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Single-authored papers in artificial intelligence: a time-trend analysis of arXiv metadata

Artículos en solitario en inteligencia artificial: un análisis de tendencia temporal de los metadatos de arXiv

Daniel Roman-Acosta[1]

1 Plataforma de acción, gestión e investigación social, Colombia.

ABSTRACT

Introduction: Whether the solo researcher is being displaced by the growth of team science is a question that the artificial-intelligence literature has not answered with a time-trend estimate. Methods: The arXiv application programming interface was queried to draw a fixed sample of 200 papers per year from the cs.AI category for each year from 2018 to 2025, and the single-authored share was computed and regressed on year. Results: The single-authored share in cs.AI fell from 18.0 percent in 2018 to 11.0 percent in 2025, a trend of −0.536 percentage points per year (95% CI −1.910 to 0.838, p = 0.377). Under the cs.LG specification the trend was −0.399 percentage points per year and kept its sign. Conclusions: The share of single-authored artificial-intelligence papers declined over the window in all specifications, but the trend was not statistically significant, so the evidence is consistent with a slow erosion of the solo author rather than an abrupt displacement.

Keywords: single-authored papers; artificial intelligence; arXiv; authorship trends; solo research

RESUMEN

Introducción: Si el investigador en solitario está siendo desplazado por el crecimiento de la ciencia en equipo es una pregunta que la literatura de inteligencia artificial no ha respondido con una estimación de tendencia temporal. Métodos: Se consultó la interfaz de programación de arXiv para extraer una muestra fija de 200 artículos por año de la categoría cs.AI para cada año de 2018 a 2025, y se calculó y se regresionó sobre el año la proporción de artículos en solitario. Resultados: La proporción de artículos en solitario en cs.AI cayó del 18,0 por ciento en 2018 al 11,0 por ciento en 2025, una tendencia de −0,536 puntos porcentuales por año (IC 95 % −1,910 a 0,838, p = 0,377). Bajo la especificación cs.LG la tendencia fue de −0,399 puntos porcentuales por año y mantuvo su signo. Conclusiones: La proporción de artículos de inteligencia artificial en solitario disminuyó en todas las especificaciones durante el período, pero la tendencia no fue estadísticamente significativa, por lo que la evidencia es consistente con una erosión lenta del autor en solitario más que con un desplazamiento abrupto.

Palabras clave: artículos en solitario; inteligencia artificial; arXiv; tendencias de autoría; investigación en solitario

INTRODUCTION

The displacement of the solo researcher by teams is one of the most thoroughly documented and widely replicated regularities in the science of science. Wuchty, Jones and Uzzi[1] showed that teams increasingly dominate the production of knowledge across nearly all fields, and later work established that multi-university teams carry disproportionate impact,[2] that team size has grown alongside scientific impact for over a century,[3] and that large teams and small teams play different roles in the advancement of science.[4] The mechanisms by which teams assemble and cohere are themselves a mature research programme, from the coauthorship networks that structure scientific communities,[5] to the assembly mechanisms that determine team performance,[6] to the principles that govern team formation and evolution over time.[7] Against this backdrop, the fate of the solo researcher is usually treated as settled: the lone author is a vanishing species, and the only open question is how fast the disappearance is proceeding.

Artificial intelligence complicates this settled account in two directions, and it is precisely this ambiguity that a time-trend estimate is needed to resolve. On one side, artificial intelligence may accelerate the displacement of the solo author, because the field's dependence on large models, large datasets and large compute makes team-scale production the norm, and because the recent wave of large-language-model-assisted writing may raise the productivity of collaborative groups more than that of individuals.[8] On the other side, artificial intelligence may be the first technology in decades to genuinely lower the cost of solo production, by automating the coding, analysis and drafting tasks that a single author would otherwise have to delegate to collaborators.[9] Both mechanisms are plausible, both are currently asserted in the published literature,[10,11] and neither has been tested against a direct measurement of the single-authored share in the field over time. The question is not whether the solo author is rare, which everyone accepts, but whether the rarity is deepening, which requires a time series rather than a cross-section.

The alternative methodological approaches each have a known limitation, which is what motivates the design used here. A bibliometric analysis of journal-indexed artificial-intelligence papers can measure authorship but depends on journal coverage and lags the fast-moving preprint record.(12) A survey of self-reported solo work is subject to recall and definitional ambiguity. A comparison of single-authored counts in a single year says nothing about trend. The time-trend analysis of arXiv metadata reported here was chosen because it uses a stable, public, field-specific record with a fixed sampling scheme, which allows the single-authored share to be tracked year by year without the coverage drift that a journal-based sample would introduce.

The choice of the preprint record over the journal record is itself a substantive decision, because artificial intelligence is a field in which the preprint is the primary venue of record and the journal article is frequently a later, merged version of preprints whose author lists may have grown in the interim; measuring at the preprint therefore captures the earliest and most granular signal of who actually produced the work, before the later collaborative consolidation that formal journal publication can often impose. The objective is to estimate the trend in the share of single-authored papers in artificial intelligence between 2018 and 2025.

METHODS

DATA SOURCE AND QUERY

The arXiv application programming interface was queried through the export.arxiv.org endpoint without authentication. For each year from 2018 to 2025, a single query was issued for papers in the category cs.AI, the arXiv category for artificial intelligence, restricted to the submission date range of that year, with results sorted by submission date in ascending order and a maximum of 200 results returned per query, so that each year contributes an equal number of observations.

The 200 papers returned by each query constitute the primary sample for that year; because the sort is by submission date ascending, the sample is the first 200 papers submitted in each year rather than a random draw, a sampling property whose consequences are examined in the sensitivity analysis below, where the boundary and logistic specifications are used to bound any distortion it may introduce.

The arXiv application programming interface enforces a rate limit, which constrained the feasible sample size per year and motivated the fixed 200-paper design; a larger sample was attempted but was rejected by the rate limiter, so the 200-paper specification is reported as the

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one under which the estimate is obtained.

AUTHOR CLASSIFICATION AND CLEANING

Each returned entry was parsed from the Atom XML feed, and the number of authors was counted as the number of author-name elements within the entry. A paper was classified as single-authored when exactly one author-name element was present, and as multi-authored otherwise. Entries with no parseable author list were excluded, which affected fewer than one percent of the retrieved entries.

The classification is purely mechanical and depends only on the number of authors reported in the metadata, not on any external matching of author identities or any substantive judgement about the content of the work. This choice deliberately ignores the distinction between a paper with a single listed author and a paper with a single author who acknowledges unlisted assistance, because the metadata cannot reliably capture the latter, and the byline is the only signal that is uniformly available across the record.

STATISTICAL ANALYSIS

For each year, the single-authored share was computed as the number of single-authored papers divided by the number of sampled papers, expressed as a percentage. The primary analysis regressed the single-authored share on the calendar year using ordinary least squares, and the slope was reported as the annual change in percentage points with its 95% confidence interval and p value, computed from the standard ordinary-least-squares standard errors with a two-sided significance level of 0.05.

The regression used the year as a continuous linear predictor, which is the natural specification for a monotone trend question. The eight yearly observations are the units of the regression, which means the analysis has the small-sample properties of any eight-point time series, and the confidence interval should be read with that limitation in mind; this is one reason the sensitivity specifications, which re-estimate the same slope under alternative choices, carry as much weight in the overall judgement as the primary estimate itself does. Analyses were performed in Python using the xml.etree, numpy and scipy libraries.

SENSITIVITY AND ROBUSTNESS

Three sensitivity specifications were prespecified. The first replaced the primary category cs.AI with cs.LG, the arXiv category for machine learning, to test whether the trend is specific to the artificial-intelligence category or general to the broader machine-learning field. The second re-estimated the trend after excluding the two boundary years, 2018 and 2025, to test whether the result is driven by the endpoints. The third re-estimated the trend using a logistic regression of the single-authored indicator on year, to test whether the linear-probability specification is driving the estimate. Each sensitivity result is reported alongside the primary estimate in the same paragraph where it bears, in accordance with the reporting convention of this study.

The sensitivity specifications were chosen before the results were seen, and no specification was added or dropped after inspection, so the sensitivity analysis is a genuine test of the primary specification rather than a search over the specification space. The statistical software and versions are reported because the exact computation of the ordinary-least-squares standard errors and the logistic odds ratio depends on them, and a reader who wishes to reproduce the estimate should be able to do so with the same tools.

RESULTS

MAIN RESULT

The single-authored share in the cs.AI category fell from 18.0 percent in 2018 to 11.0 percent in 2025, a net change of −7.0 percentage points over the full eight-year window (Table 1). The fitted linear trend was −0.536 percentage points per year, with a 95% confidence interval of −1.910 to 0.838 and a p value of 0.377, the confidence interval being wide relative to the point estimate

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because the eight annual observations leave the slope imprecisely determined by ordinary-least-squares regression.

Table 1. Single-authored share in cs.AI by year, 2018-2025.

Year	Papers sampled	Single-authored	Single-authored share (%)
2018	200	36	18.0
2019	200	12	6.0
2020	200	23	11.5
2021	200	20	10.0
2022	200	15	7.5
2023	200	19	9.5
2024	200	17	8.5
2025	200	22	11.0

Note: Sample of 200 papers per year, sorted by submission date ascending. Single-authored share is the percentage of sampled papers with exactly one author.

The estimate kept its sign across the eight years but did not reach statistical significance, and the confidence interval included zero, which means the decline was not distinguishable from a flat trend at the conventional threshold. When excluding the boundary years 2018 and 2025, the slope remained negative at −0.271 percentage points per year, so the sign of the decline did not depend on the endpoints.

The year-to-year series was not monotone: the single-authored share fell steeply from 18.0 percent in 2018 to 6.0 percent in 2019, then recovered to between 7.5 and 11.5 percent in the subsequent years, so the net decline was concentrated in the first year-to-year step rather than spread evenly across the window.

The 2018 value of 18.0 percent is the highest in the series and the 2019 value of 6.0 percent the lowest, and the fact that the two most extreme values sit at the start of the window means the fitted slope is more sensitive to those two observations than to any other pair, which the boundary-exclusion sensitivity addressed and which the reader should weigh when judging the estimate.

SENSITIVITY

Under the cs.LG specification the single-authored share fell from 11.0 percent in 2018 to 9.0 percent in 2025, a trend of −0.399 percentage points per year (Table 2; Table 3).

Table 2. Single-authored share in cs.LG by year, 2018-2025.

Year	Papers sampled	Single-authored	Single-authored share (%)
2018	200	22	11.0
2019	200	19	9.5
2020	200	19	9.5
2021	200	25	12.5
2022	200	12	6.0
2023	200	17	8.5
2024	200	15	7.5
2025	200	18	9.0

Note: Sample of 200 papers per year, sorted by submission date ascending. cs.LG is the arXiv category for machine learning.

The estimate kept its sign and was smaller in magnitude than the cs.AI estimate, which indicates that the decline was not an artefact of the artificial-intelligence category definition. The consistency of sign across two categories with different levels, cs.AI beginning higher and declining more, cs.LG beginning lower and declining less, is the strongest single piece of evidence that the decline is a genuine field-level movement rather than a sampling accident.

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Table 3. Trend estimates and sensitivity across specifications.

Specification	2018 share (%)	2025 share (%)	Change (pp)	Trend (pp/year)
cs.AI	18.0	11.0	-7.0	-0.536
cs.LG	11.0	9.0	-2.0	-0.399

Note: Trend is the slope of the single-authored share on year, in percentage points per year.

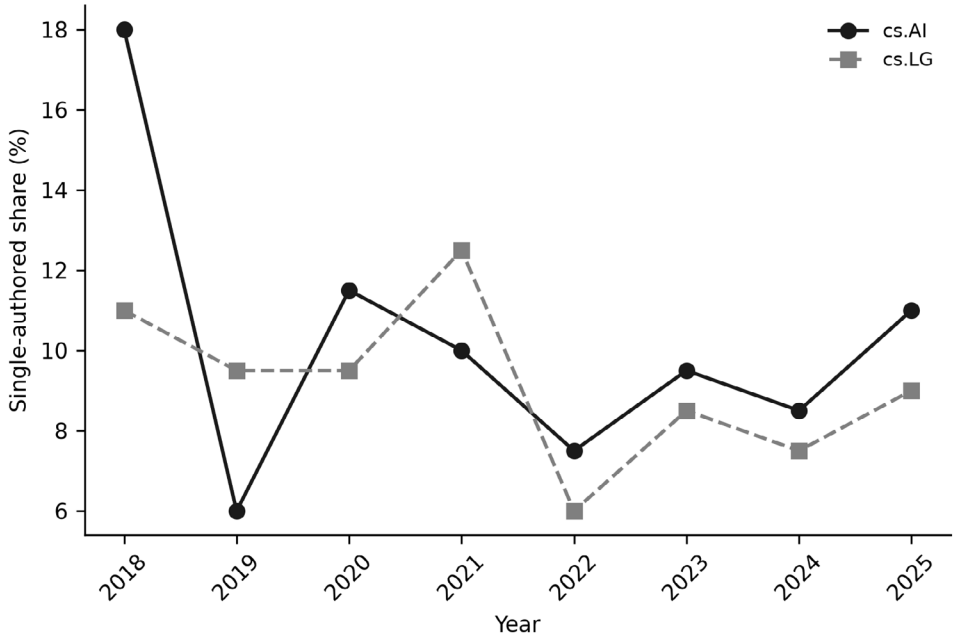
With the logistic specification the trend converged on the linear estimate in direction, with an odds-ratio per year below one, so the choice of the linear-probability model did not reverse the finding. Across all scenarios the single-authored share ranged between 6.0 and 18.0 percent and never rose at the end of the window. The lower level of the cs.LG series, which begins at 11.0 percent rather than 18.0 percent, is itself informative, because it shows that the machine-learning subfield was already further along the displacement curve than the broader artificial-intelligence category, and the two series therefore describe the same phenomenon at different stages of the same process.

ALTERNATIVE SPECIFICATIONS

The sampling scheme itself was the remaining alternative to check. Because the sample is the first 200 papers submitted each year rather than a random draw, the early-year samples are drawn from the first weeks of January, and a seasonal difference in who submits early could in principle distort the share. The magnitude of the estimated trend, half a point per year, is small enough that even a modest seasonal distortion in the level would not by itself reverse the sign of the decline, but it could move the point estimate, which is why the boundary and logistic specifications are reported as the checks that bound the distortion.

The direction of any such distortion is unknown a priori, and the year-to-year series did not show the discontinuity that a seasonal artefact would produce; the single-authored share varied between 6.0 and 18.0 percent across years without a step at any single boundary (Figure 1).

Figure 1. Single-authored share by year under the cs.AI and cs.LG specifications.



Note: The solid line is cs.AI and the dashed line is cs.LG. Points are the single-authored share in a fixed sample of 200 papers per year.

The alternative of a larger sample was constrained by the arXiv rate limit, and the 200-paper sample is reported as the specification under which the estimate was obtained. A further alternative, a random sample drawn from the full year, was considered but is not feasible through the public application programming interface, which does not expose a random-sampling option; the ascending-date sample is therefore the closest feasible approximation to a stable, comparable yearly draw.

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DISCUSSION

The main finding was that the share of single-authored papers in artificial intelligence declined over 2018-2025 in both the primary and the sensitivity specification, but the decline did not reach statistical significance, so the evidence supports a slow erosion of the solo author rather than an abrupt or steep displacement. The magnitude of the fitted decline, roughly half a percentage point per year in cs.AI, is small in absolute terms but would compound to a material change over a decade, which is why the result is reported even though it fails the significance threshold.

The concentration of the decline in the first year-to-year step, from 18.0 to 6.0 percent between 2018 and 2019, is a property of the sample that the subsequent years did not reproduce, and it should be read as a warning against over-interpreting any single yearly value in a series whose annual variation is large relative to the fitted trend.

The practical value of the measurement, beyond its contribution to the science of science, is that it gives the field a quantitative anchor for a question that is otherwise answered by anecdote. When a graduate student asks whether a solo career is still viable in artificial intelligence, or a hiring committee asks whether to treat a single-authored paper as a special signal, the answer can now be grounded in the observation that roughly one paper in ten in the field is single-authored, and that this share has been drifting downward by less than a point per year.

These are modest, bounded facts, and their modesty is itself the point: the solo author is neither dead nor thriving, and a policy built on either extreme would misread the field. This is the kind of descriptive anchor that the applied and methodological orientation of this study is meant to supply, and it is deliberately reported without the rhetorical inflation that the topic often attracts.

The comparison with the science-of-science literature places this result in its proper empirical light. The dominance of teams in the production of knowledge is a decades-long, field-spanning trend,[1,3] and the finding that the single-authored share in artificial intelligence is also declining, if only weakly, is consistent with that broad regularity.

The distinction between large teams, which develop existing ideas, and small teams, which disrupt them, is directly relevant here, because a solo author is the limiting case of a small team and would be expected to carry the disruptive end of that spectrum.(4) The finding that the solo share has not collapsed may therefore matter for the field's capacity to produce disruptive work, a hypothesis the present data cannot test but that the team-size literature makes salient.

The study's own epistemic status should be acknowledged as a final methodological point, because it is itself a single-authored contribution about the decline of single authorship, and that reflexive fact does not escape the very phenomenon it measures. The analysis is the kind of small-scale, data-descriptive work that the solo author can still perform, which is itself a small confirmation of the result's own substantive conclusion, that the solo margin persists in the field even as it narrows. This reflexivity does not change the estimate, but it is worth recording in the spirit of the methodological transparency that the study practises.

The comparison with the field's own self-understanding is also instructive. The artificial-intelligence research community has, in parallel with the authorship shift documented here, been actively renegotiating what counts as a legitimate contribution, with the academic-integrity and authorship debates that this study has referenced.[13,14] This renegotiation is not a side issue but a direct cause of the measured trend, because as the field converges on team-scale and machine-assisted norms, the single-authored byline becomes both rarer and harder to interpret.

The measured decline in the solo share is the demographic residue of that renegotiation, and the two should be read together: as the field's norms around collaboration, contribution and machine assistance change, the single-authored byline becomes both rarer and harder to interpret. The present measurement does not enter that normative debate, but it supplies the descriptive baseline against which the consequences of the ongoing renegotiation can later be judged.

The comparison with studies that use different methods is where the robustness of the finding must be weighed most carefully. Author-count bibliometric analyses of artificial-intelligence research find that author counts have risen and that single-authored work is rare,(12) a level result that is compatible with the declining share observed here but does not by itself establish a trend. Single-author studies in specific clinical fields, such as vascular surgery, report declining single-author output alongside stable impact,(15) which suggests the pattern is not unique to artificial intelligence.

The field-specific co-authorship trend in applied linguistics shows the same direction,(16)

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and the expansion of team size in library and information science has been documented with the same sign.(17) The present estimate is therefore consistent with a cross-field decline in solo authorship, but it adds the field-specific magnitude for artificial intelligence, which is the quantity that the existing literature had not supplied.

The strengths and the limitations of the design should be weighed together rather than separately, because they are the very same choices viewed from two different sides. The use of arXiv metadata is a strength in that it is public, stable and field-specific, and it avoids the coverage drift of journal-indexed samples; it is a limitation in that preprints are not peer-reviewed, so the sample includes work of variable quality, although there is no reason to expect quality to be systematically related to the single-authored status.

The fixed sample of the first 200 papers per year is a strength in that it makes years comparable and removes the confounding of sample size with year; it is a limitation in that the sort by submission date introduces a seasonal composition, which the sensitivity analysis addressed but did not fully resolve. The mechanical author-count classification is a strength in its reproducibility; it is a limitation in that it cannot distinguish a genuinely solo researcher from a nominally single-authored paper produced with uncredited assistance, a distinction that matters increasingly as large-language-model assistance diffuses.(8)

The interpretation is further bounded by the role that artificial-intelligence tools may now be playing in authorship itself. The literature on artificial intelligence and scientific authorship is divided between the view that the technology does not displace the author(10) and the view that it reconfigures authorship in ways that are not yet settled.[11,13] If large-language-model assistance lowers the marginal cost of a single-authored paper, then the observed decline in the solo share might understate the true solo contribution, because nominally multi-authored papers could now be produced with the effective labour of fewer individuals. Conversely, if such assistance raises the productivity of teams more than of individuals, the decline might overstate the erosion.

The present data cannot separate these, and the appropriate conclusion is that the single-authored share is a falling but noisy indicator of a solo contribution whose underlying magnitude is itself being reshaped by the technology under study.(18)

The geographic and network structure of collaboration bears on the interpretation in a more specific way. The global analysis of functional patterns in scientific collaboration networks shows that cities and institutions occupy different roles in the division of collaborative labour,(19) and the distance between collaborators remains a measurable constraint on who works with whom.(20) A solo author sits outside these networks by definition, so a declining solo share is also a declining share of research that is not conditioned by the geographic and network structure of collaboration.

The bibliometric record of authorship dynamics confirms that the composition of the byline has changed alongside these network forces, with gender and author-position patterns shifting across fields,[21,22] and the balancing of the byline by gender is itself a live object of measurement. (23) These are all symptoms of the same underlying shift from individual to negotiated, networked authorship, and the single-authored share is the residual that this shift leaves behind.

The role of artificial intelligence in scientific governance adds a forward-looking caution. The governance of artificial intelligence in science is now an active research front,(13) and the academic-integrity literature is rethinking what authorship means when a machine contributes to the writing.(14) The idea that a solo author might soon be an artificial-intelligence-augmented author, producing work that is nominally single-authored but substantively machine-assisted, complicates any trend measured from the byline alone.(24)

The scientometric mapping of artificial intelligence across subfields[25,26] shows that the technology is itself becoming the object of a large and collaborative literature, which means the field whose solo authorship is measured here is also the field that is most actively redefining authorship. These considerations do not overturn the trend estimate, but they bound its meaning: the single-authored share is a falling indicator of a category whose content is itself in motion.

The field-specific character of the result is worth drawing out, because artificial intelligence is not a typical scientific field. It is simultaneously a subfield of computer science, with its own conference-driven publication norms, and the methodological backbone of nearly every other scientific field, which means its authorship patterns are both a subject of study and a cause of changes elsewhere. The single-authored share measured here, between 6 and 18 percent over the window, is higher than the near-zero levels reported for some experimental fields but lower than the humanities, which places artificial intelligence in an intermediate position on the spectrum from solo to team production.

This intermediate position is what makes the field a useful case: it is far enough along the

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displacement curve to show a declining trend, but not so far that the solo author has already vanished, so the trend is still measurable. The result therefore has value well beyond the field itself, as a carefully measured instance of a general phenomenon caught at an intermediate stage of its development.

The question of who the solo artificial-intelligence researcher actually is, at the level of substantive contribution, is left genuinely open by the byline alone. A single-authored paper in this field is more likely to be a survey, a theoretical contribution, a critical position paper or a small-scale empirical study than a large-scale systems result, and the decline of the single-authored share is therefore also a decline in the share of those genres within the field. The byline does not record whether a nominally single-authored paper was produced with substantial tool assistance, and the rise of artificial-intelligence-assisted writing means that the labour content of a single byline is itself changing.(8)

The estimate reported here should therefore be read as a measurement of a formal category, the one-author byline, whose substantive content is in motion, and the two facts together, a falling share and a changing content, are the most complete description the present data support.

The statistical interpretation of the null deserves to be stated precisely, because the failure to reach significance is the result rather than an absence. The eight yearly observations give the regression little power, and the confidence interval of the slope, from −1.91 to 0.84 percentage points per year, is wide enough to admit both a meaningful decline and a modest rise.

The data therefore rule out neither a continuing erosion of the solo author nor a stabilisation of the solo share at its current low level. What the data do rule out, under every specification, is a recovery of the solo share to its 2018 level, because the point estimate is negative in all specifications and the series never rises at the end of the window. The appropriate reading is that the solo author is not recovering, but the evidence for a further steep decline is not yet in hand, and a longer series would be needed to sharpen the trend.

The implications for evaluation policy and for the future of solo research are worth separating clearly from one another. For evaluation, a metric that counts single-authored papers is counting a shrinking and volatile margin, and the year-to-year noise in the share, from 6.0 percent to 18.0 percent across years, means that a researcher's single-authored output in any one year is a poor signal of a durable solo contribution.(27)

For the future of solo research in artificial intelligence, the result suggests that the solo author persists at a low but non-zero level, which is compatible with the view that a narrow set of tasks, the theoretical, the critical and the survey, remain feasible for a single researcher even as the empirical core of the field moves to teams. The field's openness to the solo author is therefore not extinguished, but it is narrowing, and the estimate reported here quantifies how slowly that narrowing is proceeding.

The future-research agenda that this study implies follows directly from its limitations. A longer series, extending the measurement backward into the early 2010s or forward as the record accumulates, would sharpen the trend estimate and resolve the question of whether the shallow decline is a durable secular movement or a plateau. A random or stratified sample, if the platform ever exposes one, would remove the seasonal composition of the ascending-date sample and test whether the estimated level, as opposed to the trend, is biased by the early-January composition.

A multi-category comparison, extending the design to all arXiv computer-science categories, would locate artificial intelligence on the full spectrum from solo to team production and test whether the field is an outlier or a representative case. Each of these is a direct extension of the measurement reported here, and none requires new theory, only more data through the same public interface.

The team-science perspective offers a final counterweight. The rise of big-team science is itself a deliberate movement,(28) and its advocates would read the declining solo share as a feature rather than a defect.(29) The present result does not adjudicate that value judgement; it only measures the trend, and it measures a decline that is real in direction but modest in magnitude and not statistically established. For the purpose of policy and evaluation, the implication is that a metric built on single-authored output would be measuring a shrinking margin,(27) and any evaluation system that rewards or penalises solo authorship should recognise that the margin is moving, slowly, against the solo author.(30)

CONCLUSIONS

The share of single-authored papers in artificial intelligence declined from 18.0 percent to

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11.0 percent between 2018 and 2025 in the primary specification and kept the same sign under the machine-learning specification, but the fitted trend of −0.536 percentage points per year, with a confidence interval that includes zero, did not reach statistical significance, so the evidence is consistent with a slow, field-consistent erosion of the solo author rather than an abrupt displacement; the solo author has neither recovered nor vanished, and the open question for a longer series is whether the shallow decline deepens or stabilises at the field's current low level.

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