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Market power of publishers in setting article processing charges for open access journals

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Abstract
While open access journals provide readers with articles free of charge through the journals' networks, authors are required to pay article processing charges to the publishers. This study simultaneously estimates the article processing charges for 535 open access journals independently launched by publishers along with citation scores and number of articles in a journal to identify the determinants of charges. The results show that open access journal publishers set higher article processing charges for more frequently cited journals with more articles. However, concentration measured by the share squared of the number of articles in an academic field is not shown to influence the charges significantly. Moreover, this study finds that large subscription journal publishers do not generally set higher article processing charges for their open access journals. Instead, they incorporate open access journal publishers that have already accomplished great achievements into their company groups. These findings suggest that large subscription journal publishers may influence the open access journal market through mergers and acquisitions of prominent open access journal publishers in the future, although they do not yet have market power.

Keywords Open access journal · Article processing charge · Market power

JEL Classification L11 · L86

Introduction

Since the 2000s, open access journals, which provide academic literature free of charge, have developed in response to penetration of the Internet and increasing prices of subscription journals.[1] Alongside this market growth, traditional subscription journal publishers have

[1] There are three types of open access journals: gold, green, and hybrid. Gold open access articles are freely available from when they are first published. Green open access articles are deposited in a repository according to the journal's self-archiving policies. Hybrid journals are subscription journals that give authors the option of open access. This study examines only gold open access journals.

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also launched many open access journals. Based on the Directory of Open Access Journals (DOAJ), the top 10 publishers of open access journal titles in July 2019 included Sciendo, Elsevier, BMC, Wolters Kluwer, Springer, SAGE, Taylor & Francis, and Wiley—all traditional subscription journal publishers or publishers belonging to a company group. While open access journals provide articles at no charge through the journals' networks, authors are required to pay article processing charges (APCs) to publishers. In other words, the burden of journal production costs has passed from university libraries as buyers to individual authors as suppliers. Shulenburger (2016) argued that the increase in the prices of subscription journals is partly caused by the imbalance of market power between libraries and large journal publishers. In addition, Shulenburger (2016) stated that it may be easier for publishers to raise the APCs for open access journals than prices for subscription journals, since individual authors have even less ability than libraries to negotiate charges with publishers. Thus, the open access journal business is worth examining from the viewpoint of competition policy.

Although open access journal publishers impose APCs on authors, Shamash (2016) stated that APCs are often paid by research institutions to which authors belong or research funders, and that the APCs paid by institutions in the UK significantly increased from 2013 to 2015. Pinfield et al. (2017) investigated the payments for both subscription journals and APCs by research institutions in the UK, finding that their expenditure on APCs accounted for 11.8% of all expenditure on academic literature in 2014. Therefore, APC levels are important for not only authors but also research institutions.

Regarding open access journals, there are three journal categories by publisher type. The first type are journals independently launched by a research institution, generally financed by the institution's funds. Such research institutions usually impose either no APC or reduced APCs. The second type are journals independently launched by an open access journal publisher, such as PLOS, or a subscription journal publisher, such as Elsevier, and most of these journals are financed by APCs. The third type is a combination of the first two, that is, journals published in collaboration between a research institution and a journal publisher, wherein the institution often covers the APCs or parts thereof. Several large subscription journal publishers, such as Elsevier and Springer, have published many open access journals on behalf of research institutions, helping them grow rapidly in the open access journal market. For such journals, it is not possible for third parties to identify whether the relevant APCs comprise the full or reduced amount. Considering that the first and third types of journals may bias the estimation of APCs, this study focuses on the second type, that is, open access journals independently launched by subscription journal publishers or open access journal publishers, to compare APCs under the same conditions.

Dewatripont et al. (2007) estimated subscription journal prices considering the endogeneity of impact factors representing frequency of citations. Dubois et al. (2007) simultaneously estimated demand with price and impact factor to solve the endogeneity problem. In the case of open access journals, the endogeneity between price and the number of articles should be examined in addition to that between price and frequency of citations, because revenues of open access journal publishers depend on price and number of articles. Therefore, this study simultaneously estimates the three equations of APC, number of articles, and frequency of citations to identify the APC determinants after solving the endogeneity problem. This study provides material for the design of competition policy by examining whether publishers exert market power in setting their APCs for open access journals.

The rest of this paper is organized as follows. The next section surveys the related literature. The third section explains the model and data used for APC estimations, and the fourth section reports the estimation results. The fifth section discusses the implications of the findings and the final section presents the conclusion.

Related literature

Since APCs for open access journals correspond to prices for subscription journals, empirical studies on subscription journal prices and analyses of APCs for open access journals are significant for the present study. Petersen (1990) estimated the subscription prices of academic journals using such variables as number of issues, advertising, number of pages, type of publisher, and academic field by ordinary least squares (OLS), and reported that the library prices of journals launched by for-profit publishers are higher than those launched by non-profit associations. Subsequently, Petersen (1992) estimated subscription journal prices by adding the variables of journal citation count and number of circulations per issue and reported that the APCs for more frequently cited journals are higher and that publishers enjoy economies of scale. Chressanthis and Chressanthis (1994) estimated the library prices of economic journals using variables representing the number of circulations, citation count, and type of publisher by OLS. They found that frequently cited journals set higher prices and publishers enjoy economies of scale.

Although subscription journal prices were often empirically studied in the early 1990s, researchers' interest in the issue has gradually waned with the penetration of the so-called 'Big Deal' bundling service, in which the publisher provides all electronic journals under the condition that research institutions continue to purchase the subscription journals. In addition, Bergstrom (2001) pointed out that data on the number of circulations of a journal were not available after around 2000, posing an obstacle to estimating subscription journal prices. Nevertheless, considering that the pricing of such bundling services is based on individual subscription journal prices, Dewatripont et al. (2007) estimated journal prices for libraries using variables denoting citation score, type of publisher, and academic field, finding that for-profit publishers set higher prices than academic societies and that citation score had a positive impact on prices. Moreover, they investigated the relationship between prices and journal market shares of publishers, finding that publishers with greater shares set higher prices. Liu (2011) estimated the prices of subscription journals in business areas (accounting, economics, finance, management, and marketing) using a semi-logarithmic equation by OLS and found that the coefficient of for-profit publishers is significantly positive. Coomes et al. (2017) estimated the prices of subscription journals in geography by OLS and found that for-profit publishers, particularly those with large journal market shares, set higher prices. Liu and Gee (2017) estimated subscription journal prices in science, technology, and medicine using a semi-logarithmic equation and concluded that for-profit publishers overcharge libraries. These studies suggested that large subscription journal publishers exert monopoly power when setting prices. By contrast, Dubois et al. (2007) estimated the demand for subscription journals by an aggregated nested logit model with price and impact factor equations, finding that price elasticities are high, and therefore, profit margins are relatively low.

Regarding open access journals, Crawford (2018) and Morrison (2018) surveyed the market and its trends, including APCs. Solomon and Björk (2012) reported that the APCs for biomedical journals are higher than those for journals in the social sciences and arts and humanities, indicating that APCs differ among academic fields. In addition, Solomon and Björk (2012) showed that the APCs for frequently cited journals tend to be higher; Wang et al. (2015) reported a similar trend. Björk and Solomon (2015) calculated the correlation coefficient between APCs and citation indexes in Scopus in 2011 and reported that the journal-level and article-level correlations are 0.40 and 0.67, respectively. Pinfield et al. (2017) reported a strong positive correlation between APCs applied in 2014 and citation

scores in Scopus. Asai (2019a) estimated the APCs that BMC (formerly BioMed Central) applied in 2018 by a sample selection model, since some journals do not impose any APCs. Asai (2019a) found that BMC sets higher charges for more frequently cited journals. Furthermore, Asai (2019b) estimated the APCs for 509 medical open access journals by a sample selection model, finding that publishers generally set higher APCs for frequently cited journals. However, two-thirds of the 509 journals do not impose any APCs and the number of APC-funded journals independently launched by publishers is small. Therefore, further research using more samples is needed to conclude whether journal publishers exert market power when setting APCs.

Model and data

Target journals

This study focuses on open access journals independently launched by publishers to compare APCs under the same conditions. Information on whether each journal has been published on behalf of a research institution or independently launched by a publisher is gathered from publishers' websites and the DOAJ database. Where information on a research institution is lacking, this study considers the journal as independently launched by a publisher. All journals are indexed in the DOAJ and have citation scores in 2017 calculated by Scopus. Journals that were discontinued or transferred to other publishers are excluded. Journals that did not publish any articles in 2017 are also excluded. This study targets open access journal publishers that publish more than five journals to examine the APCs by individual publishers.

For the analysis, this study compiles data from Scopus for 535 APC-funded journals launched by traditional subscription journal publishers (Elsevier, SAGE, Springer, Taylor & Francis, and De Gruyter) as well as BMC, Dove Medical Press, Nature, Frontier Media S. A., Hindawi, MDPI AG, and PLOS. Although BMC was initially an independent open access journal publisher, it has been part of Springer Nature since 2008. Nature was incorporated into the Springer Group in 2015. Dove Medical Press, an independent open access journal publisher founded in 2003, has been part of Taylor & Francis since 2017. Although Hindawi was formerly a subscription journal publisher, it converted to an open access journal publisher. This study refers to Elsevier, SAGE, Springer, and Taylor & Francis as big publishers,[2] and to BMC, Nature, and Dove Medical Press as a subgroup of the big publisher group. Furthermore, this study refers to Frontier Media S. A., Hindawi, MDPI AG, and PLOS as independent publishers that provide open access journals.

Model

Open access journal publishers have an incentive to accept many articles, because their revenues are in direct proportion to the number of articles published. This relationship leads to criticism that several open access journals are 'predatory' for having published articles

[2] In this study, there are four publishers (Elsevier, SAGE, Springer, and Taylor & Francis) in the Big 5. Since there are only three journals independently launched by Wiley, which is one of the Big 5, Wiley is not included in the observations.

without proper peer reviews to earn more APC revenues. Nevertheless, such journals are not included in the observations, because the 535 APC-funded journals in the sample are compiled from Scopus and are indexed in the DOAJ.

APC, number of articles, and citation score may be related to each other. For example, the editors of journals that attract many article submissions may narrow down the submitted articles through strict peer review to maintain large citation scores. Consequently, lower acceptance rates due to strict peer reviews may increase editorial costs, leading to higher APCs. On the contrary, the publication of many articles may decrease the cost per article based on economies of scale, leading to reduced APCs. By contrast, unfamiliar journals that cannot receive many articles may discount APCs or set lower APCs to attract article submissions. Whether the influences of the number of articles and citation score on APCs are positive or negative is unknown a priori, but the problem of endogeneity in the APC estimation caused by the relationships between APC and number of articles and between APC and citation score needs to be considered to identify the determinants of APCs precisely.

Dewatripont et al. (2007) estimated subscription journal prices using instrumental variables, such as lagged citations and journal age, considering the endogenous relationship between price and citation score, although they did not refer to the endogeneity test result. Dubois et al. (2007) estimated demand for subscription journals, constructing a simultaneous equation model consisting of three equations for demand by libraries, journal price, and impact factor considering endogeneity. Since APC, citation score, and number of articles for open access journals may be interdependent, the present study simultaneously estimates the three dependent variables by three-stage least squares (3SLS).

Variables

When previous empirical studies estimated prices for subscription journals, they used independent variables, such as publisher type, number of articles, citation score, number of years since a journal's inception, publishing country, and academic field. Although this study uses the number of articles, citation score, number of years since the journal's inception, publisher type, and academic field as independent variables for the APC estimation, the variable denoting publishing country is not used for two reasons. First, open access journals do not incur printing costs; editorial work can be undertaken via a network anywhere in the world. Therefore, it seems that publishing cost does not significantly depend on the location of journal publication. Second, most of the 535 journals in the sample are published in the UK.

The publishers announce the APC for a designated year in the year before, at the latest. Since it is assumed that APCs applied in 2019 were determined in 2018, publishers use the number of articles in a journal and the citation score in 2017, as these comprise the most recent data available. The three equations are specified as follows.

$$\begin{aligned} ln\ APC = {} & \alpha_0 + \alpha_1 ln\, Article + \alpha_2 SNIP17 + \alpha_3 Year + \alpha_4 Share^2 + \alpha_5 Case \\ & + \alpha_6 Big + \alpha_7 Subgroup + \alpha_8 Independent + \alpha_9 Medicine \\ & + \alpha_{10} Science + \alpha_{11} Technology \end{aligned} \tag{1}$$

$$\begin{aligned} SNIP17 = {} & \beta_0 + \beta_1 SNIP16 + \beta_2 SNIP15 + \beta_3 Year + \beta_4 Case + \beta_5 Big \\ & + \beta_6 Subgroup + \beta_7 Independent \end{aligned} \tag{2}$$

$$\begin{aligned} ln\ Article = {} & \gamma_0 + \gamma_1 ln\ Citation + \gamma_2 Year + \gamma_3 Case + \gamma_4 Big + \gamma_5 Subgroup \\ & + \gamma_6 Independent + \gamma_7 Medicine + \gamma_8 Science + \gamma_9 Technology \end{aligned} \quad (3)$$

Regarding Eq. (1), the dependent variable is APC for original articles in 2019 measured in USD. ln represents the natural logarithm. The independent variable *Article* is defined as the number of articles in a journal in 2017. Instead of impact factor and CiteScore, this study uses the source normalized impact per publication (SNIP) as an index denoting the scale of citation, for the following two reasons. First, this score is calculated as the number of citations given in the present year divided by the total number of articles published in the past 3 years, and is normalized to correct for differences in citation practices between academic fields. Since this study covers journals across various academic fields, SNIP is selected as an independent variable to compare citation scores in different disciplines. Second, this study uses the past SNIP scores as independent variables. SNIP can be tracked to past data other than CiteScore. Since the history of open access journals is generally short, it is valuable that scores from several years ago are available. *Year* is defined as the number of years since the inception of the open access journal (2019 = 1). The DOAJ reports the academic fields for individual journals based on the Library of Congress Classification. The top three academic fields for the 535 journals are medicine (308 titles), science (115 titles), and technology (75 titles). Academic fields for the remaining 37 journals comprise agriculture, education, fine arts, general works, history, language and literature, philosophy, and social science. Journals in either medicine, science, or technology account for 93.1%, denoting that open access journals have penetrated the natural sciences field more than social sciences and arts and humanities. The variable *Medicine* is set to 1 if the journal is in medicine, and 0 otherwise; the same method is followed for the variables *Science* and *Technology* denoting academic fields. Since the 37 journals have a wide range of academic fields and the number of journals in an academic field is small, a variable denoting these academic fields is not used. The variable *Big* is set to 1 if the journal is independently launched by one of the four large subscription journal publishers, and 0 otherwise. The variable *Subgroup* is set to 1 if the journal is independently launched by one of the three publishers that belong to the big publisher group, and 0 otherwise. The variable *Independent* is set to 1 if the journal is launched by one of the four independent open access journal publishers, and 0 otherwise. A few publishers publish medical journals with titles that include the term 'case report'. Generally, the articles in case reports are short, and each case report publishes many articles. This study identifies whether the journal is a case report based on its title. *Case* is set to 1 if the journal has a title that includes the term 'case report', and 0 otherwise. The variable *Share* is the number of articles in a journal divided by the total number of articles in the academic field in the DOAJ database and is measured in percentage. *Share* squared corresponds to the Herfindahl–Hirschman index representing the market concentration.

Regarding Eq. (2), journals that acquired large SNIPs attract the attention of researchers, leading to subsequent large SNIPs through submission of excellent articles. Since it is assumed that a journal's SNIP level has continuity, this study uses lagged *SNIPs* as independent variables in Eq. (2), following previous studies, such as Dewatripont et al. (2007) and Dubois et al. (2007). On the contrary, the variables denoting academic field are not used in Eq. (2), because SNIP corrects for differences in citation practices between fields.[3]

[3] Although this study estimated the SNIP equation, including the variables representing academic field, the null hypotheses that the coefficients equal 0 were not rejected at the 10% level.

Table 1 Summary of statistics

	APC	*Article*	*SNIP17*	*SNIP16*	*SNIP15*	*Citation*	*Year*	*Share*
Mean	1791	250	1.047	1.009	0.965	3785	10.46	0.105
Median	1900	56	0.967	0.948	0.913	605	10.00	0.017
Maximum	5200	25,341	6.143	6.032	7.627	562,298	23	10.05
Minimum	250	2	0.059	0.000	0.000	3	2	0.001
SD	750.4	1460.3	0.582	0.555	0.604	25,730	4.555	0.559
CV (%)	41.9	584.3	55.6	55.0	62.5	679.8	43.6	530.3
Skewness	0.603	15.111	3.683	3.592	3.907	19.537	0.428	12.947

SD standard deviation, *CV* coefficient of variation

Equation (3) estimates the number of articles in a journal, which is one component of APC revenues. Independent variables in Eq. (3) comprise the number of citations in 2016 in addition to the variables representing publisher type, number of years since launch, and academic field. A large number of citations denotes that many readers have already read the articles in the journal, that is, there is large demand for the journal. This study uses the variable *Citation* as the number of citations in 2016, to represent the relationship between the number of articles published as supply and the size of the readership base as demand.

Tables 1 shows a summary of the statistics of the variables, excluding dummy variables, for the 535 journals. The means of *SNIPs* steadily increase from 2015 to 2017, indicating that open access journals have gradually increased in importance in academia. The coefficients of variation for *Article*, *Citation* and *Share* are more than 500%, denoting that the variations are remarkably large. For all variables, the values of skewness are positive, denoting that the distributions have long right tails.

Table 2 reports the means and standard deviations for the eight variables by publisher type. The mean *APC* for journals launched by Big publishers is 1443 USD, which is the lowest among the three publisher types. Since Dewatripont et al. (2007) reported that large publishers generally set higher prices for their subscription journals than non-profit publishers and other for-profit publishers, it seems that the position of large subscription journal publishers differs between subscription journals and open access journals. While the mean *Year* for Subgroup publishers is 13.457 years, that for Big publishers is 6.598 years. In addition, the numbers of articles and citations and mean SNIP for journals launched by Big publishers are smaller than those for Subgroup publishers. However, SNIPs for Big publishers significantly increase from 0.833 in 2015 to 1.008 in 2017. Although Big publishers are latecomers to the open access journal business compared with Subgroup publishers, their presence has been growing.

The mean *APC* for journals launched by Subgroup publishers is the highest at 2309 USD, and the null hypothesis that the mean *APC* equals those for journals launched by the other two types of publishers is rejected at the 1% level. The mean SNIP for journals launched by Subgroup publishers is significantly larger than that for other journals at the 1% level. Moreover, the Subgroup publishers publish many articles in a journal, irrespective of their higher APCs, although there is no statistically significant difference in the number of articles among the three publisher types. Larivière et al. (2015) reported that large subscription journal publishers have increased the number of articles by mergers with other publishers. Since Big publishers have incorporated Subgroup publishers into their groups, it seems that large subscription journal publishers have extended their open access journal positions in the same way in the subscription journal market.

Table 2 Mean and standard deviation by publisher type

	Big	*Subgroup*	*Independent*	Other	Total
APC	1443	2309	1529	1262	1791
	(770.0)	(463.2)	(710.2)	(242.7)	(750.4)
Article	116.3	292.5	298.7	46.6	249.9
	(169.5)	(1830)	(1519)	(42.8)	(1460.3)
SNIP17	1.008	1.154	0.995	0.639	1.047
	(0.862)	(0.534)	(0.400)	(0.227)	(0.582)
SNIP16	0.976	1.091	0.969	0.733	1.009
	(0.849)	(0.437)	(0.436)	(0.316)	(0.555)
SNIP15	0.833	1.091	0.928	0.836	0.965
	(0.917)	(0.483)	(0.442)	(0.643)	(0.604)
Citation	1031	4329	5056	344.8	3785
	(2457)	(12,771)	(39,376)	(344.8)	(25,730)
Year	6.598	13.457	9.986	7.429	10.456
	(4.100)	(3.998)	(3.219)	(3.652)	(4.555)
Share	0.077	0.071	0.160	0.017	0.105
	(0.182)	(0.349)	(0.818)	(0.016)	(0.559)
Number	117	197	207	14	535

The first row reflects the mean and the second row reflects the corresponding standard deviation.

Big: Elsevier, SAGE, Springer, and Taylor & Francis. Subgroup: BMC, Dove Medical Press, and Nature. Independent: Frontier Media S. A., Hindawi, MDPI AG, and PLOS. Other: De Gruyter

Estimation results

This study tests for endogeneity of the variables *Article* and *SNIP17* in Eq. (1) by the Hausman test. The results show that the number of articles is an endogenous variable, while the null hypothesis that *SNIP17* is an exogenous variable is not rejected at the 10% level. Although this study simultaneously estimates the two equations of *APC* and *Article* based on the endogeneity test result, the coefficients in the APC equation are almost the same as those for estimating the three equations simultaneously. Therefore, only the results of estimating the three equations simultaneously by 3SLS are reported in Table 3.

Regarding Eq. (1), the coefficient of the variable *Article* is significantly positive at the 1% level, denoting that journals with more articles set higher APCs. Since revenues of open access journal publishers are determined by the number of articles and APC level, a positive relationship between the number of articles and APC generates a large difference in revenues among open access journal publishers. The coefficient of the variable *SNIP17* is significantly positive at the 10% level, indicating that publishers set higher APCs for journals more frequently cited. If the *SNIP17* for each of the 535 APC-funded journals rose by one point, then the mean estimated APC would rise by 80 USD using the estimates and variables for individual journals. If the *Article* count for each of the 535 journals increased by 50, then the mean estimated APC would rise by 216 USD using the estimates and variables for individual journals.

The coefficients of the variables representing publisher type show that Subgroup publishers belonging to big publisher groups set higher APCs than the Big publishers themselves set. If the 535 APC-funded journals were launched by the Big publishers, then

Table 3 Estimation results: publisher type

	ln APC (1)	*SNIP17* (2)	*ln Article* (3)
Constant	6.3950 (0.1089)***	0.0332 (0.0902)	0.9290 (0.3317)***
ln Article	0.1523 (0.0135)***		
SNIP17	0.0481 (0.0280)*		
SNIP16		0.7570 (0.0349)***	
SNIP15		0.1436 (0.0324)***	
ln Citation			0.6910 (0.0277)***
Year	−0.0019 (0.0037)	−0.0092 (0.0037)**	−0.0508 (0.0122)***
$Share^2$	0.0010 (0.0030)		
Case	−0.8638 (0.0838)***	−0.0392 (0.0846)	1.8693 (0.2641)***
Big	0.0086 (0.0893)	0.1806 (0.0896)**	−0.1710 (0.2809)
Subgroup	0.4393 (0.0916)***	0.2629 (0.0901)***	−0.1758 (0.2860)
Independent	0.0224 (0.0869)	0.1882 (0.0876)**	−0.1569 (0.2733)
Medicine	0.2386 (0.0556)***		−0.7001 (0.1739)***
Science	0.2082 (0.0599)***		−0.7306 (0.1877)***
Technology	0.0940 (0.0625)		−0.5312 (0.1954)***
SE of Reg.	0.3087	0.3167	0.9727

Determinant residual covariance 0.0081

Standard errors are in parentheses. *SE of Reg.* standard error of regression

***1%, **5%, and *10% significance levels

the mean *APC* calculated using the estimates and variables for individual journals would decrease by 265 USD from the estimated mean APC. If all journals were launched by Subgroup publishers, then the APC would increase by 497 USD. If the journals were launched by Independent publishers, then the estimated APC would decrease by 226 USD. The coefficient of the variable *Share* squared is close to 0 and the null hypothesis that the value equals 0 is not rejected at the 10% level. Although Coomes et al. (2017) reported that publishers with large share set higher prices for their subscription journals, this study does not find a significant relationship between APC and concentration. It seems that the position of large subscription journal publishers differs between the subscription journal and open access journal markets. The three coefficients of variables denoting academic field are positive, implying that journals in natural sciences, such as medicine, science, and technology, set higher APCs than those in social sciences and arts and humanities. The results are consistent with those of Solomon and Björk (2012).

Regarding Eq. (2), the coefficients of *SNIP15* and *SNIP16* are positive and large. Once journals acquire reputation, excellent articles are subsequently submitted to them, which enhances the journal evaluation. Thus, the level of citation score is maintained for a long period through such a relationship between large citation scores and submissions of excellent articles. In addition, this study reports that the coefficients of the three variables representing publisher type are significantly positive at the 1 or 5% level and the coefficient of *Subgroup* is the largest.

Regarding Eq. (3), the coefficient of the variable *Citation* is significantly positive at the 1% level. A large number of citations denotes that many readers read the articles in the journal. A large readership attracts many submissions, leading to the publication of many articles, although the acceptance rate is also an important factor in the number of articles

published.[4] Judging from the three coefficients of variables representing publisher type, publisher type does not significantly influence the number of articles. By contrast, the coefficients of variables representing academic field are significantly negative at the 1% level, denoting that journals in natural sciences publish less articles than those in the social sciences and arts and humanities after controlling other variables. Since many open access journals have been launched in natural sciences, the number of articles in a journal may have reduced.

Case reports are generally read for practical use rather than academic perspective. A large positive coefficient of *Case* in Eq. (3) denotes that case reports accommodate more articles than ordinary journals. Conversely, SNIPs for case reports are relatively small and the APCs are lower judging from the coefficients in Eqs. (1) and (2). It is shown that case reports have different characteristics to ordinary journals.

This study also estimates the APCs using the variables representing individual publishers, instead of the three publisher types. Table 4 reports the estimation results. The coefficients of the four Big publishers in Eq. (1) are close to 0 and the null hypotheses are not rejected at the 10% level, while those of the three Subgroup publishers are significantly positive at the 1% level. From the viewpoint of individual publishers, large subscription journal publishers do not set higher APCs. For the four independent publishers, the coefficient of the variable denoting Frontier Media S. A. is positive and large. By contrast, MDPI AG and Hindawi have negative coefficients, although the null hypotheses are not rejected at the 10% level. Regarding Eq. (2), all the coefficients of variables denoting individual publishers are positive, indicating that the 11 publishers acquire higher SNIPs than De Gruyter after controlling the other variables. In particular, the three coefficients of the Subgroup publishers are statistically positive. Regarding Eq. (3), Frontier Media S. A. and MDPI AG publish more articles, while Hindawi publishes a small number of articles. Thus, the number of articles in a journal differs among Independent publishers. By contrast, for Big and Subgroup publishers in Eq. (3), the null hypotheses that the six coefficients equal 0 except for Taylor & Francis are not rejected at the 10% level. This result indicates that Big and Subgroup publishers are not important determinants of the number of articles.

Thus, BMC, Dove Medical Press, and Nature have larger citation scores and set higher APCs. Moreover, concentration does not influence the APC level from the coefficient of *Share* squared. Therefore, the conclusions in Tables 3 and 4 remain unchanged.

Discussion

When this study uses the number of citations as a proxy variable denoting the extent of readership, the estimation results show that journals with large readership attract many article submissions, which leads to large numbers of articles published. In addition, the APCs for journals with larger SNIPs and more articles tend to be higher. From the positive relationship between the number of articles and APC levels, the business model of open access journals may result in a revenue gap among publishers. Crawford (2018) reported that the number of open access journals newly launched increased until the late 2000s, but has declined after a peak in 2013. Recently, some of these journals have been discontinued

[4] The number of articles submitted by authors and the acceptance rate are not publicly available for most sampled journals.

Table 4 Estimation results: individual publishers

	ln APC (1)	*SNIP17* (2)	*ln Article* (3)
Constant	6.5018 (0.0976)***	−0.0008 (0.0885)	1.0440 (0.3025)***
ln Article	0.1027 (0.0146)***		
SNIP17	0.0484 (0.0249)*		
SNIP16		0.7219 (0.0344)***	
SNIP15		0.1648 (0.0319)***	
ln Citation			0.6184 (0.0291)***
Year	0.0048 (0.0036)	−0.0036 (0.0039)	−0.0126 (0.0121)
$Share^2$	−0.0019 (0.0026)		
Case	−0.7991 (0.0756)***	−0.1015 (0.0855)	1.6099 (0.2447)***
Elsevier	0.0526 (0.0832)	0.3087 (0.0944)***	0.2555 (0.2680)
SAGE	−0.0018 (0.0879)	0.0977 (0.0997)	−0.3465 (0.2901)
Springer	0.1460 (0.1067)	0.1503 (0.1211)	−0.0814 (0.3473)
Taylor	0.0263 (0.0903)	0.1166 (0.1015)	−0.6145 (0.3000)**
BMC	0.4537 (0.0807)***	0.2069 (0.0902)**	−0.3933 (0.2640)
Dove	0.4401 (0.0846)***	0.3184 (0.0931)***	−0.2076 (0.2738)
Nature	0.6512 (0.1359)***	0.2536 (0.1494)*	0.6774 (0.4364)
PLOS	0.2040 (0.1321)	0.1523 (0.1460)	−0.0151 (0.4282)
Frontier	0.5380 (0.0875)***	0.3443 (0.0949)***	0.5600 (0.2794)**
Hindawi	−0.0824 (0.0770)	0.0996 (0.0869)	−0.7548 (0.2502)***
MDPI	−0.1165 (0.0847)	0.2756 (0.0955)***	0.6941 (0.2725)**
Medicine	0.2312 (0.0493)***		−0.6637 (0.1616)***
Science	0.2161 (0.0530)***		−0.7857 (0.1739)***
Technology	0.1394 (0.0540)***		−0.4518 (0.1766)**
SE of Reg.	0.2664	0.3086	0.8749

Determinant residual covariance 0.0045

Standard errors are in parentheses. *SE of Reg.* standard error of regression

***1%, **5%, and *10% significance levels

or transferred to other publishers, while several open access journals, such as *Scientific Reports*, continue to publish numerous articles. Considering market trends and business models of open access journals, it is time for open access journals to diverge based on whether they are thriving. When the research institutions to which authors belong pay their APCs, authors may be insensitive to APC levels. In this case, authors would not hesitate to submit their articles to prominent journals with higher APCs. Thus, for open access journals to survive, it may be more important for them to gain recognition than to constrain APCs.

The estimation results show that journals with larger readership publish more articles and set higher APCs. Although previous studies on subscription journals have found that publishers enjoy economies of scale, the present study finds no economies of scale in the open access journal market. Instead, open access journals with many articles acquire substantial revenue by setting higher APCs. Doing so may balance the publisher's budget, since some journals with small numbers of articles discount their APCs or reduce them.

This study found that APCs for journals independently launched by the large subscription journal publishers are lower than those launched by publishers belonging to the

subscription journal publisher groups. Instead, the latter publishers have been more influential in the open access journal market. Although large subscription journal publishers have provided hybrid journals that give authors open access choice, they are latecomers to the gold open access journal business. Although it seems that late entry influences APC levels, their citation scores have been growing for a short period. In addition, they have merged with several open access journal publishers with established achievements. Larivière et al. (2015) found that journal acquisitions have increased the market shares of large subscription journal publishers since the late 1990s, raising their profits. Using a difference-in-differences approach, McCabe (2002) found that mergers between subscription journal publishers are generally associated with price increases. If these results are applied to the open access journal market, mergers between traditional large subscription journal publishers and open access journal publishers with excellent achievements may increase APCs through their market power. Although this study finds no evidence that large concentration in an academic field leads to higher APCs, the market concentration and activities of large subscription journal publishers in the open access journal market need to be monitored in the future.

Conclusion

This study simultaneously estimated the three equations of APC, SNIP, and number of articles to identify the determinants of APCs. The results show that journals with larger SNIPs and more articles set higher APCs. However, the study did not confirm a significant relationship between APC level and concentration, as measured by the share squared of the number of articles in an academic field. Furthermore, large subscription journal publishers do not set higher APCs for their open access journals. Although these results denote that large subscription journal publishers do not have market power in the open access journal market at present, they have merged with several open access journal publishers with excellent achievements. Therefore, we should monitor the activities of large subscription journal publishers and APC levels.

However, the history of APC-funded open access journals is relatively short, and the market has been changing rapidly. Moreover, while large subscription journal publishers have published many open access journals on behalf of research institutions, such as academic societies and universities, the number of journals independently launched by publishers is relatively small. Therefore, the conclusions of this study should be treated as preliminary, and further investigation using more samples is necessary.

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