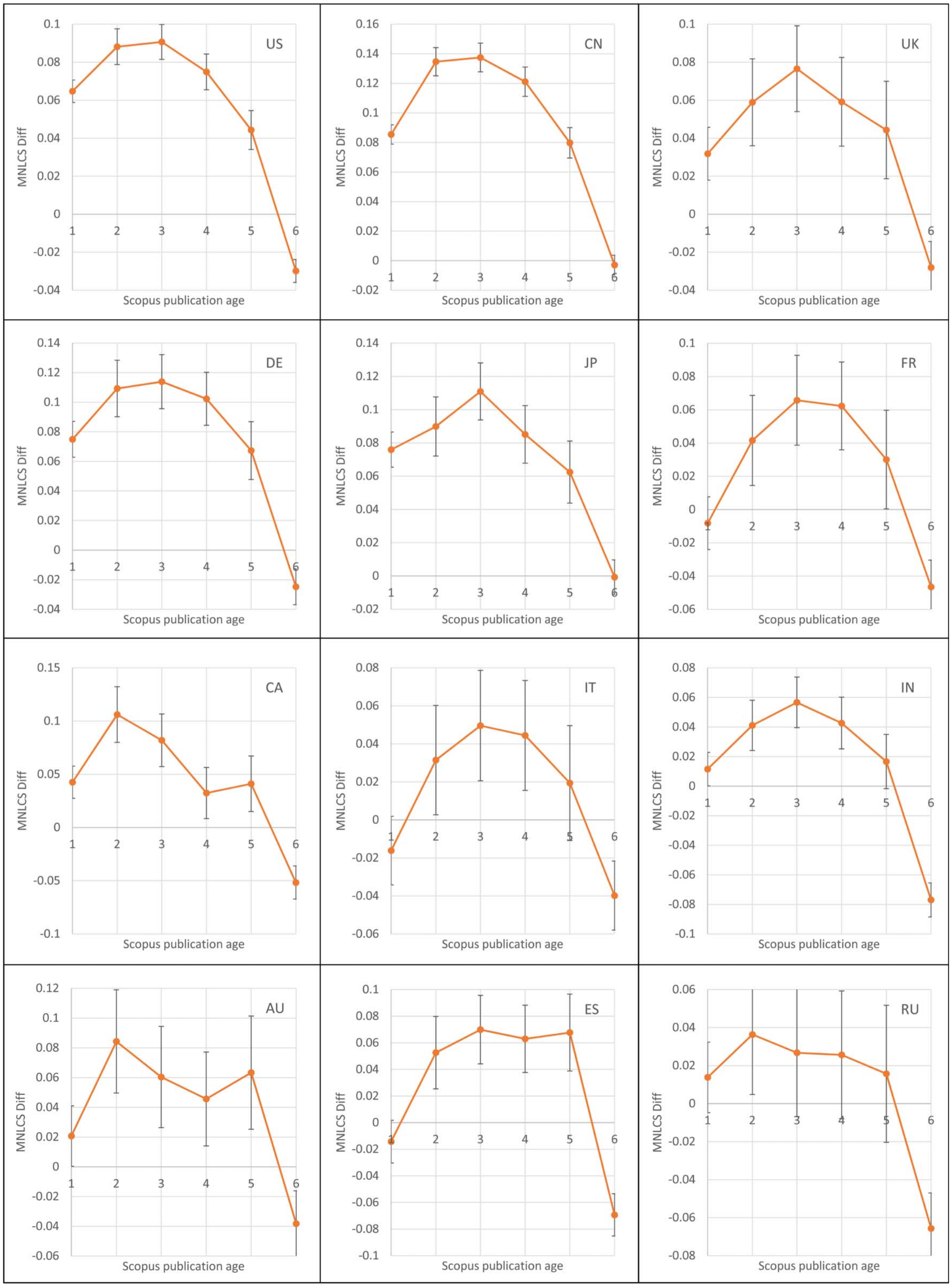


**Figure 3.** Average citation impact relative to the national average for researchers with a 6-year publishing career: first Scopus journal article in 2001–11 and last Scopus article in 2006–16, both with the same country affiliation. Researchers ever collaborating with more than nine co-authors are excluded.

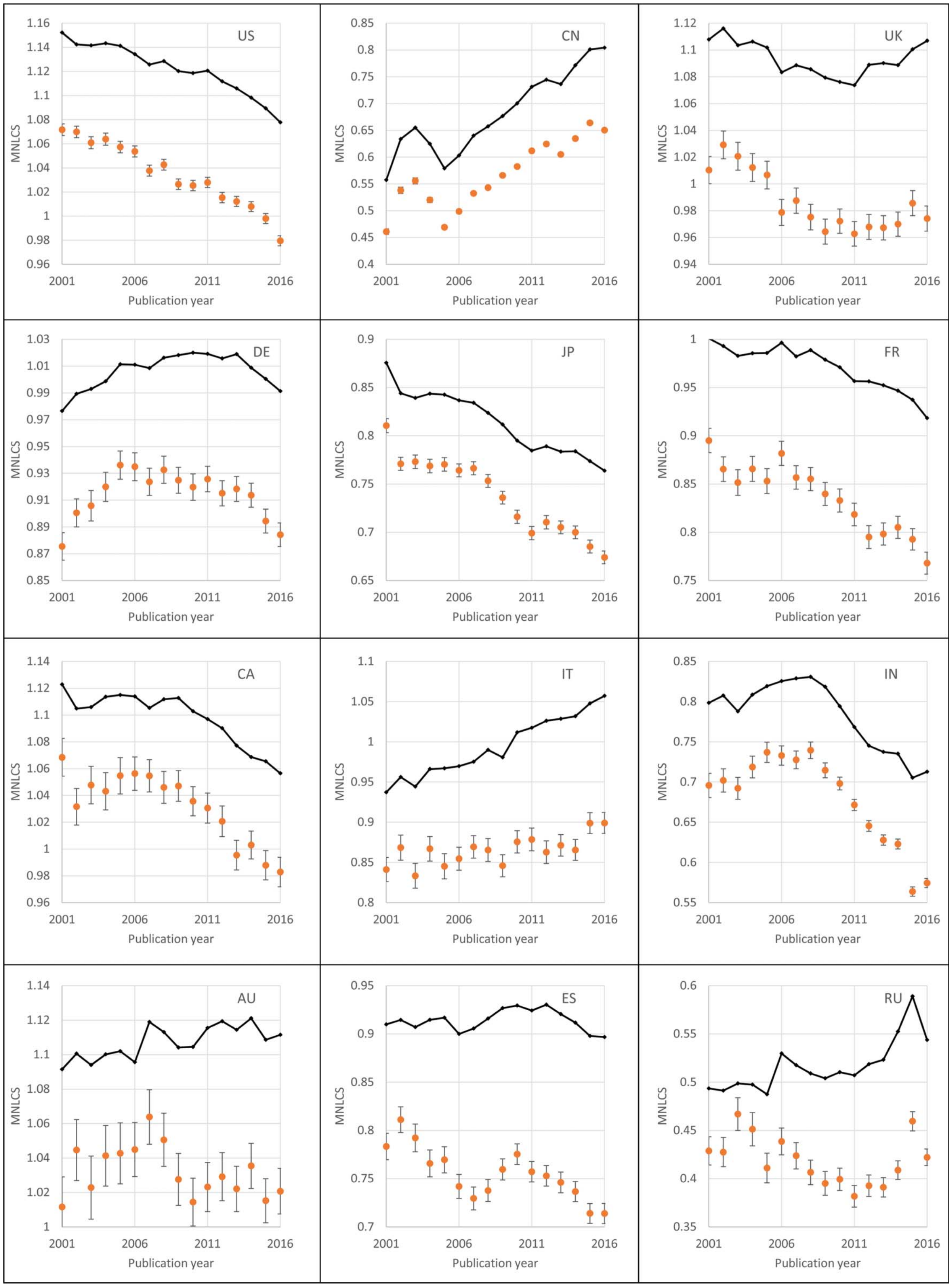


**Figure 4.** Average citation impact for researchers with a single Scopus journal article in 2001–16. Researchers ever collaborating with more than nine coauthors are excluded. The black reference line without error bars is for all researchers with a first and last article from the same country and no collaborations involving more than nine researchers.

samples. This is because all researchers qualifying as long-term have at least one journal article in 2001 and all have at least one publication in 2016–2019, so the sample from 2001 is comprehensive (i.e., including all qualifying researchers, because they must publish in 2001 to qualify) and the 2016 sample is likely to be more comprehensive than average (because every researcher must have a publication in 2016–2019 but not necessarily any publications in 2002–2015). In contrast, data from all other dates overrepresents researchers who publish more frequently and are therefore more likely to publish in any given year. As more productive researchers tend to author higher impact articles in some fields (Kolesnikov et al., 2018), the initial increase and final decrease in MNLCS may be due to changes in the nature of the sample rather than changes over time in the average citation impact of long-term researchers. Nevertheless, three patterns are clear and apply to, or are consistent with, all countries.

- The average citation impact of long-term researchers is above the national average for all, or almost all, of the first 16 years of their career.
- Trends in the average citation impact of long-term researchers broadly follow the national average (i.e., when the national average citation impact increases, the long-term researcher citation impact average also tends to increase).
- The average citation impact of long-term researchers tends to get closer to the national average over time, meaning a decrease relative to the national average. This is clearest for the United States, China, the United Kingdom, Germany, Japan, Canada, and Italy. Spain does not show a trend, but the confidence intervals are wide enough to make such a trend plausible. France and the Russian Federation show the opposite trend, but the confidence intervals are wide.

Medium-term researchers (11 years publishing journal articles in Scopus) also do not tend to show increasing average citation impact (Figure 2). Again, first and last publishing years (ages 1 and 11) represent, on average, a less productive researcher sample and should be ignored for trends.

- The average citation impact of medium-term researchers is usually above average for the host country at the start of their Scopus publishing careers (exceptions: France, Italy, India, Spain, Russia).
- The average citation impact of medium-term researchers decreases relative to the host country average citation impact at the end of their Scopus publishing careers (possible exception: Australia).
- The citation impact in the final year of publishing is substantially below the citation impact in the first publishing year, relative to the national average.

Short-term researchers (6 years publishing journal articles in Scopus) tend to follow an inverse U-shaped distribution (Figure 3). Again, first and last publishing years (ages 1 and 6) represent, on average, a lower publishing sample and should be ignored for trends.

- The average citation impact of short-term researchers is above average for the host country for most of their Scopus publishing careers.
- The average citation impact of short-term researchers usually decreases relative to the host country average citation impact at the end of their Scopus publishing careers (exceptions: Canada, Australia, Spain).
- The citation impact in the final year of publishing is substantially below the citation impact in the first publishing year, relative to the national average.

Single-article researchers (one journal article in Scopus) do not have a career trend, but their average citation impact at different years can be examined (Figure 4).

- Single-article researchers produce articles with citation impact substantially below the national average in all countries.
- The gap between the average citation impact of single-article researchers and the national average is usually approximately constant over time (exceptions where the gap widens: UK, Italy, Australia, Spain, Russia).

### 4.1. Productivity Normalized Long-Term Researcher Career Impact

Because researchers coauthoring more articles tend to have higher citation impact, the trends in Figures 1–3 could be due in part to more productive researchers being overrepresented in years between the start and end year, increasing the average citation impact of articles published in these years. To adjust for this possibility, long-term researchers were investigated in a second way: by calculating within career MNLCS changes for all researchers and then averaging by career (Figure 5). For reference, the same calculation was performed for all researchers from the country, irrespective of their first and last publication year. The results offer a different perspective on the data and differ substantially between countries.

- **United States**: average (field and year normalized) citation impact decreases sharply after the first publication year and then steadily throughout the career (after researcher career normalization). The initial sharp drop is specific to career starting whereas the remaining decreases mirror the falling average citation impact of U.S. research. Thus, the initial increase in citation impact for U.S. long-term researchers overall (Figure 1) is due to a greater number of higher impact, more prolific researchers publishing at least one article in these years. **Canada** and **Japan** follow similar patterns but with slight variations.
- **China**: average citation impact increases sharply after the first publication year and then steadily throughout the career. This broadly reflects the trend for China overall, except that the increase in citation impact for long-term researchers falls behind that for China overall in the long term. Presumably, younger researchers in China are increasingly producing higher impact research earlier in their career, increasing the national MNLCS. **Italy** and **Russia** follow similar trends.
- **United Kingdom**: average citation impact seems to decrease throughout careers, although the wide confidence intervals and occasional sharp fluctuations undermine any conclusions drawn. A similar pattern is evident for **Germany**, except that in Germany the trend is more clearly that the average citation impact of long-term researchers tends to decrease relative to the national trend.
- **France**: average citation impact seems to be steady throughout long-term researcher careers, despite the French average falling. This is close to opposite to the situation for China.
- **India**: average citation impact seems to decrease throughout long-term researcher careers, except for a stable period 2003–2011. The average citation impact of Indian long-term researchers does not fall as quickly as the national average, however, mirroring to some extent the situation of France.
- **Australia:** average citation impact seems to fluctuate throughout long-term researcher careers, although it is difficult to be sure of any trends due to the wide confidence intervals. It is possible that it is approximately constant, however. The same is true for **Spain**.


**Figure 5.** Average citation impact changes over careers (MNLCS for each year subtract the MNLCS average 2001–16 for the researcher) for researchers with a first Scopus journal article in 2001 and at least one Scopus article in 2016–19, both with the same country affiliation. Researchers ever collaborating with more than nine coauthors are excluded. The blue line without error bars is the same calculation for all researchers with a first and last article from the same country and no collaborations involving more than nine researchers.

## 5. DISCUSSION

The results are limited by various factors that influence their interpretation. The field normalization is conducted relative to the first and last country affiliation, whereas a researcher may work overseas or (more commonly) make international visits (Børing, Flanagan et al., 2015; Cañibano, Otamendi, & Solís, 2011) and have their citation impact influenced by this (Yamashita & Yoshinaga, 2014). The lines for long-term researchers ignore productivity, so that they overrepresent long-term researchers who publish more articles. The calculations do not take into consideration factors such as team size and international collaboration, which can be related to citation impact (Guerrero Bote, Olmeda-Gómez, & de Moya-Anegón, 2013; Larivière et al., 2015; Sud & Thelwall, 2016). They also give each author full credit for journal articles, irrespective of the number of coauthors. The method also ignores researchers who permanently move to or from the countries examined. Effective publishing career lengths may differ from those found in Scopus due to career gaps or publishing other types of output, including non-English papers (Kulczycki, Guns et al., 2020) that are less likely to be in Scopus. The results aggregate disciplines, so one country's researchers may have a different trend in some fields. The MNLCS difference results aggregate careers starting at different times, although university structures have evolved (Whitley, Gläser, & Engwall, 2010). Finally, the restriction to researchers who never coauthor Scopus-indexed articles with 9+ people and the domestic researcher restriction mean that the set analyzed is artificial, created with conditions related to indicator validity rather than management decision-making.

If researchers ever collaborating with 9+ authors are not excluded, so that all authors with their first and last Scopus journal articles from the same country were analyzed, then there are similar trends in the results (Appendix). The main difference is that the average impact of all researchers is higher, due to the inclusions of some higher impact collaborative papers. This similarity suggests that the results of this paper might apply to all domestic researchers, although, as argued in Section 3, the inclusion of highly collaborative papers reduces the validity of the results.

### 5.1. Longer Term Researchers Generate Higher Citation Impact

For all countries, the average citation impact of longer-term researchers who never collaborate with 9+ coauthors tends to be above the national average, except perhaps after 10–16 years or at the end of their career. This higher average citation impact is apparent from the start of a career, on average, and is not therefore due to greater experience. This finding is consistent with longer term researchers having an underlying above average likelihood of creating higher citation impact research from the start of their careers, which is presumably during or shortly after their PhDs. Many different factors might explain this phenomenon.

- Junior researchers with an above average facility to generate impactful research are more likely to decide upon, or successfully maintain, a long-term academic (publishing) career.
- Junior researchers wishing to have an academic publishing career are more likely to pick a basic research specialty, generating more citations than more applied research.
- Longer term researchers are more likely to operate in higher impact subfield specialties (e.g., scientometrics within library and information science).
- Longer term researchers build networks or a reputation that attracts attention to their full body of work, including their early papers.
- Longer term researchers generate more citations through self-citations from later work.

### 5.2. Singleton Articles Have Substantially Lower Citation Impact Than the National Average

Although this follows from the above point, there is nevertheless a substantial gap between national average research impact and the impact of singleton articles with fewer than 10 authors. The following is a possible explanation, in addition to the above.

- Singleton articles are more likely than other articles to be written by practitioners and aimed at other practitioners, therefore containing less citable content.

### 5.3. Citation Impact Does Not Increase During Careers

The long-term trends for the sets analyzed here broadly agree with a prior finding that average citation impact peaks 4–8 years after the PhD award in three U.S. social sciences (Sugimoto et al., 2016). Nevertheless, it is surprising that citation impact does not tend to increase during careers, given that researchers might learn from their work, build up greater background knowledge and pick up new knowledge from others during their careers. This does not translate into an increase in average citation impact, perhaps for one of the following reasons.

- Researchers' knowledge becomes out of date in some fields, with more junior researchers learning more current methods, compensating for deficiencies in other areas of knowledge. Quebec professors have been found to start relying on older literature from age 40 (Gingras, Larivière et al., 2008), which is consistent with this hypothesis, but a larger study of five fields disagreed (Milojević, 2012).
- Some longer term researchers might continue with problems that were topical when they trained, and their work is less citable because there are fewer new articles to cite it.
- Longer term researchers who improve become internationally mobile (not necessarily to a high-resource economy) and self-select themselves out of the sample by permanently changing their national affiliation.
- As a special case of the above, for countries other than the United States, successful longer term researchers move to the United States (or other high-resource economies), so the non-U.S. samples represent, on average, less successful researchers who have built domestic careers.
- Longer term researchers might coauthor an increasing fraction of their papers with doctoral students, achieving lower citation impacts with them. In some fields (excluding science and engineering) in Quebec, one study suggests such papers have lower citation impact (Larivière, 2012).
- Some longer term domestic researchers may work partly abroad, with higher impact publications associated with this move.
- Factors known to associate with higher impact research, such as international collaboration or team size might affect careers differently over time.
- The career citation impact trajectories of scientists publishing at least one article with more than 10 authors might differ from the set analyzed here, but a parallel analysis dropping the collaboration condition gives similar results (see Appendix). An alternative plausible interpretation of the results (suggested by a reviewer) is that domestic researchers who do not secure large collaboration networks tend to have decreasing citation impact.
- Changes in national research infrastructure may affect researchers differently by career stage. For example, substantial increases in research funding and infrastructure over many years (e.g., in China) may help senior researchers (who may win most of the funding) or young researchers (who can more easily learn expensive new technologies), so impact comparisons for long careers may not be fair on some groups.

### 5.4. Last Articles Usually Have Lower Citation Impact Than First Articles in a Researcher's Career

The above factors may also help to explain the lower citation impact of medium and short-term domestic researchers' final articles for all countries. This pattern cannot be checked for long-term researchers because many of their careers may be continuing. Also, recall that the value for the first and last articles is likely to be based on a larger sample than the value for intermediate years. This is likely because the endpoints presumably include a larger share of less prolific authors, for example including authors that only published in the first and last years. In addition, final articles might be relative failures that trigger the abandonment of publishing, or papers that are given less effort as a career is coming to an end. One study of physics has suggested that bad luck producing low impact work can prematurely terminate an academic career (Petersen, Riccaboni et al., 2012), which is an alternative possibility.

## 6. CONCLUSIONS

Given the importance of organizing academia for efficient knowledge production, the findings may have policy implications. Recall first, however, that the study only applies to domestic researchers (first and last Scopus-indexed journal article from the same country) who avoid large collaborations (papers with 10+ authors, but see Appendix) and different patterns may occur for other types of researcher. The impact of interest here is relative to the national average rather than absolute or relative to the world average, under the assumption that factors outside the control of a researcher, such as economic development and research investment, can have a substantial influence on the national research capacity. Moreover, there are many valid types of impact other than citation impact, so low citation impact should not be equated with failure or below-par performance. Instead, low impact may signal more applied research or, for senior researchers, collaborations with inexperienced junior researchers where the main purpose of the collaboration may be to train the researcher rather than to produce high-impact work. Thus, the discussion below should be interpreted as points to consider rather than evidence-based advice.

The main finding is that, for the 12 countries analyzed, the expected career-long increase in research capability (e.g., Bozeman et al., 2001) does not fit the pattern for citation impact of the careers of domestic academics. Instead, on average, domestic scholars achieve their longer term average citation impact from the first or second Scopus-indexed publications and do not then tend to increase their average citation impact. Because of the sampling issue discussed above, it is not possible to make the definite claim that the second publication tends to have more citation impact than the first, despite the evidence of the graphs. Thus, domestic academics should not expect to naturally increase the average citation impact of their work with age, and managers should not expect this or plan with this expectation.

Despite the above finding, long-term domestic researchers who never write with 9+ co-authors have more impact than the national average in all countries examined. This does not seem to be due to the extra experience gained with age, as citation impact does not improve with age but seems to be a characteristic of the researcher that is present from, at the latest, their second Scopus-indexed publications. Thus, managers should expect higher citation impact from longer-term domestic researchers, and this should be evident almost from the start of their career, on average. This characteristic seems likely to be either the researcher's focus on a long-term academic career, or researchers being selected for academic posts based on early citation impact success or employers correctly judging that applicants are likely to generate long-term citation impact success (or something associated with it, such as higher research quality). Thus, the trend suggests an effectively working science system, at least in terms of citation impact and careers. In this context, the below average citation impact for researchers only writing one paper is not a problem: Given that there are more PhDs than available jobs, it is preferable for the system as a whole if researchers who attract less academic interest for their work do not become long-term researchers. As stated above, this is an oversimplification because the analysis only includes citation impact and researchers are often also expected to generate wider societal impacts.

The main cause for concern in the results is a tendency in some, but not all, countries for domestic researcher impact to decline towards the end of their careers (or after around 10–16 years for ongoing researchers), at least for academics who never write with 9+ coauthors. If future research shows this to be caused by negative factors, such as career stagnation, rather than positive factors, such as mentoring junior researchers, then action is needed. In this case, universities might consider taking remedial action to support their senior researchers to learn new skills to move to a more current field. Alternatively, managers may encourage senior researchers into mentoring or other support roles, but this must take into consideration that longer-term researchers in many countries still seem to generate above average citation impact, even if it is declining. Similarly, research funders might wish to target their funding more at junior researchers or to develop schemes to help experienced researchers to regenerate their careers.

## AUTHOR CONTRIBUTIONS

Nabeil Maflahi: Writing—original draft, Writing—review & editing. Mike Thelwall: Methodology, Writing—original draft, Writing—review & editing.

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The authors have no competing interests.

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## DATA AVAILABILITY

The processed data used to produce the tables and graphs are available in the supplementary material (https://doi.org/10.6084/m9.figshare.13537178). A subscription to Scopus is required to replicate the research (with updated citation counts), with the methods described above.



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## APPENDIX: PARALLEL ANALYSIS REMOVING THE COLLABORATION RESTRICTION

This section repeats the graphs in the paper but without the restriction that the researchers should never collaborate with 9+ coauthors (Figures A1–A5 duplicate Figures 1–5 in the same order). Coauthorship size is determined by Scopus, which may not list all authors for large consortia for technical reasons, because the journal does not list them all (some journals limit the number of authors they will list within an article) or because the consortium is listed as the author.


**Figure A1.** Average citation impact of long-term researchers with a first Scopus journal article in 2001 and at least one Scopus article 2016–19, both with the same country affiliation. No collaboration criteria were applied. The black reference line without error bars is for all researchers with a first and last article from the same country (i.e., the same parameters as the orange line except the specified start and end years).

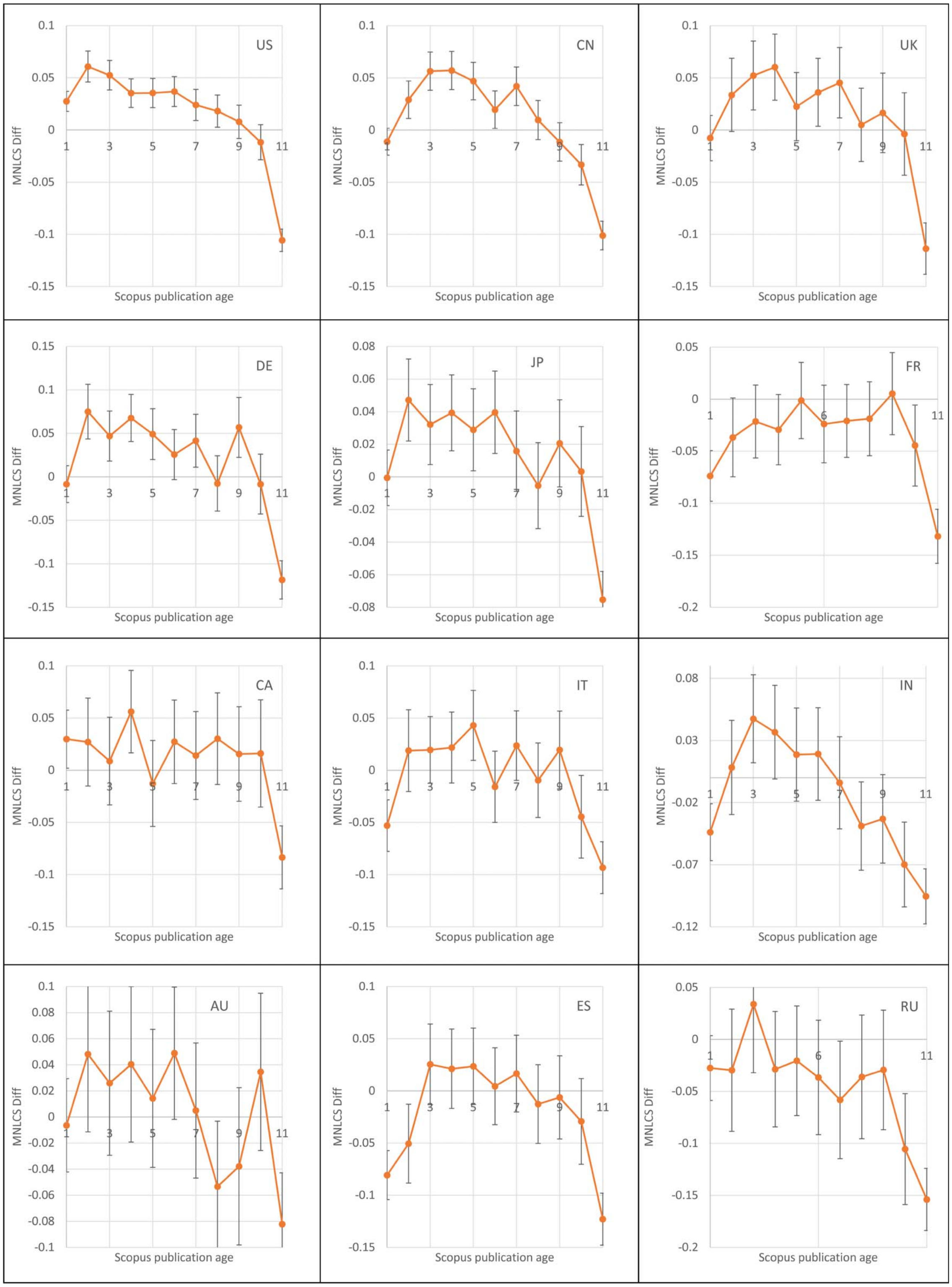


**Figure A2.** Average citation impact relative to the national average for researchers with an 11-year publishing career: first Scopus journal article in 2001–06 and last Scopus article 2011–16, both with the same country affiliation. No collaboration criteria were applied.

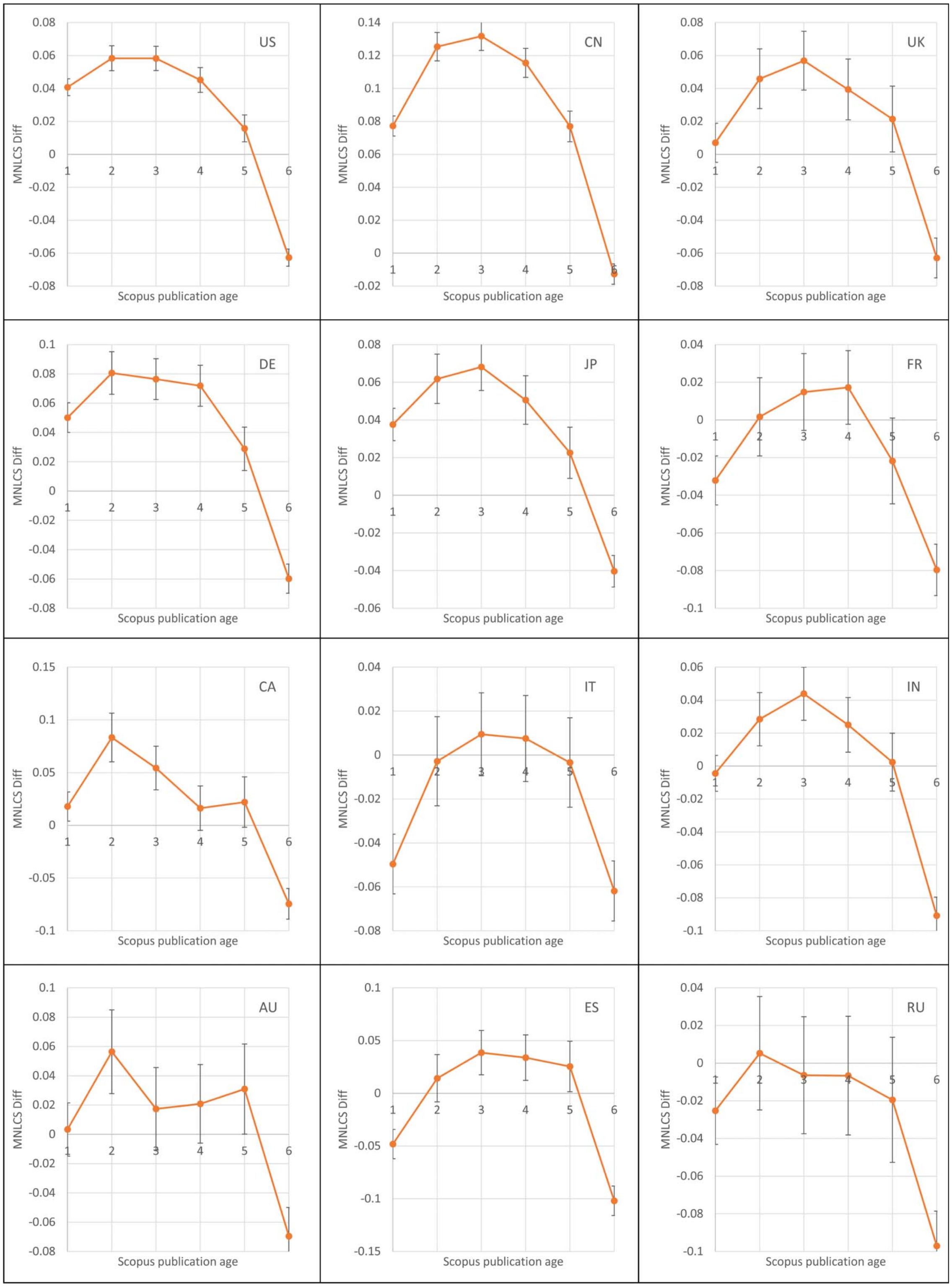


**Figure A3.** Average citation impact relative to the national average for researchers with a 6-year publishing career: first Scopus journal article in 2001–11 and last Scopus article 2006–16, both with the same country affiliation. No collaboration criteria were applied.


**Figure A4.** Average citation impact for researchers with a single Scopus journal article in 2001–16. The black reference line without error bars is for all researchers with a first and last article from the same country. No collaboration criteria were applied.


**Figure A5.** Average citation impact changes over careers (MNLCS for each year subtract the MNLCS average 2001–16 for the researcher) for researchers with a first Scopus journal article in 2001 and at least one Scopus article 2016–19, both with the same country affiliation. The blue line without error bars is the same calculation for all researchers with a first and last article from the same country. No collaboration criteria were applied.