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Higher education expansion and the rise of China in economics research

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ABSTRACT

China has seen a massive higher education expansion, which the literature has dated to the 1999–2008 period with quantitative and qualitative outcomes. However, the consequences for the publication success of Chinese authors worldwide are not well studied. We review the respective Chinese higher education policies and document the dramatic rise in publication success, with a focus on the field of Economics. A substantial set of regressions and robustness checks confirm the understanding that the higher education expansion has indeed let to a substantial worldwide rise in scientific publications in refereed economics journals fueled by the general incentives of the reform, through research collaborations and other quality improving factors.

1. Introduction

Following the economic reforms and education massification policy introduced in the late 1970s, the past four decades have witnessed a significant increase in the number of publications from China. For a number of years the focus was mostly on research in science and engineering (Constant, Tien, Zimmermann, & Meng, 2013; Marginson, 2021), but there has been sustained effort to raise both the quality and quantity of research in social sciences as well (Xu, 2021). For instance, data extracted from the *World of Science (WoS)* database of *Clarivariate*[1] shows that the number of publications in economics with a Chinese author increased from 37 in 1990 to 2192 in 2020. The level of change in overall research output has been largely driven by a number of education reforms introduced in the 1990s and 2000s, including a shift in policy of *learning* about innovative research from to the one of *contributing* to the accumulation of knowledge (Xu, 2021). This led to spending "more on research and development than any other major developed economy in the West" (Constant et al., 2013, p. 110).

The proper implementation of China's higher education policy was initiated in the 1990s, as by then Chinese policymakers had

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[1] https://clarivate.com/webofsciencegroup/solutions/web-of-science/

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realised the importance of higher education as one of the most important elements of growth and development. Education policy had two main elements: to create world-class universities in China and to give opportunities to a significantly growing population to get higher education in order to prepare them for the knowledge-based economic environment (see Constant et al., 2013; Mok & Marginson, 2021). The first objective had a direct impact on the level of research conducted in China, and the second one is likely to have indirectly had a long-term impact as the expansion policy included a significant number of students going abroad for higher education, including for postgraduate and PhD level degrees. Capacity building by internationalisation has been key for this strategy to establish China as a magnet for international talents through foreign students and international researchers (Constant et al., 2013). The success of educational expansion has been quite remarkable, since the participation rate has changed from 9.8% in 1998 to 54% in 2020 (Chan & Zhang, 2021).

As the underlying objective of the higher education reforms was to have research that helps with policies to achieve high economic growth, one main consequence of education reforms and expansion policy was likely to be an increased number of academic articles written by Chinese authors. This assertion has only partially been explored as a number of authors have studied the impact of educational expansion on various policy-relevant aspects. This includes impact on the labour market (Li, Whalley, & Xing, 2014; Knight, Deng, & Li, 2017; Li, Ma, Meng, Qiao, & Shi, 2017; Xing, 2018; Yang, 2018; Huang & Zhu, 2020; Dai, Cai, & Zhu, 2021), inequality (Meng, Shen, & Xue, 2013), rural children's schooling (Lu & Zhang, 2019), intergenerational education mobility (Guo, Song, & Chen, 2019) and social mobility (Chan & Zhang, 2021), among others. However, the effect of education policy on scientific publications has not attracted the same level of attention in the literature. We aim to fill this gap.

We use data from *Microsoft Open Academic Graph (OAG)* and *WoS* to understand the extent to which education policies have had an impact on research production. Using *OAG*, we first present the descriptive analysis of the number of publications in economics and a number of different fields in Science. This helps provide an overall understanding of the expansion in peer-reviewed academic publications originating from Chinese authors residing in China as well as in other countries. We then use data from *WoS* to conduct the empirical analysis to determine the effect of China's education reforms on publications specifically in economics by Chinese researchers. Our results show that the higher education expansion, following its announcement in 1998, has increased the (annualized) probability of publication by a Chinese author by about 45% during the decade 1999–2008, especially in the later period of the reform (2004–2008). The result is robust to the placebo test timing the policy change to the years immediately prior (1994–1998) or subsequent (2009–2013) to the actual period of higher education expansion, and to omitted variable bias, which we test using the methodology developed by Oster (2019). When we replace the key explanatory variable with a proxy capturing the effect of the expansion on the rapid growth of Chinese students enrolling in universities in China and other regions of the world, we find significant increases in productivity among Chinese authors based in China as well as North America, the United Kingdom, and Rest of the World (mostly Japan, Singapore and South Korea). This is primarily due to higher international collaborations. Productivity increases also arise when the dependent variable measures if an article includes the words 'China' or 'Chinese' in its abstract or keywords, suggesting that the higher education expansion affected not only the productivity of Chinese authors but also the stock of China-related content.

The empirical analysis includes various measures of academic productivity, including publication quality. There are mainly two approaches used in the literature to assess the quality of publications (see Ketzler & Zimmermann, 2013). One uses citation index of an article to quantify the quality of an individual paper. The higher number of citations indicates that the article contributes more to the accumulation of knowledge as it has higher relevance and more recognition by the wider scientific community. The other approach is to use the actual rank of a journal relative to others in the same field. We include both indicators based on the data portal SCImago Journal Ranking (it simply ranks journals within a field), which is a commonly used source for evaluating journal quality (Mañana-Rodríguez, 2014). SCImago ranks journals in terms of We restrict the ranking analysis to the field of ' Economics and Econometrics' (more than 650 journals) in the estimation and find that the increase in publications with a Chinese corresponding author is negatively related to the ranking of the outlet in which they appear but positively related to the number of citations. These results suggest that Chinese-authored articles tend to appear in journals that have lower ranking but they are more cited than similar articles authored by non-Chinese researchers. We note, however, that the citation approach, while useful in terms of determining the quality of each article, is not useful in making comparisons since older articles are obviously more likely to have more citations than a relatively more recent article.

There is limited existing research on the quality and quantity of research papers from and/or on a particular country, and most of the papers on this topic use data from Europe and/or the US. For instance, Ketzler and Zimmermann (2009) measure the extent of research output of a number of economics institutes in Germany. Their main objective is to assess the impact of a request made by the German Scientific Counsel to economic institutes in Germany, in 1998, for strong academic foundation for economic policy advice. Using data from the Social Science Citation Index (SSCI), they find a significant increase in publications between 2000 and 2006 from all relevant institutes in Germany. In a related paper, Ketzler and Zimmermann (2013) use citation analysis to study the research output in economics of German research institutes. Unlike the former paper in which they used impact factor of the journal to determine the quality of the paper, in the (2013) article they used citation index for each paper from each institute. They then used the analysis to rank different institutes in Germany in terms of quality of research output. Cardoso, Guimarães, and Zimmermann (2010), on the other hand, conducted analysis focusing on cross-country comparison of research quality. They used data from EconLit and SSCI and found that over the period of their study (1991 to 2006), the US maintained the dominant position in economics research, though a

number of European countries made a remarkable progress in both the quality and quantity of publications, mainly because of collaborative research.

The closest paper to ours, in terms of country focus regarding journal publications, is Xie and Freeman (2018). They use data from Scopus to assess the quantity and quality of papers published by Chinese authors. Using descriptive analysis, they find that China's contribution in terms of world share of publications in science and technology increased from 4% in 2000 to 18.6% in 2016. We differ from Xie and Freeman (2018) in a number of ways. First, our primary focus is publications in economics, not science and technology. Second, unlike them we conduct quantitative analysis to assess the impact of education reforms on publications on China and by Chinese authors. Third, we cover a longer time period – from 1990, when China was in its early its transition to a more open economy, to 2021.

The rest of the paper is structured as follows. In the next section we outline the history of education reform, whose main objective was the massification of education in China.[2] Section 3 discusses the available data set and provides a descriptive analysis of the research issue. Section 4 outlines the empirical model while Section 5 presents the results of the econometric analysis and the robustness tests. Concluding remarks appear in the last section.

2. Massification and Internationalisation of Education in China

Economic reforms and education expansion in China started in the 1970s when Deng Xiaoping begun to implement Zhou Enlai's "Four Modernizations" policy of science, industry, agriculture and national defence (Constant et al., 2013; Marginson, 2021). Even though the initial emphasis of the education policy was on the promotion of science and technology, the importance of humanities and social sciences became clear as early as the late 1970s. Deng, in a speech in 1979, expressed the concern that China not only lags behind in sciences, but also in social sciences research compared to the world, stating that "Only by admitting we lag behind we can no longer lag behind" (Xu, 2021).[3] The initial government policy was about learning from the world, with the emphasis on paying attention and learning from the cutting-edge research from global academia. Learning from the West included also attracting the West to China (Constant et al., 2013). This policy was later changed to one of contributing to the world research and has been in place since the early 2000s.

Even though the education reforms started in the 1970s, the depth and breadth of those reforms only intensified from the mid-1990s. The consequence of one of the modernizations, science, was the massification of education (Mok & Marginson, 2021). Education reforms in China have been across a wide spectrum of the sector with a number of policies introduced over the last three decades. It started with the introduction of Project 211 in 1995, which was a special funding programme to create high quality research-intensive universities. At the time it was the only national key construction programme in the education sector that was included in the Ninth Five Year (1996–2000) Plan (Ngog & Guo, 2008). Project 211 was followed by Project 985, introduced in May 1998, to increase the funds to create world-class universities based on the top universities in the US. The remit of Project 985 was much narrower than Project 211 and therefore initially only Peking and Tsinghua Universities were included in Project 985, but soon a number of other elite universities joined the Project, not least due to the scale of government funding provided to the 985 universities.[4]

The objectives of the education reforms, according to Jiang Zemin, President of China from 1989 to 2002, who introduced Project 985, were to train new talent, produce high quality original research and make significant outstanding contributions to the society, primarily helping the national development (Ngog & Guo, 2008). An obvious consequence of this was a significant increase in papers published on China, not only in science and technology (which was the main impetus at the start of the education reform in 1970s), but also in humanities and social sciences, including economics. This was partly a result of the outward looking government policy where the emphasis changed from one of a "humble learner to a proactive and responsible contributor" (Xu, 2021).

The contributor aspect involved not only translating research papers from Chinese to English but also to have academic journals in English. An early example is the research journal *Social Sciences in China*, which was the first social science journal in English published in China. The focus is on issues related to China and its articles are mainly translations from the *Zhongguo Shehui Kexue*, a prominent Chinese academic outlet. A more recent similar venture is the English language *China Economic Quarterly International* started in 2021, related to the Chinese-language *China Economic Quarterly*. It covers all fields of economics with a special interest in issues related to the Chinese economy. *Social Sciences in China* is now published by Taylor & Francis and *China Economic Quarterly International* by Elsevier.

It became quite apparent early on that concentrating on the public provision of education was not adequate for the proper and effective implementation of the education massification policy As a result, the Chinese government allowed the private sector (*minban*) to provide higher education as well. Between 1998 and 2019, there was a five-fold increase in public universities, from 500 to 2500 and a similar increase in *minban* as well, from a very few to 500 private universities by 2019. There are diverse types of *minban* higher education institutions including independent colleges that are associated with public universities to ensure the quality of education (Mok & Marginson, 2021).

Massification of higher education was certainly not limited to the provision of university education within China.

[2] For a detailed discussion of all facets of the economic and education reforms in China from the 1970s to 2000s, see the special issue of *International Journal of Educational Development* (2021), vol. 84.

[3] According to Zheng (2010), the opening-up policy initiated by Deng Xiaoping was the "most powerful driving force behind China's rapid transformation" (p. 799).

[4] Between 1996 and 1999 Peking and Tsinghua both received 1.8 billion yuan ($225 million). Similar levels of funding were later provided to Fudan, Zhejiang and Nanjing universities.

Internationalisation was one of the core elements of that policy (Constant et al., 2013). Consequently, there has been a surge in Chinese students seeking higher education abroad. This was supported by a large number of institutional relationships China had established. By 2007, China had agreements with 188 countries and regions in the world, resulting in the mutual recognition of academic degrees with 32 of them (Constant et al., 2013). In the last two decades a significant number of Chinese students have gone overseas for higher education, particularly to the US, Japan, South Korea, UK, France, Germany and Australia, as well other countries. Constant et al., (2013) and Mok and Marginson, (2021) provide a detailed breakdown of policies, flow statistics and destination countries. A number of students to overseas universities were funded by government scholarships, but a significant number was privately financed. Students went not only for undergraduate education, but for postgraduate as well, including for PhD degrees.

The government offered significant incentives (e.g., high salaries and housing subsidies) to bring back foreign educated Chinese.[5] This policy has been particularly relevant for the government's policy of creating world class universities (i.e., since the introduction of Projects 211 and 985), as significant incentives have been provided to overseas based Chinese academics at some of the most prominent universities like Harvard, MIT, Princeton, Oxford and Cambridge, among others. The foreign trained academics who returned to China had established overseas academic networks with which they continued to collaborate after returning, and therefore the volume of research on China, using Chinese data, has increased significantly since the mid-1990s (see Constant et al., 2013, and the data and analysis section for more details). Xie and Freeman (2018) show that China's share of articles published in physical sciences, engineering and mathematics jumped from 4% of the total articles on these topics published in 2000 to 18.6% in 2016, which was higher than the US's total. Constant et al., (2013, fig. 9, p.124) provide the background for this by revealing the focus of research for 2007 data. The share of scientific articles by field in China had been 59% for Natural Sciences (US: 27%), 17% for Engineering (US: 7%), 8% for Medical Sciences (US: 28%), 15% for Biological Sciences (US: 28%), and 1% Social/Behavioral Sciences (US: 9%). This explains the background of the Xie and Freeman (2018) results, but marks also the huge gap Social and Behavioral Sciences had.

As discussed before, government policy has recognized and valued the importance of supporting the humanities and social sciences beyond the sciences. Not much is known about the success of this strategic move. Therefore, the objective of this paper is to explore the impact of education expansion on research in the field of economics. Since "Chinese universities are, to a large extent, the government's educational and research arm for economic and social development" (Zha and Hayhoe, 2014, p. 45), our focus of research in this paper is on the articles written by Chinese authors over the past thirty years.

3. Data and research questions

3.1. Sources

We collected information from various distinct bibliometric sources. We use the *Microsoft Open Academic Graph (OAG)* database, which is a snapshot of the *Microsoft Academic Graph (MAG)* database but it is freely available for research use.[6] It contains 208,915,369 publications and their associated information between 1990 until November 2018, the most recent period freely available. The main advantage of the *OAG* is the vast number of observations gathered, which spans across multiple fields. We use these data to understand the evolution of articles published by Chinese researchers, across a variety of fields over the period of interest. However, since information on the nationality and affiliation of the authors is patchy and incomplete in the *OAG*, we only use it for descriptive data analysis.

Due to the limitations of the *OAG* data set, we perform the empirical analysis on data obtained from the *World of Science (WoS)* provided by Clarivariate. This database has complete records on publications in economics as well as the address of the corresponding author for each article. The slight drawback is of course that we don't have information about the affiliation of all authors, but just the corresponding, though that is still an improvement on the OAG data. *WoS* also contains information on the type of publication (book, article, special issue…), title, keywords, abstract, authors and their affiliations, citations, publisher, DOI, journal title, volume and page numbers, and field of study.

Finally, journal rank and number of citations are obtained from the SCImago Journal Ranking database, where we focus on the field of Economics and Econometrics. This database provides a series of indicators broadly associated with publication performance.

3.2. Descriptive analysis

To explore the evolution of the relevance of Chinese researchers over the past 30 years, we need to first clarify our understanding of "Chinese" given the limited abilities to identify ethnic origin in the available data. The term "Chinese paper" or "Chinese authored

[5] See Constant et al. (2013) for a detailed review of these policies. Over 100,000 students have been going abroad each year since 2002. The return rate was a meagre 14% at the start of 2000s, but following different policies to encourage Chinese graduates to return, the return rate went up to 78% in 2018 (Mok and Maginson, 2021).

[6] MAG contains heterogeneous information about scientific publications including the publication year, title and abstract, authors of the publications, organization of the authors, as well as the field of study. It collects academic records and updates the graph database on a bi-weekly basis, but access is limited by monthly quotas and traffic throttles, which prevents the analysis by non-subscribers.

article" in this section means that at least one of the authors of a publication has a Chinese name.[7] To determine Chinese names among all the authors in the OAG database, we used the *DragonMapper Pinyin identifier* (Roten, 2017). We then calculate the ratio of publications with at least one Chinese named author divided by the number of articles without Chinese author names and group the results by publication years. This was then applied to all papers in the top-10 journals[8] in Economics and three STEM-related fields, namely those attracting increasing academic and societal interest over the period: Chemistry, Engineering and Computer Sciences.[9] Fig. 1 depicts the Chinese to non-Chinese paper ratio of publications in top journals/conferences in these research fields.

Articles in the top-10 field journals in economics with at least one Chinese author have steadily grown, but its evolution since 1990 is nowhere near the explosion experienced in STEM-related fields. The relative growth of Chinese single authored or coauthored articles in Engineering and Chemistry has been remarkable, as the ratio (multiplied by 100) has risen from about 0.20% in 1990 to 1.25% for Chemistry and 2% for Engineering in 2017, a complete overhaul. In the case of Economics the ratio is about 0.20%, up from less than 0.05% in 1990, while in Computer Science it is about 0.35%, up from about 0.20%. Notwithstanding that many Chinese academics work in countries other than China, it is unlikely that the massive growth in Chinese authorship displayed in Fig. 1 has occurred without a substantial contribution from authors based in China.

Restricting the analysis to Economics, we retrieved all papers published in the top-5, top-10 and top-20 journals based on their recent average rank (see footnote 8), and report the ratio of Chinese to non-Chinese papers in Fig. 2 below.

While there is a steady increase in the share of Chinese authored and co-authored papers across the three sub-groups of journals, it is worth noting that the fastest growth takes place in journals ranked top-10 and top-20, which comprise variety of outlets published across a number of countries. In contrast, growth in the top-5 journals has been slower, nevertheless trebling in the period examined. Those journals have close social ties to US-based institutions (Colussi, 2018) and are possibly less interested in non-US research. Papers written about the US are much more likely to be published in top-5 journals (Das, Do, Shaines, & Srinivasan, 2009).

As the OAG includes the abstract of each publication, we examine differences and similarities in the most common words appearing in Chinese and non-Chinese articles. For the whole period, the relevant keywords are distributed somewhat differently: Chinese papers tend to focus on international relations issues ("trade", "international trade", "trade liberalization", "exports", "foreign direct investment", "political connections"), as well as "economic growth". In contrast, non-Chinese papers have a higher incidence of terms related to methodological issues like "experiments", "behaviors", "adverse selection", "Markov chain", "Monte Carlo" above and next to "bargaining", "exchange rates" and "inequality". This brief examination suggests a need to control for the area of research in the empirical analysis.

4. Empirical model

China's higher education reform affected a number of variables, such as the number of university enrolments and graduations, research expenditures, number of international students, and government expenditures in higher education. The expansion was announced in 1998, its execution started in 1999 and the policy lasted until 2008. This timing of the higher education reform relies on Knight et al. (2017), who consider it as a 'natural experiment' due to the sudden and strong policy change shown by the reforms, which is also supported broadly by other researchers.[10]

We initially capture the policy impact on the performance of Chinese researchers through a dummy variable that captures the effect

[7] Although more than 50% of the observations in *OAG* do not provide author affiliations, which is a limitation to observe, the data show a rising number of Chinese authors and China-based institutions affiliated with the articles published by the highest ranked journals in Economics. It is hence not just Chinese-named authors who publish their work, but also authors from China's universities and research centres.

[8] We refer here and later to top-5, top-10 and top-20 journals in Economics using the ranking sourced at https://ideas.repec.org/top/top.journals.all.html. These are: top-5 = American Economic Review, Econometrica, Journal of Political Economy, Quarterly Journal of Economics and Review of Economic Studies; top-10 = top-5 and Journal of Economic Growth, Journal of Economic Perspectives, Journal of Economic Literature, Journal of Finance, Journal of Financial Economics; top-20 = top-10 and American Economic Journal: Macroeconomics, American Economic Journal: Applied Economics, Journal of International Economics, Journal of Labor Economics, Journal of Monetary Economics, Journal of Econometrics, RAND Journal of Economics, Renewable and Sustainable Energy Reviews, Review of Economics and Statistics, and Review of Financial Studies.

[9] Top outlets for the three fields outside Economics chosen were: *Computer Science*: "computer vision and pattern recognition", "neural information processing systems", "international conference on computer vision", "European conference on computer vision", "national conference on artificial intelligence", "international conference on robotics and automation", "international world wide web conferences", "human factors in computing systems", "knowledge discovery and data mining", "international joint conference on artificial intelligence", "meeting of the association for computational linguistics"; *Chemistry*: "Semiconductors and Semimetals", "IEICE Electronics Express", "Advances in Applied Mechanics", "IEEE Communications Surveys and Tutorials", "Advanced Materials", "International Materials Reviews", "Materials Today", "ACS Nano", "Annual Review of Biomedical Engineering"; *Engineering*: "Semiconductors and Semimetals", "IEICE Electronics Express", "Advances in Applied Mechanics", "IEEE Communications Surveys and Tutorials", "Advanced Materials", "International Materials Reviews", "Materials Today", "ACS Nano", "Annual Review of Biomedical Engineering". Outside economics, and especially in engineering and computer sciences accepted papers at top conferences are highly valued. In economics, no conferences are included in our analysis. Rankings sourced as follows:Chemistry: https://www.rasayanika.com/2021/03/23/top-20-chemistry-journals-you-can-refer/Computer Science: https://www.guide2research.com/topconf/Engineering: https://www.scijournal.org/articles/top-engineering-journals

[10] The literature includes Li et al. (2014), Xing, Peng, and Li (2018), Yang (2018), Guo, Song, and Chen (2019), Lu and Zhang (2019), Chan and Zhang (2021), Dai et al. (2021) and Huang and Zhu (2020)). Yang (2018) writes (p. 65): "Higher education in China has expanded dramatically since the Ministry of Education (MoE) launched the Action Plan of Education Promotion for the 21st century in 1998."

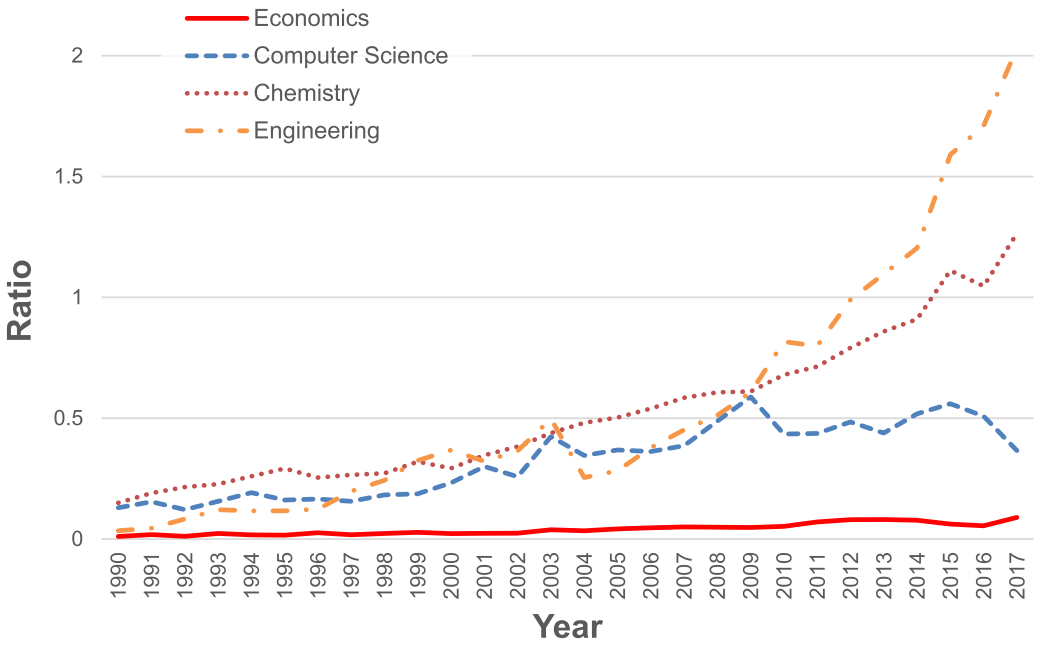

Fig. 1. Chinese to non-Chinese ratio of publications in top journals/conferences in four research fields: 1990 to 2017.
Source: *Open Academic Graph (OAG)* database on articles published in top-10 journals and conferences. Ranked journals are listed in footnotes 8 and 9. Note: Relative number of papers with at least one Chinese named -author to those without any. Our calculated ratios are multiplied by 100.

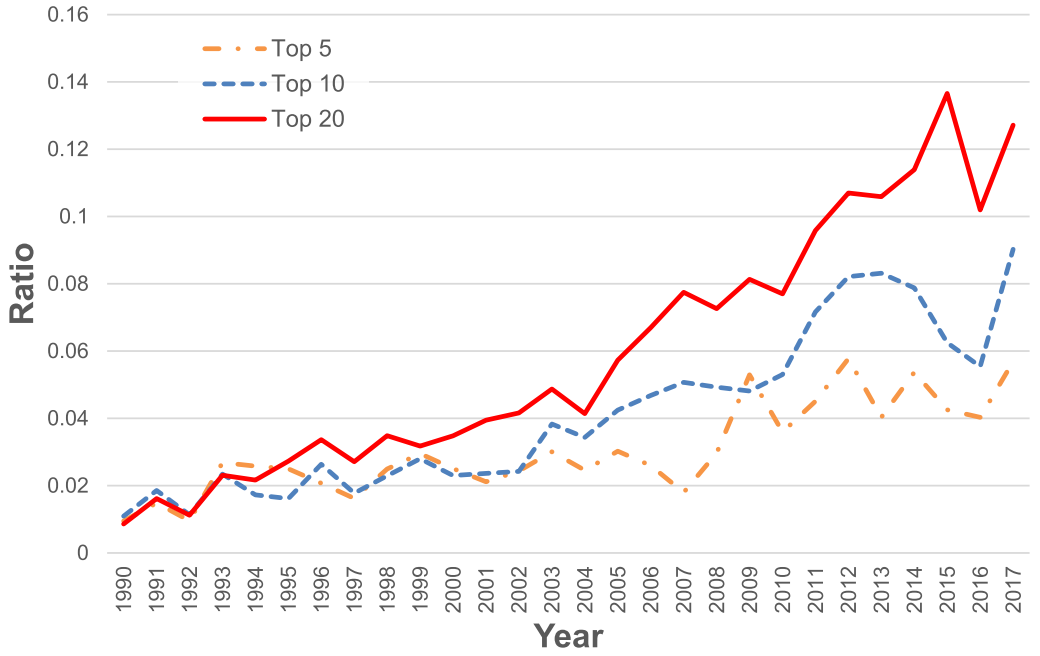

Fig. 2. Ratio of Chinese to non-Chinese authored articles in top 5, 10 and 20 Economics journals from 1990 to 2017.
Source: *Open Academic Graph (OAG)* database on articles published in top-10 journals. The list of the top-10 journals in Economics is reported in footnote 8. Note: Relative number of papers with at least one Chinese named co-author to those without any. Our calculated ratios are multiplied by 100.

in China only: we interact China's country dummy variable with a (1,0) dummy for the higher education reform policy period 1999–2008. More precisely, we estimate the following model:

$$Y_{icft} = \alpha + \beta X_{ct} + \gamma c_{China} t_{99-08} + c + f + t + \varepsilon_{icft} \quad (1)$$

Model details are:

- Y is a dummy variable indicating if article i published in year t in research field f (fields: e.g. development economics, agricultural economics, finance…) has at least one Chinese author[11];
- The article is linked to country group c (6 groups: China, US & Canada; Australia & New Zealand, Europe & Israel, United Kingdom, and Rest of the World) according to the affiliation of the corresponding author. Note that our data on country group c is restricted to corresponding authors only[12];
- X is a vector of controls that varies over time and contains the logarithm of the GDP per capita of the corresponding author's country of residence and the logarithm of the workforce employed in the research sector in the same country;
- the product of two dummies, $c_{China} t_{99-08}$, is the variable identifying the policy change (1999–2008 = 1; 0 otherwise) in China (=1; 0 otherwise);
- the vectors c, f, and t indicate country groups, research field of study and year fixed effects; ε is an idiosyncratic error term.

The constant α and the vectors of parameters β and γ are estimated by Ordinary Least Squares (OLS) with robust standard errors to account for heteroskedasticity resulting from the linear probability approach.

Research field fixed effects and year dummies filter out general time-dependent factors and differences in the publication conditions within research fields, assuming that the choice of field is not affected by educational policies. The country of residence of the corresponding author controls for the differences in research conditions and research policies at the national level. It is important to note that including the country groups and year fixed effects effectively control for the variance in outcome that is specific to each geographic region and for each year but not their interaction. In other words, by including the fixed effects c and t in the model, the variation captured by the education expansion dummy is only identified by the interaction between Chinese author's output in China and the decade 1999–2008. Our key parameter of interest is γ, the coefficient of the higher education expansion.

5. Results

5.1. Baseline results

The baseline point estimates and standard errors of various specifications that add various types of controls are reported in Table 1. We introduce regressors step by step; the pure education expansion coefficient just with time fixed effects (column I) is large and remains robust when research field fixed effects are introduced (column II). We then introduce country group fixed effects for the region of residence/affiliation of the corresponding author as recorded in the *WoS* database (column III). Adding country group fixed effects has a strong impact on the size of γ - the coefficient of interest - and the adjusted R^2 of the regression, which rises from 0.16 to 0.50. This change in R^2 also highlights the relevance of disentangling the effect of the reform of interest from other country-specific factors that influence research productivity. We add the logarithm of GDP/capita and the logarithm of the scientific workforce in Model IV, which increases the parameter estimated for education expansion, although not much. However, this reduces the number of observations by about a third, while both variables might also be considered to be endogenous. We see Model IV as a (successful) robustness check of the preferred specification in Model III. We find all reported estimates to be statistically different from zero – in most cases at the 1% level of significance.

The results across the specifications indicate a positive and statistically significant effect of the expansion on the research productivity of Chinese authors in China. The point estimates in specifications III and IV are stable: in the range 0.049–0.054. Given the pre-expansion average probability of publication of 0.11, the coefficients imply that the expansion raised the probability of publishing for a Chinese author by about 45%. The higher education expansion, which raised the number of Chinese universities and academics while introducing a competitive system rewarding quality academic research, emerges as having had a large and statistically significant positive effect. Such effect is clearly present even when we control for the country's (log of) GDP per capita (+0.018), and for the size of China's scientific workforce (logarithm of the R&D workforce: +0.075), which is still smaller than that of the US.

5.2. Robustness and heterogeneity

Although encouraging, the baseline results reported in Table 1 are open to several potential concerns about the empirical strategy

[11] As mentioned in Section 3, we use *DragonMapper Pinyin identifier* (see Roten, 2017) to determine Chinese names among all the authors in the OAG database.

[12] Country of residence of the corresponding author at the time of publication is derived from the *WoS* information about the author's affiliation. Hong Kong-based authors are classified in *WoS* as being in mainland China from 1998 onwards. Identifying the country of residence of the corresponding author is important to separate the effect of the higher education expansion, which is specific to the decade 1999–2008 in China, from those of other confounders of Chinese author research productivity.

Table 1
Baseline results for articles by Chinese authors.

	I	II	III	IV
Education expansion	0.848*** (0.006)	0.809*** (0.007)	0.049*** (0.007)	0.054*** (0.007)
Log GDP/capita				0.018*** (0.002)
Log Sc Workforce				0.075*** (0.004)
Constant	0.051*** (0.017)	0.181*** (0.021)	0.816*** (0.016)	0.648*** (0.047)
Year FE	Yes	Yes	Yes	Yes
Field of research FE	No	Yes	Yes	Yes
Country FE	No	No	Yes	Yes
Adj R^2	0.0991	0.1565	0.5028	0.5348
p-value	0.0000	0.000	0.000	0.000
N	47,967	47,967	47,455	32,693

Note: Dependent variable is a (0,1) dummy for an article authored by a Chinese researcher residing in China or elsewhere. Coefficients obtained by OLS with robust standard errors. FE = fixed effects. Education expansion is the interaction of the dummy variable for China with the period 1999–2008: it is equal to 1 and 0 otherwise.

Table 2
Robustness tests: pre-, during and post-reform effect on publications by Chinese authors.

Test performed:	EE: 1999–2008	EE: 1994–1998	EE: 2009–2013
Education expansion	0.049*** (0.007)	0.006 (0.005)	0.004 (0.006)
Adj R^2	0.5028	0.5027	0.5027
N	47,455	47,455	47,455

used, and the likely influence of omitted variables on the coefficients obtained. We hence carry out a number of tests. To start with, we use the five years before and after the period identified by the literature as the time of the higher education expansion, respectively, to shift the time of the expansion, akin to a 'placebo' test. The results are reported in Table 2.

The results yield coefficients that are no different from zero, supporting the hypothesis that the 1999–2008 decade in China, the time identified with the higher education expansion, has a special positive relationship with the probability to publish for Chinese authors that is not otherwise explained.

The presence of an omitted variable bias is another potential confounder for the results presented in Table 1. We follow Oster (2019) to assess the severity of this problem.[13] We find the delta of a theoretical 'no effect' from the education expansion to be 159.02 for Model III and 69.5 for Model IV, implying that selection on unobservables should be 159.02 and 69.5 times the selection of observables, respectively – a very unlikely scenario (Oster suggests a benchmark ratio of 1). As a result, it is unlikely that Model III and Model IV suffer from severe omitted variable bias. Overall, the results of the robustness tests make the point estimates reported in Table 1 credible.

We conclude our initial investigation by exploring the heterogeneity of the higher education expansion variable when it is split into two 5-year components (1999–2003 and 2004–2008, respectively), and report the results in Table 3.

The point estimate is no different from zero for the first period, consistent with the hypothesis that the education expansion took some time before generating publications due to significant time lags between the necessary time it takes to qualify as a researcher as well as writing and submission of papers and their publication dates. However, the effect is positive and highly significantly different from zero in the second period, suggesting that the conditions for publishing faced by Chinese economists were strengthened and deepened over time.

5.3. An alternative identification strategy

The main limitation of our model presented above is how the measurement of the education policy change is captured, i.e., by the product of two dummy variables, c_{China} and t_{99-08}. By construction, this approach restricts the effect of the higher education expansion to researchers based in China. However, the expansion in China generated a set of incentives that influenced Chinese and non-Chinese economists well beyond China's domestic borders. As an example, students seeking tertiary and postgraduate education overseas were encouraged and sponsored to do so, as evidenced by many Chinese researchers being trained in foreign universities. We show such

[13] This method evaluates the robustness to omitted variable bias by testing the stability of the coefficients when control variables are progressively added in a regression under the assumption that the relationship between treatment and unobservables can be recovered from that between treatment and observables, and that the hypothetical model that includes treatment, observables, and unobserved produces a R_{max} that can be less than 1 (e.g. because of measurement error). Oster's method is used to calculate either (i) the ratio of unobserved/observed selection ('delta') required to nullify the effect of the treatment; or (ii) the bounds of the treatment coefficient when delta varies between 0 (no unobserved selection) to 1 (equal observed and unobserved selection). Robustness to omitted variable bias occurs if delta >1 or if beta is never zero when delta is in the interval [0,1].

Table 3
Heterogeneity across two time periods, split between early and latter years of reform.

	1999–2003	2004–2008
Education expansion	0.014 (0.020)	0.055*** (0.006)
Year FE	Yes	Yes
Field of research FE	Yes	Yes
Country FE	Yes	Yes
N	47,455	47,455

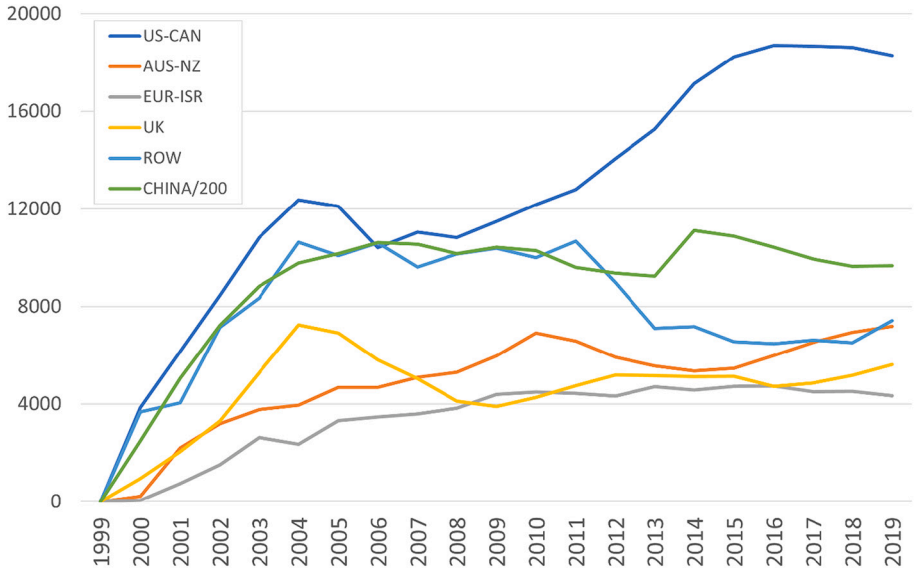

Fig. 3. Annualized flow of Chinese university students enrolled in China and other major destinations: 1999 to 2017.
(Source: *Unesco* (international enrollments) and *China Statistical Yearbook* (domestic enrollments), various years. Note: The flow of students enrolled in China in the figure is scaled 1:200.)

evolution in Fig. 3 using data from UNESCO (international students from China) and China's Statistical Yearbook (domestic students).

The figure shows that the expansion was accompanied by large and increasing outflows of university enrolments in both China and abroad, which stabilised around 2004–2005, except for North America, whose tertiary institutions continued to receive growing numbers of Chinese students till about 2015. We exploit the data on the university enrolments of Chinese students to better capture the effect of the expansion globally. In particular, we measure the educational expansion by the cumulative annual flow of Chinese students enrolled in universities in China, and in the five other geographic regions, so that the new variable $PROXY_{ct}$ is set equal to: (i) zero for the years prior to 1999 and after 2008, and (ii) the logarithm of the cumulative annual flow of Chinese students enrolled at university in China and in each of the five other geographic regions during 1999–2008. The modified regression is:

$$Y_{icft} = a + bX_{ct} + \delta PROXY_{ct} + c + t + f + \eta_{icft} \quad (2)$$

where Y, X, c, t, and f are the same as in Eq. (1). In Eq. (2), however, $PROXY_{ct}$ varies by country group and by year, unlike the dummy interaction of our initial approach. This identification strategy enables us to explore possible externalities of China's higher education expansion on research production in other parts of the world.

We estimate Eq. (2) by OLS with robust standard errors, and report the results in Table 4 across three research outcomes: (i) if at least one author is Chinese; (ii) if the corresponding author is Chinese; (iii) if the word 'China' appears in the title or abstract of the publication. As in the above analysis, (i) captures 'all' authors while (ii) captures the country where the corresponding author is based (since we have that information only for the corresponding author). In addition, we capture a new category related to whether research article was on China. The purpose extra category is ascertain the extent of research on China following the reform. Again, we estimate models (III) and (IV) analogous to those presented in Table 1.

The results presented in Table 4, for model specifications without and with vector X, respectively, confirm the previous results from Eq. (1). More specifically, results show that China's education expansion has increased the probability of publication for at least one Chinese author, as well as the publication of article content related to China.

To calculate the average impact of the expansion using the results of Table 4, one can take the point estimate of 0.004 multiply it by the average value of PROXY (equal to 2.215), and divide the result by the probability of Chinese authorship before the expansion (11%): the result is 8%, which is the implied average increase in research productivity. This is lower than the effect obtained from Eq.

Table 4
Articles by Chinese authors and articles on China – new identification variable.

	Author has Chinese name	Corresponding author has Chinese name	Title or abstract has 'China'	Author has Chinese name	Corresponding author has Chinese name	Title or abstract has 'China'
$PROXY_{ct}$	0.004*** (0.001)	−0.0005 (0.0009)	0.0096*** (0.0018)	0.0046*** (0.001)	−0.001* (0.0008)	0.007*** (0.002)
X_{ict}	No	No	No	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.5028	0.8137	0.3746	0.5346	0.8426	0.3807
N	47,455	47,455	47,455	32,693	32,693	32,693

Note: Dependent variable is a (0,1) dummy equal to 1 if: (i) one of the authors has a Chinese-sounding name (first and fourth columns); (ii) the title or abstract contains the word 'China' (third and sixth columns). Regressions performed by OLS with robust standard errors. FE = fixed effects. *X* contains GDP per capita and the logarithm of the scientific workforce. Education expansion covers the period 1999–2008. PROXY is the logarithm of the annual cumulative flow of university students enrolled in China or originating from China to one of the 5 geographic areas previously defined (US-Canada; Australia-New Zealand; Europe + Israel; UK, Rest of the world). International student data are sourced from UNESCO. Domestic student data are sourced from China's Statistical Yearbooks.

(1), which can be identified directly from Table 1 as it is the product of two dummy variables (4.9%), as one would expect: the flow of Chinese university students enrolled captures only one of the several domains affected by the higher education expansion. This hypothesis is confirmed also by the Owen-Shapley R^2 decomposition (Huettner & Sunder, 2012), which calculates the contribution to R^2 for each of the variables used in the regression. The contribution of the new $PROXY_{ct}$ variable is 1.77%, which is lower than the 3.79% of the interacted dummy of Eq. (1).

With reference to omitted variable bias, the results based on $PROXY_{ct}$ do not appear affected by it, as Oster' (2019) *delta* underpinning the regressions varies between 47 and 65 in the case of Chinese authors, and 14–19 in the case of China in the title or abstract, respectively. These values are well above the notional benchmark of 1.

Table 5 highlights that the effect of the expansion has not been uniform over the period, as already found in our initial analysis. The probability of publishing for Chinese authors is five-fold higher in the pre/during-reform period (first columns of the table) relative to the period that includes after the reform (fourth column). The policy change has also raised the probability of Chinese corresponding authors– an effect that reverts sign after the reform ends in 2008, though this reflects higher publication rates (and better data collection in the *WoS*) from authors from the rest of the world. Articles with China content however are more likely to be published after the policy change (sixth columns) rather than during and before it (third column), though this may reflect time lags between submission and publication dates as previously stated.

5.4. International externalities

In this section we want to further explore the heterogeneity across the six main regions where Chinese researchers are based. Given that the reform resulted in a significant increase of Chinese students going to different parts of the world for further education, it is important to ascertain from which countries/regions does most of the research by Chinese authors originates. We exploit the new identification variable for the education expansion to analyse the effect of the policy change on researchers living in countries other than China, and report the results of the main dependent variables when Eq. (2) is separately estimated for each of the six country groups. The results are summarised in Table 6.

The expansion had heterogeneous effects across space: the probability of publication for a Chinese author seems to have been driven by research originating in North America, the United Kingdom, and the Rest of the world (which includes Hong Kong till 1998, and then Japan, Korea and Singapore), with no detectable effects from other regional groups. The lack of a statistically significant effect for Australia and New Zealand is at first surprising, given the large inflow of university students from China. However, many Chinese students graduating from Australia and New Zealand seem to complete only a university degree rather than advancing to PhD, and tend to return home to engage in non-academic or non-research-intensive careers.[14]

Chinese researchers have also become more likely to be corresponding authors in China but not elsewhere – in fact it is less likely and statistically significantly different from zero in North America, possibly because the authors' rank in economics journals tends to follow the alphabetical order. With respect to article content, the policy change has boosted interest for China-focused articles in China as well as in North America and the UK, the two countries where collaborating with Chinese coauthors has also increased. It seems to have instead become less likely in the rest of the world, though this reflects publication growth from countries other than China.

5.5. Research performance

Publication success is affected by the performance of researchers, cooperation strategies and publication ambitions. Chinese higher

[14] https://www.universityworldnews.com/post.php?story=20130517142757453

Table 5
Heterogeneity by time periods.

	1990–2008			1999–2021		
	Author has Chinese name	Corresponding author has Chinese name	Title or abstract has 'China'	Author has Chinese name	Corresponding author has Chinese name	Title or abstract has 'China'
$PROXY_{ct}$	0.021*** (0.005)	0.040*** (0.005)	0.000 (0.004)	004*** (0.001)	−0.002* (0.001)	0.011*** (0.002)
N	13,199	13,199	13,199	43,410	43,410	43,410

Note: Dependent variable is a (0,1) dummy equal to 1 if: (i) one of the authors has a Chinese-sounding name (first and fourth columns); (ii) the corresponding author has a Chinese-sounding name; (iii) the title or abstract contains the word 'China' (third and sixth columns). Regressions performed by OLS with robust standard errors. FE = fixed effects. Education expansion covers the period 1999–2008. PROXY is the logarithm of the annual cumulative flow of university students enrolled in China or originating from China to one of the 5 geographic areas previously defined (US-Canada; Australia-New Zealand; Europe + Israel; U, Rest of the world). International student data are sourced from UNESCO. Domestic student data are sourced from China's Statistical Yearbooks. Regression excludes controls X_{icft} to use higher number of observations.

Table 6
Coefficient estimates by country groups.

	Author has Chinese name	Corresponding author has Chinese name	Title or abstract has 'China'
Policy effect in			
China	0.002 (0.001)	0.002* (0.001)	0.011*** (0.003)
US-CAN	0.006** (0.002)	−0.002*** (0.0005)	0.008*** (0.002)
AUS-NZ	0.002 (0.013)	0.0002 (0.003)	0.001 (0.014)
EUR-ISR	0.0003 (0.001)	−0.0003 (0.0003)	0.001 (0.005)
UK	0.011** (0.005)	−0.002 (0.001)	0.017*** (0.005)
RoW	0.034*** (0.009)	0.001 (0.002)	−0.015* (0.009)

Note: Dependent variable is a (0,1) dummy equal to 1 if: (i) one of the authors has a Chinese name; (ii) the corresponding author has a Chinese name; (iii) the title or abstract contains the word 'China'. Regressions performed by OLS with robust standard errors. FE = fixed effects. Education expansion covers the period 1999–2008. PROXY is the logarithm of the annual cumulative flow of university students enrolled in China or originating from China to one of the 5 geographic areas previously defined (US-Canada; Australia-New Zealand; Europe + Israel; U, Rest of the world). International student data are sourced from UNESCO. Domestic student data are sourced from China's Statistical Yearbooks. Regression excludes controls X_{icft} to use higher number of observations.

Table 7
Heterogeneity by quality indicators by time periods.

		1990–2021	
	Multi-authored	Log citations	Journal rank
$PROXY_{ct}$	0.012 (0.008)	−0.036 (0.022)	0.002 (0.002)
N	9553	8608	8608

	1990–2008			1999–2021		
	Multi-authored	Log citations	Journal rank	Multi-authored	Log citations	Journal rank
$PROXY_{ct}$	0.195*** (0.034)	−0.224*** (0.078)	−0.003 (0.006)	0.012 (0.008)	−0.036 (0.023)	0.002 (0.002)
N	978	822	822	9454	8542	43,410

Note: Dependent variable is a (0,1) dummy equal to 1 if: (i) one of the authors has a Chinese name; (ii) the corresponding author has a Chinese name; (iii) the title or abstract contains the word 'China'. Regressions performed by OLS with robust standard errors. FE = fixed effects. Education expansion covers the period 1999–2008. PROXY is the logarithm of the annual cumulative flow of university students enrolled in China or originating from China to one of the 5 geographic areas previously defined (US-Canada; Australia-New Zealand; Europe + Israel; U, Rest of the world). International student data are sourced from UNESCO. Domestic student data are sourced from China's Statistical Yearbooks. Regression excludes controls X_{icft} to use higher number of observations. Journal rank is 1/ln(H index) so higher value of variable indicates higher journal rank.

education policies have affected those factors as our review in Section 2 has revealed. We explore that aspect further by applying Eq. (2) to three distinct indicators of research performance: collaborations, citations of the paper, and the quality of the journal where articles are published.[15] The results are reported in Table 7, which separates coefficients obtained on pooled years 1990–2021 from the subperiods covering the decades that capture the early and later part of the reform (as per our PROXY measure in Eq. 2).

The results show no statistically significant effect when looking at the entire period (top panel), mostly because research

[15] We use the World of Science ranking of the journals.

productivity has fast risen globally in the past decade. However, when we split the estimations between two different time periods, the result for multi-authored and citations becomes significant for the 1990–2008 period. China's higher education expansion had large and positive effects on collaborations with authors within and especially outside China, as indicated by the large and statistically significant coefficient of $PROXY_{ct}$ in the multi-authored column (+0.195). Higher supply of articles from Chinese authors and co-authors, as well as articles on China, seem to have been accompanied by lower likelihood of citations for each publication, as indicated by the negative and statistically significant effect. No statistical effect can be detected on the quality of the publications as measured by the rank of the publishing journal.

Overall the results suggest that the higher education expansion has increased the productivity of Chinese authors, mainly through collaborations.

6. Conclusions

The paper has studied the evolution of the academic standing of Chinese researchers measured by the publications of Chinese researchers. Publications are the key indicators in academia, which we study through the use of data from *Microsoft Open Academic Graph (OAG)* and *World of Science (WoS)*. Since the late 1970s, the Chinese authorities have initiated a larger number of economic reforms and education massification policies with a massive higher education expansion in the 1999–2008 decade which led to a substantial increase of the number of university students, the creation of world class universities, providing incentives to publish a high quantity and quality of research as well as implementing other human capital strategies like attracting foreign students and researchers and sending students and researchers for global human capital investments and academic collaborations. It started first in science and engineering before it also reached the social sciences including economics. With a focus first on learning, the emphasis shifted soon to the contribution of knowledge creation. Section 2 of the paper has reviewed these policies.

The main objective of this paper was to analyse the effect of China's education policy reforms, implemented from 1998 to 2008, on research articles by Chinese authors published in economics journals. We used *DragonMapper Pinyin* identifier to determine whether at least one of authors of an article is Chinese.

Descriptive and analytic evidence presented confirm a significant associated rise in publications in economics by Chinese authors, although much smaller than found in engineering and chemistry. We further provide econometric evidence that the higher education expansion had a significantly positive and robust correlation with publications by Chinese authors. This holds when controlled for performance indicators and factors covering the evolution of other determinants at the paper and country levels.

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