Back to disciplines: exploring the stability of publication regimes in chemistry: the case of the Journal of the American Chemical Society (1879–2010)

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Back to disciplines: exploring the stability of publication regimes in chemistry: the case of the *Journal of the American Chemical Society* (1879–2010)

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Based on a case study, this article explores the stability of publication regimes (as defined by Hilgartner (2015, 2017)) in chemistry. Starting with a slight detour via open access (OA) policies, it concentrates on the conditions of editorial production and trade of a scholarly journal, from an historical perspective enriched by a sociology of valuation and pricing. Prices are seen as social constructs as I consider the modalities of market coordination among actors of the publishing enterprise in a major scholarly society, the American Chemical Society (ACS). The study focuses on the *Journal of the American Chemical Society* (*JACS*), a periodical that was founded in 1879 by the ACS, of which it is the "flagship" journal. The investigation relies mainly on a detailed examination of the *JACS* imprint from a diachronic perspective (1879–2010). I describe how scientific papers (as singular entities) gradually entered into a commodity market, first with the page-charge mechanism and the imposition of authors' fees, up to the emergence of the Article Processing Charge (APC) model, where the authors/institutions pay fees to have the electronic versions of their articles in OA. The proposed timeline in five periods is marked by two points of rupture that correspond to State intervention and the adoption of federal laws. Inherited from the deployment of science regimes in the post-WWII period, revenue collection models were collectively invented by the ACS and its members as successive adjustments to address massive imbalances caused by changes in scientific, institutional, and regulatory environments. Specific market mechanisms and modes of coordination have been put in place to support the development and guarantee the continuity of a disciplinary program (that of chemistry) in the frame of what I call a disciplinary publication regime.

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Introduction

With the creation of the Internet, many of the assumptions underpinning the established scholarly communication system have been challenged (Borgman, 2007). In the past decades, digitalization has been accompanied by commercialization, with an increasingly concentrated journal market led by a handful of large, for-profit publishing houses (Strasser and Edwards, 2016). Starting in the 1990s under the heading Open Access (OA), a broad debate on necessary transformations took place among stakeholders in the scientific world. Various actors who did not defend the same objective of a "transition" towards OA put forward numerous reformulations of the movement. Today, the removal of barriers to the online access and re-use of scholarly research is driven by a mix of technological, financial, moral, and commercial imperatives. For the European Union, as well as for governments and funding agencies the message is: the future is open. All projects receiving Horizon 2020 funding are required to make sure that any peer-reviewed journal article they publish is openly accessible and free of charge, or else risk financial penalties (European Commission, 2017). OA policies are broadly developing around the world in various ways.

As a discipline, chemistry has a large consensual knowledge base, as well as a clear sense of cumulative knowledge growth (Cronin et al., 2004). Journals are the main way in which research is published. Chemistry is also a field where OA is less widespread than in related disciplines such as physics or biology (Björk et al., 2010). While chemists frequently share data, experiments, and so on, they do not do it so "publicly". Openness both underscores and challenges existing property and privacy regimes. Nowadays, the most widespread OA model in chemistry is the Article Processing Charge (APC) model, where the authors/institutions pay fees to have the electronic versions of their articles in OA[1] (Table 1). In some cases, these costs, billed after peer reviewing, are added to subscriptions charged to institutions (a phenomenon often described as double dipping). According to a survey covering all disciplines in 30 countries (Lara, 2014), 47% of the authors provide themselves the funding for OA APCs.

In this context, the debate on OA to research papers is gradually focusing on the economics of APCs, as evidenced by recent literature (Tenopir et al., 2017; Pieper and Broschinski, 2018; Khoo, 2019). APC expenditures are high, especially in research-intensive countries. In Germany, the number of APC-relevant publications for a given institution accounts for 40% to 60% of their total output, depending on the research intensity and reputation of the research institution (Schimmer et al., 2015: p. 9). Following the development of OA policies focusing on Gold OA, "transformational agreements" are signed between publishers and institutions/consortia, in which the latter are offered compensation for the extra cost of paying APCs to journals already covered by subscription. Several countries have organized the collection of APC expenditures at the national level by asking volunteer institutions to provide feedback.[2] Their goal is not only to develop an overall vision and increase transparency, but also to better control rate increases in order to support "the transition to an OA publishing system" (Eellend and Smith, 2016: p. 5). These projects feed into dynamic comparisons, with price ranges that are made public and circulate in many spaces, allowing the least advanced institutions to make cost projections.

In France, the CNRS issued a policy brief in 2015, stating that "the "generalization" of OA with payment of APCs would entail unsustainable costs for the CNRS (and more broadly for French public research)" (Direction de l'Information Scientifique et Technique, CNRS: p. 6). This note introduced "a new actor of expenditure: 'the author'". However, payment by the author is an old affair: as King and Alvarado-Albertorio (2008) pointed out, in 1977 the author intervened in the payment of more than half of all articles, in the form of page charges for 38% of the articles, according to the estimate. Is this system of expenditure based on article tariffing really new? Where do these prices come from, and how are they defined? More broadly, what does a tariff-centered history tell us about the general movement of "articlization" that has been empirically demonstrated by Paye and Renisio (2017)[3]?

Analytical frame: conceptualizing the "publication regime" in a relational sociology perspective

There is a vast body of theoretical and empirical literature on the valuation and pricing of goods. Economic sociologists have analyzed questions of value and price in substantive empirical studies that have enriched the understanding of the conditions of economic exchange on various markets (Muniesa et al., 2007; Beckert and Aspers, 2011). These markets can be grouped into three types (Beckert and Aspers, 2011: p. 30): first financial markets; second markets for aesthetic goods such as wine, fashion, contemporary art and food; third markets in which ethical issues figure prominently such as the market for organ transplantation (Steiner, 2010). Some authors draw a distinction between theoretical approaches on one hand—be focused on the role of networks, organizations, the cultural dimension or performativity—and the various substantive areas of economic sociology on the other: the sociology of markets, the sociology of money, the social studies of finance, the sociology of evaluation and worth, and so on (Aspers and Dodd, 2015).

Whatever the approach chosen, the academic publishing market is rarely studied from the perspective of the economization literature (meaning here studies of the construction of markets and the associated anthropology of calculation), with the exception of a few works on scholarly books (Karpik, 2011; Gulledge et al., 2015). In the case of the scientific journals, the limits of standard economic theory are salient since the scientific community constitutes both the supply and the demand. This inadequacy is all the more pronounced nowadays because academics have entered into a commercial relationship from which they were previously absent:[4] with the development of the APCs and complex workflows for paying fees, we are no longer in the context of a business-to-business model driven by a simple contract between libraries and publishers.

This article aims to provide an analysis of the conditions under which pricing systems of disciplinary journals are produced in a particular political and institutional context (the USA). This paper, which follows on from sociological studies of prices, notably those of Zbaracki and Bergen (2004), Barrey (2006), Bidet (2010), and Finez (2014) looks at the context, tools, actors involved in the genesis of tariff modulation of academic journals and, in so doing, redefines the principle of access to the scientific litterature. Prices are part of the terms of trade and are socially constructed by the actors in the exchange (White and Eccles, 1987: p. 985). The tariff is a defined price, made public and for which there is no longer any uncertainty about the amount of the exchange. Even if not administered by the State, a tariff is regulated by a legal framework that constrains the conditions of exchange and influences price formation.

In this work, markets are understood as devices for qualifying goods and calculating their value (Callon and Muniesa, 2005). I take the academic journal and its registration in the commercial space as the main focus of study and critically examine the modalities of market coordination among actors. Like other cultural goods or professional services, the academic journal is part of an economy of singularities (Karpik, 2007, 2011). Singularities are multidimensional and indivisible goods and services,

Table 1 Range of APCs for journals that cover the chemical sciences broadly speaking.

Publisher or journal	Price per article (Open Access fees)			Licence information	Remarks
	GBP	USD	EUR		
RSC Advances	£750			CC-BY CC-BY-NC	Discounts for members (individuals)
The Proceedings of the National Academy of Sciences (PNAS)		$1500		CC BY-NC-ND ($1150) CC BY ($2200)	OA fees added to publication fees Regular research articles: $1640–4265 (6 to 12 pages) Brief Report articles: $2200
Royal Society of Chemistry (RSC) Communication in all journals except *RSC Advances, Chemical Sciences* & *Nanoscale Advances*	£1000				Discounts for members (individuals)
Royal Society of Chemistry (RSC) Paper in all journals except *RSC Advances, Chemical Sciences* & *Nanoscale Advances*	£1600				Discounts for members
PLOS *PLoS ONE*		$1595		CC-BY	
Nature Research (part of Springer Nature) *Scientific Reports*	£1290	$1790	€1490		
International Union of Crystallography *IUCrJ*		$1750		CC-BY	
The Royal Society All journals except *Royal Society Open Science* & *Open Biology*	£1700	$2380	€2040	CC-BY	Discounts for members
PLOS All journals except *PLoS One (PLOS Medicine, PLOS Biology…)*		$3000		CC-BY	
American Chemical Society (ACS) All journals except *ACS Central Science*		$1500–4000		CC-BY-NC-ND CC-BY (extra fee of $1000)	Discounts for members/ subscribers (individuals & institutions)
Nature Research (part of Springer Nature) Nature-branded journals & Nature partners journals, except Communications Journals, *Nature Communications*	£700–2500	$1100–3300	€900–2900		Prices varies between journals
BMC (part of Springer Nature) BMC journals	£940–1870	$1475–2680	€1200–2170	CC-BY 4.0	Prices varies between journals
Springer (part of Springer Nature)	£1920	$3000	€2200	CC-BY CC-BY + CC0	
Nature Research (part of Springer Nature) All Communications Journals	£2170	$3170	€1490	CC-BY	
Wiley All journals		$3000		CC-BY CC-BY-NC-ND	Discounts available
Elsevier All journals		$500–5000		CC-BY CC-BY-NC-ND	Prices varies between journals
Cell Press (part of Elsevier) *Chem*		$3500–5200		CC-BY CC-BY-NC-ND	Prices for a no posting embargo period
Nature Research *Nature Communications*	£3490	$5200	€4290		

characterized by their symbolic value and uncertainty as to their quality. The price should be seen as a quality in the same way as the other qualities. This is not a summary of the significant qualities of the good; price formation is only one of the links in a long series of equivalency determinations (Callon, 2005, 2009).

Who are the actors in these equivalency determinations? How are they articulated in the long run? Placed at the center of my reflection, the journal is seen as an actor (or actant according to the sociology of translation (Akrich et al., 2006)) and not only as a showcase or revealer. The journal is both a set of copies and a "collection" of articles, a material object (with a required number of pages or words, a format to be complied with, etc.) and a social organization or institution that creates that object.

There is a long tradition in STS of studying what Bruno Latour has called "inscriptions" (Latour and Woolgar, 1986). In her early work, Karin Knorr-Cetina (1995) argued that "the scientific paper hides more than it tells on its tame and civilized surface"—meaning that it generates amnesia about the conditions of its production. This point has long been made with regard to how experimental practices are (not) reported in journal articles. However, few if any studies have examined how the conditions of the *editorial* production of a journal article are similarly occulted. In line with recent historical research on scientific journals (Baldwin, 2015; Fyfe et al., 2017; Csiszar, 2018), this paper focuses on this blind spot.

In this article, I examine the modalities of market coordination in a historical sociology perspective. I take a chemistry journal as a case study. Like physics or earth sciences, chemistry is a mature discipline that has built its publishing system on professional norms, conventions and standards, and that relies—especially in

the United States—on the development of a scholarly society (the American Chemical Society, ACS), which is not a commercial corporation. Publishing is a complex process that is only partially controlled by the author (Gläser, 2006). I analyze the relationship between the journal and the authors (whether they are or not individual members of the ACS, American or non-US-based, etc.), between the journal and the scientific institutions (whether they are public organizations, universities or firms), etc. Considering markets as socio-technical universes, I integrate elements such as the budget balance, the materiality of the article, legal norms, and so on in the analysis. Through the study of the justifications and concerns that accompanied the adoption of tariffs over a long period, I propose a story of a journal centered on its price and based on its conditions of trade and circulation.

What does this story allow us to see? From this case study, I show the precariousness of the journal's funding model in a learned society (the ACS) constantly seeking a balanced budget. I analyze the circulation of business models from one discipline to another, using chronological milestones identified by Tom Scheiding (2009, 2013) in his work on physics. Scheiding documented the development by the Finance Committee of the American Physical Society (APS), of the page-charge pricing mechanism ($2 per page) in *Physical Review*, its leading journal. In 1931, the American Institute of Physics (AIP) was created, with the aim of centralizing the publishing operations in physics as a whole. The ACS made a different choice later: that of developing its capacity internally, with the creation in 1969 of a division dedicated to publications. As we will see, publishing activities are carried out within the framework of an organizational continuum with a series of organizations (ACS divisions and journals, the printing house, etc.) closely linked to each other that have enabled the production of the journal (and the article) from start to finish.

My purpose in this paper is first to study the collective process of the market entry of a disciplinary journal in the long run. Prices do not "emerge" as a meeting of supply and demand in the market but result from a "price-setting" work (Barrey, 2006) carried out by actors that I identify and whose price-setting strategies I describe. I show the processes through which "price setters" used the competitive context and the legal framework that constrained the terms of trade to move forward in their own logic of action. The historical perspective has the advantage of highlighting the fact that the current state was by no means a foregone conclusion.

Second, this paper is based on empirical research on publishing practices of chemists in academia. In the social games of the university and the discipline, chemists, as other academics, are involved in many heterogeneous practices of valuation, which include discursive activities (such as writing publications), citing colleagues, etc. (Angermuller, 2017). Claiming for a Strong Program in discourse studies, Angermuller argues that discourse has to be understood as a source of value and not just a means to represent value. By pursuing discursive practices, academics are then always engaged in social practices of constructing subject positions (Angermuller, 2018). Based on this proposal, this study is also an opportunity to investigate the notion of *publication regime* that S. Hilgartner first explored[5] in 1995 and refined in 2017 (Hilgartner, 1995, 2017). The publication regime (referred to throughout his 2017 book as the "scientific-publication regime" or the "journal regime" or "publication regime" for short) is the familiar regime that regulates publication in scientific journals, evaluating manuscripts and constituting the scientific literature. The governing frame[6] of the publication regime defines key agents (authors, reviewers, readers) and roles (writing, reviewing, citing) while choreographing the flow of scientific texts through three jurisdictional spaces (unpublished, under review, and published) and specifying the control relationships operative in each. In the social sciences, the use of the term regime is often reduced to the idea that it imposes order on a domain or activity, most often through a combination of formal rules, informal norms, material means and discursive framings. In addition, the term emphasizes the regimentation, the imposition of discipline that is inherent in any embedded means of communication. As Hilgartner emphasized, this regimentation "should be considered not only as constraining action but also as enabling action; it both opens up and limits possibilities." (Hilgartner, 1995: pp. 244–245).

What is also of interest in Hilgartner's work (1995, footnote no. 11) is the idea that the regimes that constitute high-profile journals (he chose the particular case of *Cell*) can be viewed as particular instantiations of the publication regime as a general social form. This is a challenging proposal that I will test with this case study. Does the *Journal of the American Chemical Society* (*JACS*), a periodical created in 1879 by the ACS and which is referenced as its "flagship journal" instantiate a publication regime that is specific to chemistry?

To tackle the question of the disciplinary publication regime, my study has two main thrusts: I first choose a chronological framework with a narrative centered on price-setting strategies and pricing policies over the period 1879–2010 (Section "A five-phase periodization"). In the discussion part (Section "Discussion"), I broaden the scope of the previous results by looking at a recent example (the launch by the three largest chemical societies of a preprint server in 2017).

Data and methodology

The empirical material I draw upon consists mainly of primary and secondary historical sources. I have systematically analyzed the *JACS* over the period 1879–2010, in particular its imprint (a mandatory insert where all the legal information relating to a press medium, including subscription and postage rates can be found) in a diachronic perspective. Other entries include instructions to authors, indexes, advertising spaces, etc. The story is complemented by information from *Chemical and Engineering News* (*C&EN*), a weekly review founded in 1907, which is the official organ of the ACS,[7] books published during the anniversary commemorations of the ACS (Browne and Weeks, 1952; Reese, 2002) since, to my knowledge, there is no academic monography tracing the history of the ACS, administrative reports and research articles. For the most recent period, I rely on press releases, testimonies, as well as data collected from chemistry journals websites. The methodology is based on content analysis of this material with a focus on pricing policies.

The ACS is not only the largest scholarly society in chemistry but also the richest in the world (Samuel Reich, 2012). Today, *JACS* is a periodical that produces more than 19,000 articles a year. Its history is inseparable from the history of the ACS, which I briefly present in Box 1.

Since its creation in 1879, the *JACS* has been central to the ACS *Publication Program*,[8] as illustrated in Fig. 1. This pattern reflects the increasing number of specialty journals and the progressive differentiation along specialty lines. A document from 1968 describes the editorial philosophy that guided the development of the program (Kuney, 1968: p. 251): each new journal endorsed by the ACS has a more limited thematic coverage than the previous one. This is also a point mentioned by Browne and Weeks (1952):[9] the editorial policy of a new journal may be that of the parent journal, but it may also be different. In 1968, the positioning of the *JACS* was as follows:

> *Journal of the American Chemical Society* (*JACS*). Founded as Proceedings in 1876; became the journal in 1879. Papers

Box 1. | The American Chemical Society

The ACS is a learned society founded in 1876 in New York by a group of 35 chemists. It was incorporated 60 years later in Washington DC. In 1937, President Roosevelt signed the Public Act No. 358, which provided the ACS with a federal charter of incorporation (under Title 36 of the United States Code). This charter codified the main operating principles, the constitution being the founding text that organizes them.

The promotion of scientific interests through publications is one of the missions described in the charter:

The objects of the American Chemical Society shall be to encourage in the broadest and most liberal manner the advancement of chemistry in all its branches; the promotion of research in chemical science and industry; [...] the increase and diffusion of chemical knowledge; and by its meetings, professional contacts, reports, papers, discussions and publications, to promote scientific interests and inquiry [...].

The ACS is a 501 (c) non-profit organization that, as such, is exempt from federal income tax. It relies on collegial governance with multiple bodies (Board of Directors, Council, Divisions, Committees, etc.). There is a considerable number of bylaws and regulations that organize the life of the society. In other words, the ACS is a huge, well-oiled machine. As early as 1908, the ACS organized itself into technical divisions, to enable interaction between scientists who worked or had a common professional interest in a particular field. The first five divisions created were: 1) organic chemistry (the one with the most members today), 2) industrial chemistry and chemical engineering, 3) agricultural and food chemistry, 4) fertilizer chemistry, and 5) physical and inorganic chemistry.

Today the ACS has about 160,000 members in all areas of chemistry and chemical engineering. It is organized into 32 technical divisions and 186 local sections. This organization is based on a territorial grid, with local entities (the sections) that are autonomous. The life of the society is punctuated by two annual meetings (the National Meetings), which are organized in spring and autumn. In addition to defending sectoral interests, these meetings provide information and services for members.

> are from basic work in organic, physical, inorganic, and biological chemistry. Accepted only if they cut across one of the following fields of expertize: *JACS* prints Communications to the Editor, preliminary reports not exceeding 1000 words in lengths of unusual significance or urgency. *JACS* also presents informative reviews of books on chemistry and related subjects. Published biweekly. (Kuney, 1968: p. 251)

Fifty years later, the format of the *JACS* has not changed, give or take a few adjustments: it always brings together articles, communications (short papers that describe significant research) and book reviews. Today, the specific format of the journal, as it has come down to us through the accumulation and the sedimentation of history, is both a huge publishing infrastructure and communication system that is increasingly called into question. ACS's current offer includes 50 journals and magazines.[10] More than properties such as membership growth or the ever-increasing volume of publications that are often highlighted in the institutional communication of the ACS, I will stress the permanence and the importance of a long-term study.

JACS is weekly today, whereas in 1930 it was published monthly. It is organized in annual volumes, which are subdivided into issues. I first proceeded by sampling, and then focused on specific periods that I documented extensively. For instance, the interwar period was pivotal for the sustainability of journals (Tesnière, 2014).[11] In the late 1930s, the ACS entered a period of stability in the number of its members and the process of disciplinary construction of chemistry was considered as achieved (Scheiding, 2011; Nye, 1999: p. 225).

The study intentionally ignores *Chemical Abstracts*, which fulfill a particular function: that of an index of periodicals, which provides summaries and indexes information contained in various supports, published in around 50 languages. *Chemical Abstracts* are not articles but abstracts, which is why I do not mention them in this study. They nevertheless played a vital role in the development of the discipline and its taxonomy. They are also the primary source of revenue for the ACS (Samuel Reich, 2012).

A five-phase periodization

In this section, I reconstruct the story of a scientific journal (the *JACS*) embedded in a program (the ACS Publication Program). This story, which is not intended to be exhaustive, traces the conditions of *editorial* production rather than scientific production; although their role is crucial (they are the ones who feed the journal), contributors are not at the core of the narrative. Starting from the date of creation of the *JACS*, I propose a five-phase periodization based on the evolution of the journal's purchasing modalities and business models. The analysis refers not only to major events (economic crisis, wars) but also to research that documented the expansion of American science during the twentieth century.

From creation in 1879 to the 1960s: in search of a balanced budget. The *JACS* was founded in 1879. The journal then experienced regular growth, steadily in line with the number of ACS members (Kuney, 1968: p. 261). From 1893 to 1901, it published an average of 850 pages of original articles per year and about 59 pages of book reviews. In the early years of ACS, each member received all ACS publications free-of-charge, i.e., *JACS*, *Chemical Abstracts*, *I&EC*, etc.

The period of the First World War does not appear to have been one of turmoil. The rapid growth in membership that began in the 1890s continued over the next few decades, followed by the creation of four new divisions in 1919 (Thackray, 1988: pp. 184–185).

In 1929, the budget of the Publication Program was in deficit for the first time; the crisis affecting American society as a whole was also experienced at the ACS. The Board of the ACS urgently allocated a sum of $20,250 to the *JACS*, to cover costs corresponding to 1200 pages. Irving Langmuir, then president of the ACS, reported that "no organization will be able to support or hope to maintain an unlimited publishing program".[12]

In 1932 the depression became acute. The Council adopted the principle of a separation between membership and subscription to periodicals, with the exception of the *News Edition* (the ancestor of *C&EN*), which was sent free of charge to all members. A portion was deducted from membership fees to support the publication program: $2 were allocated to *JACS* and $2 to *Chemical Abstracts* (Kuney, 1968: p. 255). Bylaws were amended to exclude *Chemical Abstracts* from membership fees while the $2 were allocated to a fund created to subsidize the periodicals deficit. The principle of the provision was set out in the ACS bylaws (Browne and Weeks, 1952: p. 334). In this way, each ACS member helped support the publication function of the society, whether or not they subscribed to journals other than *C&EN*. The mechanism adopted (levy on membership fee) was internal to the society.

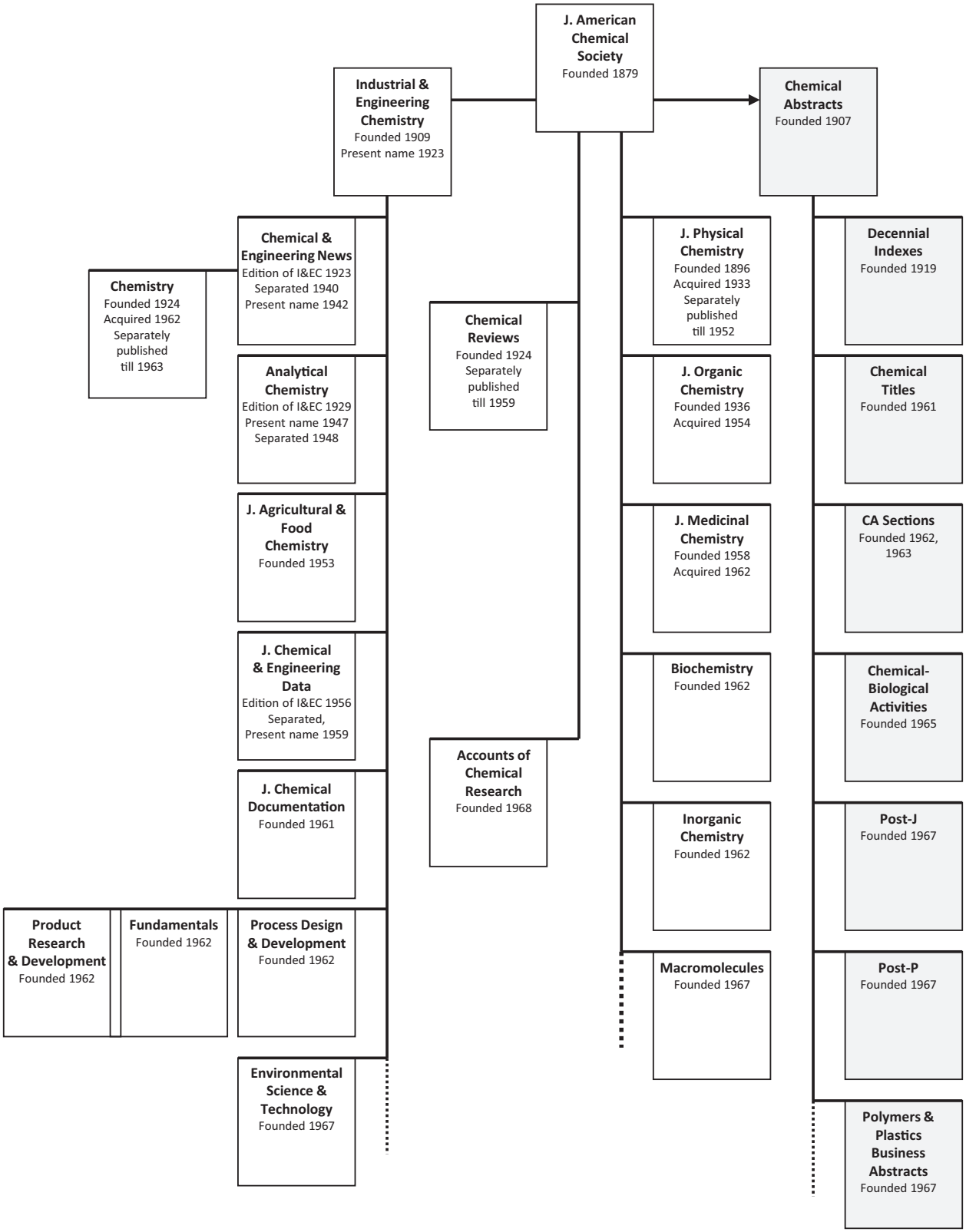


Fig. 1 Chronological description of the ACS Publication Program (adapted from Kuney, 1968: p. 252). Each journal has a start date, may have been acquired or separated from the program, and has a brand name that may have changed.

From 1934, the *JACS* was sent only to those who paid a subscription charge in addition to their dues, and no longer to all members. The mechanism became an "*elective system*", outwardly oriented (Browne and Weeks, 1952: p. 334). As a result of these budget allocations, the program returned to surplus, with respective surpluses of $20,000 (1934), $35,000 (1939), and $50,000 (1949) that were used by the ACS to support other journals than the *JACS* (Browne and Weeks, 1952: p. 334).

The 1935 report of the Secretary of the ACS mentioned that "the society had a successful year financially. The new plan, as

already reported to the membership, has been worked out and is giving almost universal satisfaction".[13] The *JACS* editor reported that an accumulation of accepted manuscripts has resulted in considerable delay in the publication of articles during the year, but the *JACS*' balance had been restored by December 1935.[14]

With this plan, the Publication Program operated beyond the strict break-even point over a long period, based on a model that ensured the maintenance of a balance between revenue and expenditure. Browne and Weeks (1952: pp. 332–333) presented a retrospective publication cost analysis for the *JACS* (1884–1949). They argued the average price paid by the reader stabilized at between 0.16 and 0.19 cents per page per copy since the adoption of the plan (1934). They pointed out however that a page in 1948 or 1949 contained many more words than a page in 1918.

Each monthly issue contained about 50 articles, communications (between 5 and 10) and book reviews (up to 10). The Notice to Authors of January 1940[15] (two pages) stated: "the manuscripts should be addressed to specialists in their field rather than to the general reader". A short introductory paragraph was requested to describe the importance and main objectives of the presented research. The layout of figures, graphs and tables, as well as typography rules were specified. In particular it was suggested to use abbreviations such as %, Å, cm, etc. or Fig. "in the interest of economy". In this notice, it was recommended that Communications be no longer than 500 words. Supplementary material to accepted articles were archived in the form of microfilms or prints at the American Documentation Institute (ADI).[16]

After the Second World War, R&D investment programs developed widely as a result of the massive intervention of the federal State (Lécuyer, 2015: p. 429; Berman, 2012: pp. 19–57). The metaphor of research as a process of production emerged in the post-war period: "we must manage growth". Advertising revenues for the Publication Program came primarily from *C&EN* and *Analytical Chemistry*, as part of a partnership with Reinhold Publishing Corporation that lasted >30 years (Kuney, 1968: p. 255). However, there was no advertising in the *JACS*, apart from a few references to the ACS products.[17]

The 1960s: introduction of the page-charge pricing mechanism. At the 140th ACS National Meeting in Chicago (1961), Louis P. Hammett, chairman of the Board of Directors of the ACS, announced that journals were once again presenting an "operating deficit".[18] The deficit was about $421,000, with expenditure exceeding subscription revenues plus other secondary sources of revenue, such as advertising. In 1962 this deficit was about $513,000. Hammet claimed that the ACS could offset the deficit temporarily by tapping into the reserve fund but that this would reduce the net market value of the fund by 29%. He did not see this as a sustainable solution.

The question was studied for months internally; debates are synthetized in two *C&EN* articles.[19] The Board proposed that the ACS set up a page-charge pricing mechanism for its "fundamental" journals. In a statement published on October 25, 1961, the Federal Government's Council of Science and Technology approved both the principle of the page charge and the use of federal funds in paying such charges. This was however subject to conditions: that the journal be published by a not-for-profit organization, and that the payment be voluntary and not contingent on acceptance. Referring to the use of grants, it imposed an implicit condition of novelty.

The 1962 article pointed out: "Philosophical justification of the page charge is based upon the contention that the cost of publication is properly a cost of research. Traditionally, the costs of research cover the time spent by the author and his secretary to prepare his report".[20] Based on a "realistic assessment" of the Publication Program, Hammett mentioned that "little content got published that was not an important part of the scientific record".[21] The ACS then considered that research was not complete until its results had been made available to others. Hence, some of the costs became a charge that could rightly be attributed to a research budget and the federal funds that it received.

As of January 1963, a page-charge payment mechanism came into effect; in the October 5, 1962 issue there was a Special Notice to Authors dedicated to it.[22] The following points were made:

- The page charge is a publication service charge designed to aid in covering the costs of publishing an article in a journal. The page charge covers only costs of setting the article in type and preparing it for the press. As administered by the ACS, it will also include 100 reprints supplied to the authors.
- Payment is expected from sponsored funds supporting the research reported. Page charge payment is not a condition for publication.
- The editor's decision to publish is made before assessment of page charges and the editor's office will not be advised on charges or payment.
- With the institution of page charges, subscription rates to ACS journals should be stabilized at current levels for an indefinite period of time.

This notice referred to a series of questions and answers in *C&EN*, which justified the strategic choices made by the ACS.[23] The answers were said to have been drafted by the Committees on Finance and on Publications, with the assistance of ACS staff, through a two and a half year process. The argument was thus developed through a long list of Q&A:

- What is the page charge used by the scientific and technical journals? Its operation is briefly described (see above). The page charge payment is a novelty in scientific practice, but it has been tested for 25 years by the AIP.[24] Others have adopted it in recent years. The number of journals using it has increased markedly during the past 5 years. About half of all U.S. scientific societies will probably be applying the page charge by the end of 1963.
- The question of reception is asked. ACS reports that the attitude of industry towards the page charge where it has been applied has been favorable.[25] The attitude of university scientists toward the page charge appears mixed. Most of those who publish in the *Journal of Chemical Physics* and other AIP publications have accepted its existence as a reality born of necessity. A study recently completed by the ACS indicates that 50 to 60% of the articles appearing in ACS basic journals are subsidized by government funds, 30 to 35% by industrial funds, and about 10% by university and private funds. The following questions are addressed to academics.
- Most existing page charges range from $15 to $50. The page charge will not apply to any Chemical Abstracts Services publication, *Chemical Reviews*, *C&EN* or any journal substantially supported by advertising.
- Why not increase journal subscription prices? Experience indicates that this produces so many cancellations as to reduce income.
- Why not ask industry to subsidize fully the basic journal program? Industry is by no means the only beneficiary. The amount of industry subsidization is already quite large, not only directly through high subscription rates and corporation associates, but especially by contributions of the time of hundreds of its people who are active in ACS work. Over half of the subscriptions to all ACS basic journals are sold abroad, and it is unfair to ask American industry to subsidize the

whole operation. The page charge will yield a fairer and more nearly proportionate support.
- Why not sell more advertising in basic journals? This has been tried to a limited extent in the past and yielded a net advertising deficit.
- Why not publish less material? This would depart from the objectives and traditional responsibilities of the Society.
- Why not increase ACS dues? To meet the existing and predicted costs would require increases of such size and frequency as to reduce membership severely. Moreover, it would not be in order to ask members to subsidize journal losses without asking contributions from non-members who benefit.

The January 1963 issue of the *JACS* did not include a reference to the page charges. In November 1964, the Notice for Authors[26] did not refer to it either. Unusually, the December 1964 issue showed advertising inserts for laboratory glassware and analytical instruments. My hypothesis is that the mechanism was discussed for 2 years. Scholars in universities were asked to commit by making special efforts and changing their attitudes because "a reasoned attitude has been used in reaching the decision to apply the page charge".[27] The first reference to the page charge (five lines) appears in the Notice to Authors of November 5, 1966.[28] For the *JACS*, the requested amount was $35 per page.

How did the chemists react? In his history of *Chemical Abstracts*, E. J. Crane (publisher of CAS from 1915) reported that two positions clashed internally: the journal as a source of increasing income and membership *vs*. the journal as self-sufficient (Crane, 1952: p. 342). Yet I found no mention of any other opposition in the documentation consulted.

In 1966, 70% of the costs per page were provided by the authors or their supporting institutions. Members were the core of subscribers, but non-members contributed half (48%) of subscription revenues (Kuney, 1968: p. 255). The page charge mechanism helped to stabilize membership rates for members at less than $20 a year over the decade (Kuney, 1968: p. 256).

Applying the 1961 federal statement implied separating the editorial function from the act of making a payment. This was to result in the creation of a division of ACS (the ACS Publications Division), whose activities were grouped under a single banner in 1969. This division has a staff of about 400 people today.[29]

As internationalization developed, the question of payment by foreign institutions arose. This was also a problem at the APS, as Scheiding points out (2009: p. 234): foreign authors did not pay the page charges. The APS then developed a coercive model that imposed an additional publication delay of 2 to 3 months on authors (mostly non-Americans) who did not pay the fees.[30] The ACS did not use this mechanism. In other words, special attention was paid to international authors.

In 1960, the *JACS* was available in A4 format. Published articles included an abstract (which was not identified as such) and acknowledgments (which refereed to funders but not only). They were *contributions from the department* (or *laboratory* or *firm*) enriched with tables and figures, illustrations, micrographs, and so on. Communications were short (less than one page, in two columns), contained references, and were signed by the department/laboratory/firm and its authors.

At that stage the *JACS* was published twice a month. Notices for Authors were more accurate than before. The prerequisites were described in the General Considerations (for instance "Manuscripts of articles to be considered for publication in the *JACS* may deal with any phase of 'pure' or 'fundamental' chemistry as distinguished from 'applied' chemistry'"[31]). In General Instructions, there were details about the formats and nomenclature, which was supposed to be consistent with the uses of *Chemical Abstracts*. Typography was covered in Tables, Figures and Graphs, Formulas and Equations. Microfilms and Photoprints Supplements, Proofs and Reprints covered questions of document reproduction. A Serial Number for preservation at the ADI ($2) was issued for each piece. Each issue included an Author Index and two pages of advertising.

The end of the 1960s was a prosperous period in terms of income, with a page billed $50 in 1969. It was also the moment of creation of the "*ACS Handbook for Authors*" (1967). Prepared by the editors and editorial staff of the ACS, the handbook was distributed to all subscribers. The purpose was to help the author in the preparation of the manuscript, editing and proofreading (Laitinen, 1967). As all the staff had contributed to compiling and drafting it, it allowed the ACS to consider the circulation of manuscripts between journals of its program. The second edition was published in 1978. The third (1986) was more than a Handbook and became a true "style manual",[32] which included a chapter devoted to "Copyright and permissions".

The 1970s: experiences and threats. The beginning and the middle of the seventies were difficult times for the ACS. In chemistry labs, research continued against a backdrop of declining public funding, which was allocated primarily to military and space programs (the Vietnam War was underway) and to the development of social programs. H. Skolnik, Documentation Manager at the Hercules Inc. R&D Center and Chemical Literature Analyst, reported that in 1976 chemistry and physics journals were the most affected by inflation, compared to other fields (Skolnik, 1982).

As a result of the impact of the first oil shock, the cost of paper went up for the ACS journals and magazines (64% higher in December 1975 than in 1973, cf. Reese, 2002: p. 38). The '70s also witnessed the emergence of commercial publishers. They did not have page charges although, as Sloknik points out, their average prices were much higher. In 1975, only an increase in subscriptions decided as an emergency measure limited the deficit.

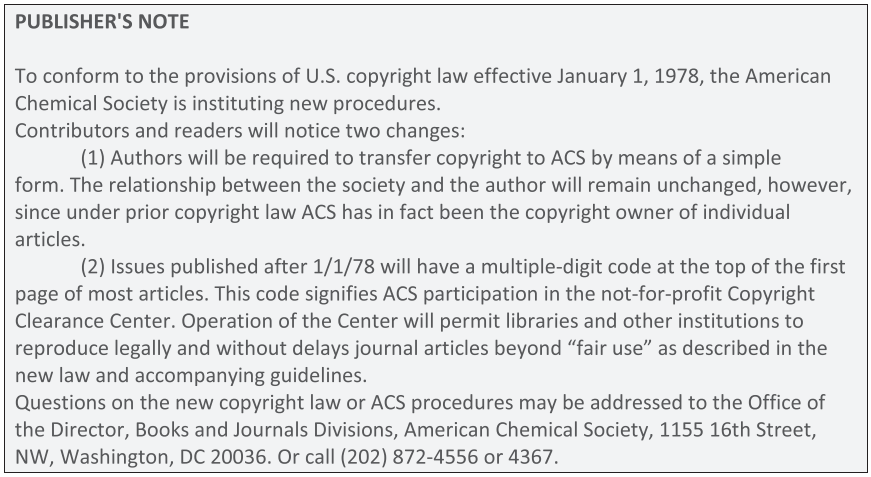
From 1970 on, the format of the article was close to the current form. A banner "*American Chemical Society. Publications Division*" appeared in early 1970, showing the names of the three managers, whose functions were identified.[33]

In January 1976, Cheves Walling, 10th editor of the *JACS* from 1975 to 1981, indicated in a supplement to the Notice to Authors:[34] "Receipt of manuscripts for 1975 have continued at approximately the same level as in recent years, and will total over 3100 for the year, of which 53% are full papers and 47% communications. Necessarily, the number which we can publish is determined by our page budget, 7700 pages in 1975, and our backlog has grown somewhat during the year. We anticipate an increase in our budget to 9000 pages for 1976, which should enable us to cut this backlog substantially over the next year."

He continued: "Without denigrating the importance of early publication of important results, Communications to the Editor continue to be a major editorial problem, and, it seems to me, consume an inordinate amount of time of editors and referees. […] Frankly, many of the manuscripts we receive do not fall into the requested classification [that of a work of unusual interest and importance, and which will be comprehensible and useful to readers in this abbreviated form] and we must decline almost half of those we receive."

The problem highlighted by Walling was recurrent. The page charge mechanism was also a way to encourage shorter articles.[35]

In 1973, the ACS opened a R&D department to conduct studies to better understand readers' needs (Reese, 2002: p. 39). A survey showed that *JACS* readers read most communications but few



PUBLISHER'S NOTE

To conform to the provisions of U.S. copyright law effective January 1, 1978, the American Chemical Society is instituting new procedures.
Contributors and readers will notice two changes:

(1) Authors will be required to transfer copyright to ACS by means of a simple form. The relationship between the society and the author will remain unchanged, however, since under prior copyright law ACS has in fact been the copyright owner of individual articles.

(2) Issues published after 1/1/78 will have a multiple-digit code at the top of the first page of most articles. This code signifies ACS participation in the not-for-profit Copyright Clearance Center. Operation of the Center will permit libraries and other institutions to reproduce legally and without delays journal articles beyond "fair use" as described in the new law and accompanying guidelines.
Questions on the new copyright law or ACS procedures may be addressed to the Office of the Director, Books and Journals Divisions, American Chemical Society, 1155 16th Street, NW, Washington, DC 20036. Or call (202) 872-4556 or 4367.

Fig. 2 Insert announcing the implementation of the Copyright Transfer Form in the journal *Environmental Science & Technology*. Adapted from *Environmental Science & Technology* (vol. 12, No. 1, Jan. 1978, p. 7).

articles in a *JACS* issue. A study on the "dual journal" concept was funded by the National Science Foundation ($130,000). The proposed system aimed at publishing two "companion journals": the first (*summary journal*) consisting of communications and two-page summaries, while the second (*archival journal*), proposed to libraries, offered expanded articles with additional material provided by the author.[36] Walling indicated that "no change in the form of the journal will occur without very careful consideration and discussion".[37] The test started in 1976 but was not conclusive: most of the chemists involved were not willing to abandon the traditional journal for composed abstracts (Reese, 2002: p. 39). The introduction of a new communication regime (as in the case of the early GenBank, an abstract service from journals that housed sequence data that Hilgartner (1995: p. 251) documented), was a missed opportunity.

The 1970s were the years when the ACS was the most "endangered". Like other learned societies, it was under attack by the federal authorities. In 1976, the *JACS* was added to the list of journals that violated the United States Postal Service's rules regarding delivery via second-class mail. Insofar as the articles were paid for, the journal that compiled them was considered to be an advertising product, subject to higher mailing rates.[38] The ACS was particularly concerned about the symbolic consequences of re-qualifying articles as advertising, and the negative effects of page fees, which were not mandatory. In 1976, 47% of the pages printed in the *JACS* were covered by the page charges, which amounted to $233,000 and accounted for 18% of the Society's revenues.[39]

The 1980s: a gradual phasing-out of page charges. In 1978 the main laws governing intellectual property in the United States changed. This was the second tipping point in the story, after the turning point of the 1960s. The Copyright Act was adopted on October 19, 1976 (it took effect from January 1, 1978). The consequences went well beyond the simple "Copyright ACS" that appeared in the *JACS* in 1941. The justification surrounding the Copyright Act was that it formalized a hitherto implicit transaction between the author (who submitted the manuscript) and the journal (which organized all the rest: peer evaluation, printing, mailing, etc.). It was also and above all a more rigorous definition of the conditions of use of photocopying in libraries.

The first Copyright Transfer Form appeared in the *JACS* in January 1979.[40] This form transferred the property rights to the ACS in a formal written manner. By signing it the authors of articles signed over all of their rights to the ACS.

I have not found any specific comments on the implementation of this form, with the exception of an insert in the January 1978 issue of *Environmental Science & Technology* (Fig. 2):

The relationship between the ACS and the author was said to remain unchanged, but the format and status of the article did change: the article was given a unique alphanumeric code and mention was made of the amount paid by the ACS to the Copyright Clearance Center (a license broker) followed by ©American Chemical Society. The names and respective institutional membership of the authors were specified with asterisks. Compared to the 1960s, the contribution of department X or Y had become secondary.

In January 1978 the Internal Revenue Service (IRS)[41] questioned the ACS about its tax exempt status, as it did with other learned societies. The IRS considered it anomalous that non-members of the ACS had higher subscription rates than ACS members.[42] Like the US Postal Service, the IRS considered that the collection of the page charges and the transfer of ownership were incompatible with the very principle of the journal. Later in 1978, ACS protested IRS's stance, but the matter was never brought to court.

As of January 1, 1979, the Board of Directors reduced the non-mandatory payment to $40 per page. The reason given was that the majority of authors paid all or part of these fees; by reducing the page charges, authors and their sponsors would always be more able to honor them. "While [page charges] remain non-mandatory, it is hoped that this will permit a much larger fraction of authors to pay the full charges. In fact, the extent to which they are able and willing to do so will probably determine whether we can continue with the present non-mandatory system".[43]

In his report in January 1979, Walling, editor of the *JACS*, insisted: "the Board believes that by reducing the per-page rate authors and their sponsors will be even better able to honor the charge. It may in the long run be possible to operate ACS journals without page charges, but such an eventuality would necessarily be dependent on economic conditions. In the meantime it is most important in the interest of financial soundness of ACS journals that page charges continue to be honored to the highest possible extent".[44] The ACS was no longer calling for support of growth but for responsibility. In other words, the concessions to the IRS concerned the page charge mechanism, which was not a problem because the revenue of subscriptions had become much higher than that of page charges. There was no question of abandoning the transfer of intellectual property.

The 2000s: pricing the article as a singular entity. At the turn of the 2000s, the statutes of the Journal and of articles changed

Table 2 Models of revenue sources by period (1879–2010).

No.	Dates	Revenue collection model	Implication for the author	Highlights of the period	Expression of concerns
1	1879–1932	Levy on membership fee	Each member of the ACS receives the *JACS* free of charge.	Development of the *JACS*. Mainly national audience.	Economic crisis, depression
2	1934–1962	Levy on membership fee + elective system	Subscription charge due, in addition to membership fee.	Opening outside of the ACS	Operating deficit
3	1963–1977	Levy on membership fee + elective system + voluntary contribution	Page charge fee (up to $70 in 1975).	Adoption of the federal statement imposing a novelty condition on the article. Increase in revenues, experiments, threats.	Decrease in public funding. Inflation of paper costs. Reminder of US Postal Service rules governing the sending of 2nd-class post
4	1978–2003	Levy on membership fee + elective system + voluntary contribution	Progressive decrease of page charge fees. Transfer of the article's copyright to the ACS.	Adoption of the Copyright Act. Growth in the number of foreign authors. Emergence of institutional subscriptions. Experiments, threats.	Requirement of the Internal Revenue Service (IRS) on the "tax exempt" status of the ACS
5	2006-...	Hybrid OA business model	Removal of the page charge fee. Optional pricing per article	Contractual relations between the author and the ACS.	OA policies

radically. Institutional subscriptions, which appeared in 1998, saw their amounts grow exponentially in 10 years, but indistinctly up to (and including) 2009. As of 2010, institutions were differentiated: subscription rates were no longer stipulated in the *JACS* imprint. Contractual negotiations took place between the ACS and its partners; amounts varied according to the size and research intensity of the institutions.

The article became an entity in itself: it was provided with a Digital Object Identifier (an international standard created in 1998) that replaced the Publisher Item Identifier in 2000.

In the years to follow, the Copyright Transfer Form became more and more restrictive. The 2006 version added the F clause to the five preceding paragraphs, which transferred the copyright on all the figures of the manuscript to the ACS.

The page charge was discontinued in 2004.

In 2006 the ACS launched its ACS AuthorChoice Program in response to the various national legislations on Open Access that were developing in Europe and the United States.[45] It complemented the ACS "Articles on Request" program authorizing individual authors to post the URLs of the article on a website. ACS AuthorChoice provided a mechanism for individual authors or their research funding agencies to sponsor immediate access to their article upon online publication on the ACS journals' websites. This policy enabled paying authors to post electronic copies of published articles on their personal websites. In addition, authors can also place electronic copies of their paper in institutional repositories for noncommercial scholarly purposes immediately upon publication. ACS retained copyright to the article.[46]

Since 2006, ACS AuthorChoice exists still under the same name: it is a fee-based option for contributing authors. Authors who are ACS members and/or affiliated with an ACS subscribing institution receive significant discount (respectively US$1500 as ACS member and US$1000 as an ACS member and affiliated subscriber in 2006), compared to the base fee (US$3000).[47] These amounts are considerably higher than the per-page rate that was in force up to 2004, even at its highest level ($70 in 1975). At the date of writing, ACS AuthorChoice has been expanded with a menu of licensing options.

The position of the ACS has evolved along with OA issues in the last decade. In response to a 2013 White House Office of Science and Technology Policy directive that instructed federal agencies to offer better access to federally funded research, the ACS joined other publishers in establishing the Clearinghouse for the Open Research of the United States (Chorus) to allow free access to published articles. In 2014, the ACS announced a new series of open access options for authors that include more flexible re-use licenses for articles and free deposits of NIH-funded ACS articles to PubMed Central (for 2014 only). Tariff options mainly concern licenses (the least restrictive, the most expensive). In 2015 the ACS launched *ACS Central Science*, the first fully OA journal in the society's history. There are no subscription fees to read the articles, nor any author processing charges to publish in the journal unless authors want to distribute articles under a Creative Commons license. A second OA journal, *ACS Omega*, launched in 2016.

Discussion

Who are the "price setters" in this long story? The narrative lists the names of chemists who have held high-level positions in important bodies in the chemical sciences (and have been rewarded for doing so): Evan J. Crane, editor of *Chemical Abstracts* (1915–1958), awarded the Priestley Medal, the highest honor of the ACS in 1951; Irving Langmuir, president of the ACS in 1929, winner of the 1932 Nobel Prize in Chemistry (one of the ACS journals is named after him); Louis P. Hammet, professor of chemistry at Columbia University, chairman of the Board of Directors of the ACS in 1961, awarded the National Medal of Science in 1967; Cheves Walling, 10th editor of the *JACS* from 1975 to 1981, distinguished professor emeritus of chemistry at the University of Utah, member of the National Academy of Sciences and the American Academy of Arts & Sciences, who also served industry; Herman Skolnik, co-founder of the then ACS Division of Chemical Literature in 1948, etc.

Similarly, the story brings to light a series of entities closely linked to each other in an organizational continuum: the ACS divisions (Publications Division, Division of Chemical Literature, Chemical Abstracts Service, etc.), the R&D department that did not exist for long, the journals (*JACS*, *C&EN*, *Analytical Chemistry*, *Chemical Reviews*, *Environmental Science & Technology*, etc.), the printing house (Reinhold Publishing Corporation), but also the

institutions (National Science Foundation, US Postal Service, etc.) and firms that contributed to price-setting in a constant dialog with the ACS. Tariffs arise from the linking of heterogeneous and plural "spaces" of calculation, where libraries are absent.

Table 2 summarizes the characteristics of the five periods described above. Each period has a distinct revenue model and specific modes of market coordination. This study shows that these "prices forms" are produced in five temporally and spatially specific places of the market. All periods are interspersed with short phases lasting 2 to 3 years.

The first period (period 1) is based on the principle of membership fees (each ACS member is de facto a reader of the *JACS*), which is superimposed on the "elective system" (period 2), where a subscription charge is added to the membership fee. These two phases extend a long period of time, which goes from the date of creation to the 1960s. Two pricing mechanisms are in place: the first is initially directed towards the interior of the society (according to the principle of membership fee) and then opens outwards (principle of the subscription charge). This long period was that of the development of the journal, where the stakes were primarily those of a socialization process attending the consolidation of a discipline at national level. The individual scientist may have been quite isolated; the publication process was "artisanal" and not associated with major financial issues.

Periods 3 and 4 (those of the voluntary contribution) are called interim periods. Period 3 went from the mid-1960s to the early 1980s. It was marked by abundance: the end of the 1960s was synonymous with increasing revenues, while the early 1970s was the time of experimentation and threats. The predominant model can be regarded as the crowdfunding model we know today. Research became international and the tension between being a member and an author was increasing.

Period 4 started in the early 1980s. Institutions became involved in this trade and the article became the basic unit of exchange. With the adoption of the Copyright Act, coordination changed into a regime of contractual relations (period 5), which manifested itself, almost concomitantly, with the introduction of institutional subscriptions in 1998 and the gradual phasing-out of page charges. In 2004, the chemistry community found itself with no alternative but to comply; the ACS started to develop a wide range of services to researchers.

In 2006, the ACS adopted a business model that is currently described as the *hybrid open access* model. This revenue collection model was a break with the cumulative model (the "price form" no. 4) that previously existed. The model of revenue sources has remained the same since 2006 even if it has been refined: in compliance tariff options are added to "price form" no. 5 mainly concern licenses (the least restrictive, the most expensive) to be compliant with OA policies.

This study shows the processes through which "price setters" used the competitive context and the legal framework that constrained the terms of exchange to move forward in their own logic of action. Specific market mechanisms and modes of coordination have been put in place to support the development and guarantee the continuity of a disciplinary program (that of chemistry). In the wake of these developments, an event in August 2017 reinforced the hypothesis of a "disciplinary publication regime" that I have suggested: the launch by the three largest chemical societies of a preprint server (ChemRxiv) "designed specifically for the global chemical sciences community". ChemRxiv is co-owned and collaboratively managed by the ACS, the Royal Society of Chemistry, and the German Gesellschaft Deutscher Chemiker. After a timid start (it took a year of preparation before the official launch) it seems that preprints have started to feed the server progressively. Not all journals were happy about ChemRxiv, even within the ACS. Some warned that any content of a submitted paper that has been made publicly available, in this or other ways "may jeopardize the originality of the submission and may preclude consideration for publication". However, 80% of ACS journals do allow preprints, while others are still formalizing their policies to permit them. At first glance, it would seem that the preprints server acts as a reservoir where chemistry journals can pick up papers of interest to them, as illustrated by a RSC collection of published articles that have previously been submitted to ChemRxiv. Moreover, a new feature (Direct Journal Transfer) helps authors submit their posted preprints from ChemRxiv to established journals for editorial consideration and peer review. The business model adopted by the community seems similar to an auction, and the "traditional" functioning of the journals is not under threat. This would allow me to consider the development of ChemRxiv as an episode in the life of a "disciplinary publication regime" that guaranteed the continuity of a disciplinary program and has demonstrated its strength and stability.

Conclusion

Starting from the page-charge mechanism, this study describes a trajectory of market entry for scientific articles in chemistry. The proposed chronology is marked by two points of disruption that correspond to the adoption of federal legal provisions: authorization of the payment of publication fees on grants in 1961, and the Copyright Act in 1976 (and its application in 1978). These legal provisions have introduced real changes, especially the previously implicit condition of novelty, and to some extent have led to irreversibilities. They have also allowed the ACS to convert its scientific credibility into a financial credit.

The hegemony of American chemistry journals has not always existed: as a professional group the ACS benefited from favorable conditions granted to philanthropic foundations to develop during the twentieth century. The study highlights the essential role of the State in a U.S. context, but the global consequences of this North-American history are still to be analyzed.

Entry through the ACS has allowed us to study a non-commercial production system that is rooted in a capitalist context marked by numerous and profound transformations (economic, technological, legal, cultural, etc.). It also gives an account of different periods in the evolution of a profession. "Price (or tariff) setters" of the ACS acted in these particular contexts that constrained their action but made it possible, timely, and sometimes necessary. They collectively move towards the regimentation in the frame of a disciplinary publication regime.

The inventiveness shown by the ACS, especially in crisis situations (1930s, early 1970s) is noteworthy. Chemists imagined early on that publication could be more than an internal newsletter or a simple communication tool.

This study questions the changing status of the journal, based on the prevailing model in chemistry today: the tariffing of the article. Is it peculiar to chemistry and its "organic" relationship with industry (which "contributes by the time of hundreds of people who are active in the work of the ACS", as mentioned in section The 1960s: introduction of the page-charge pricing mechanism)? Are these results generalizable to journals published by other learned society (the RSC) or private publishers (Wiley)? In the field of chemistry, expansion to other contexts or type of journals would undoubtedly afford interesting points of comparison.

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Notes

1 The journals and publishers appearing in this table are extracted from a database that I constituted for the needs of my research from a query (subject area = chemistry) in Ulrichsweb database, which has worldwide coverage. There are 2564 titles covering the discipline of chemistry, of which 2277 have been active since 2001. Among these journals, I have chosen a representative sample of about ten publishers to which I have added a few multidisciplinary journals (PLOS, Nature Research, BMC) in which chemists also publish.
2 OpenAPC initiative under the guidance of Bielefeld University.
3 In their quantitative study of the Research Excellence Framework in the UK (data collected during the five last cycles of REF), Paye and Renisio suggested that the rise of the article format is a general trend of the considered period (1992–2014).
4 We will see that authors were not entirely absent in the past since they did have to pay the page fees from 1963 onwards.
5 In his 1995 paper, Hilgartner sketches a rough outline of the scope of the journal regime (referenced above as publication regime) through five examples. In the regime of journals, there is a fairly sharp division between published and unpublished material (example 1). Articles that are later deemed to be incorrect remain part of the permanent record (example 2,). Scientists submit articles directly to journals (example 3). At the organizational and inter-organizational levels, the regime of journals has achieved a fairly orderly division of labor and a relatively stable economic structure (example 4). The assembly of information and knowledge from multiple publications is a task performed by readers (example 5, p. 248). The journal regime is mainly defined as the opposite to what it is intended to be replaced by (the new communication regimes based on biomolecular databases) (Hilgartner, 1995: pp. 245–248).
6 The governing frame refers to the organized set of schemata that provides a template that actors employ to guide action and interpretation (Hilgartner, 2017: p. 12).
7 Like Physics Today for the APS, its function is also to animate the professional community; Reese (2002) describes it as the cement of the chemical society.
8 This is the term used by the author (Kuney).
9 "At various times journals of narrow scope have been suggested" (Brown and Weeks, 1952: p. 207).
10 The ACS now uses the term ACS Journals rather than the Publication Program, see http://pubs.acs.org/page/about-us.html.
11 The interwar period was the one where German chemistry lost ground: from 1938, the percentage of English documents indexed in *Chemicals Abstracts* exceeded that of documents in German (Bottle et al., 1983).
12 "President Langmuir pointed out to the editors that, with the expense of recording research, or any future or prospective funds, no organization could undertake, or hope to maintain, any program of unrestricted publication". Proceedings of the ACS 1930. Issued with the January Number 1930 (*JACS* vol. 52, Issue 1): 2.
13 Proceedings of the ACS 1935, provided with the February 1935 issue (*JACS* vol. 57, Issue 2). Report of the Editor of the ACS for 1934: p. 5.
14 "The journal began 1934 with some accumulated excess of accepted manuscripts, and there was a considerable delay in publication throughout the year. The situation was, however, partially remedied in December, so that the Journal finished the year on a relatively fast publication schedule." Proceedings of the ACS 1935, provided with the February 1935 issue (*JACS* vol. 57, Issue 2). Report of the Editor of the *Journal of the American Chemical Society* for 1934: p. 1.
15 *JACS* vol. 62, No. 1, January 1940.
16 Created in 1937, the American Documentation Institute (ADI) aimed at encouraging preservation of microfilm documents, see its history here: http://www.loc.gov/rr/scitech/trs/trsadi.html#history.
17 To simplify, in the remainder of the article I will use the terms tariff and price interchangeably.
18 *Chem. Eng.* News, Sept. 18, 1961: p. 104.
19 *Chem. Eng.* News, Sept. 18, 1961: pp. 104–105; *Chem. Eng.* News, March 19, 1962: pp. 92–93.
20 *Chem. Eng.* News, March 19, 1962: p. 92.
21 *Chem. Eng.* News, Sept. 18, 1961: p. 104.
22 *JACS* vol. 84, No. 19 October 5, 1962.
23 "Beginning with the January issue, 1963, a page charge for publication will go into effect. The ACS position is described in detail via a series of questions and answers in 'The Case for Page Charges'", *Chem. Eng.* News, March 19, 1962: p. 92.
24 "Is the page charge not a departure from traditional practice of scientific journals? Yes, from long-standing tradition, but the page charge is not new." *Chem. Eng.* News, 1962, 40 (12): p. 93.
25 The argument continues: "We believe that members of the chemical industry will cooperate in the matter of the page as they always have done when ACS needed assistance with constructive work." *Chem. Eng.* News, 1962, 40 (12): p. 92.
26 *JACS* vol. 86, Issue 21, 1964. Notice to Authors of Papers (Nov 5, 1964).
27 *Chem. Eng.* News, March 19, 1962: p. 93.
28 *JACS* vol. 88, Issue 21, 1966. Notice to Authors of Papers (Nov 5, 1966).
29 2001 figures show 350 employees (*Chem. Eng.* News 78 (8): p. 59).
30 John T. Scott, Physics Today 23 (1970), Report on AIP-1969: p. 44.
31 *JACS* vol. 85, Issue 4, 1963. Notice to Authors, Feb. 5, 1963: p. 1.
32 In his review, Kaufmann (1986) highlighted that the ACS Style Guide contained all of the information covered by its predecessor, the Handbook for Authors, and more. The ACS Style Guide, which included editorial style and usage conventions for the production of illustrations, chemical structures, and tables, was also applicable to the scientific literature. It also presented an overview of electronic manuscript submission and oral presentations.
33 *JACS* vol. 92, Issue 1, January–March 1970.
34 *JACS* vol. 98, Issue 1, January 7, 1976. A report to readers and authors (author: C. Walling).
35 As stated by Walling "As the charge is based on page units, it is more likely to encourage shorter articles".
36 *Chem. Eng.* News, 1975, 53 (27): p. 6.
37 *JACS* vol. 98, Issue 1, January 7, 1976. A report to readers and authors (author: C. Walling).
38 "Articles appearing in copies of issues of [*JACS*] for which payment has been made, accepted, or promised are considered advertising matter. Therefore, such articles must be marked "advertisement" and charged the advertising mailing rate." Notice from the local post office in Washington, D.C., *Chem. Eng.* News, 1976, 54 (45): p. 5.
39 *Chem. Eng.* News, 1976, 54 (45): p. 5.
40 *JACS*, vol. 101, Issue 1, Jan. 3, 1979.
41 The IRS is the government agency that collects income tax, various taxes (employment taxes, corporation tax, inheritance, etc.), and enforces tax laws regarding the federal budgets of the United States.
42 "A report from the [IRS] district director's office contended that the pricing differential constitutes a monetary benefit to the members of the society, and Section 501(c)(3) requires that 'no part of the net earnings' of the society 'shall inure to the benefit of any private shareholder or individual'. This difference in subscription price, according to the report, constitutes inurement of a benefit." *C&EN* 1980, vol. 58 (45): p. 8.
43 *JACS* vol. 101, Issue 1, Jan 3, 1979, A Report to Readers and Authors (5A).
44 *JACS* vol. 101, Issue 1, Jan 3, 1979, Publisher's Note (5A).
45 In 2006, the U.S. Congress debated legislation that would have instructed the National Institutes of Health (NIH) to require all funded researchers to submit copies of their final, peer-reviewed journal articles to PubMed Central, an OA repository operated by the NIH, within 12 months of publication. Despite the opposition from publishers, the PubMed Central legislation was passed in December 2007 and became effective in 2008.
46 ACS AuthorChoice Press Release, 2006.
47 Author's Choice, *ACS Chem. Biol.* 2006, 1 (8), p. 471.

References

Akrich M, Callon M, Latour B (eds) (2006) Sociologie de la traduction: Textes fondateurs. https://doi.org/10.4000/books.pressesmines.1181
Angermuller J (2017) Academic careers and the valuation of academics. A discursive perspective on status categories and academic salaries in France as compared to the U.S., Germany and Great Britain. High Educ 73(6):963–980. https://doi.org/10.1007/s10734-017-0117-1
Angermuller J (2018) Accumulating discursive capital, valuating subject positions. From Marx to Foucault. Crit Discourse Stud 15(4):414–425. https://doi.org/10.1080/17405904.2018.1457551
Aspers P, Dodd N (eds) (2015) Re-imagining economic sociology (1st edn). Oxford University Press
Baldwin MC (2015) Making *Nature*: the history of a scientific journal. University of Chicago Press, Chicago
Barrey S (2006) Formation et calcul des prix: le travail de tarification dans la grande distribution Sociologie Du Travail 48(2):142–158. https://doi.org/10.4000/sdt.23779
Beckert J, Aspers P (eds) (2011) The worth of goods: valuation and pricing in the economy. Oxford University Press
Berman EP (2012) Creating the market university: how academic science became an economic engine. Princeton University Press, Princeton [N.J.]
Bidet A (2010) Dessiner le marché, démultiplier le calcul. Les rationalisations matérielle et formelle dans la téléphonie au tournant des années 1980. Revue Française de Socio-Économie 5(1):165. https://doi.org/10.3917/rfse.005.0165
Björk B-C, Welling P, Laakso M, Majlender P, Hedlund T, Guðnason G (2010) Open access to the scientific journal literature: situation 2009. PLoS ONE 5 (6):e11273. https://doi.org/10.1371/journal.pone.0011273
Borgman CL (2007) Scholarship in the digital age: information, infrastructure, and the Internet. MIT Press, Cambridge, Mass
Bottle RT, Rennie JS, Russ S, Sardar Z (1983) Changes in the communication of chemical information I: some effects of growth. Inform Sci 6(4):103–108. https://doi.org/10.1177/016555158300600402
Browne CA, Weeks ME (1952) A history of the American Chemical Society, seventy-five eventful years. American Chemical Society, Washington, pp. 336–367
Callon M, Muniesa F (2005) Peripheral vision: economic markets as calculative collective devices. Organ Stud 26(8):1229–1250. https://doi.org/10.1177/0170840605056393

Callon M (2009) Postface: la formulation marchande des biens. In Evaluer et valoriser: Une sociologie économique de la mesure. Presses universitaires du Mirail, Toulouse, pp. 247–269
Cetina KK (1995) Laboratory studies: the cultural approach to the study of science. In Jasanoff S, Markle G, Peterson J, & Pinch T (eds), Handbook of science and technology studies. Sage Publications. pp. 140–166
Crane EJ (1952) Chemical abstracts. In A history of the American Chemical Society, seventy-five eventful years. The American Chemical Society, Washington, pp. 336–367
Csiszar A (2018) The scientific journal: authorship and the politics of knowledge in the nineteenth century. The University of Chicago Press, Chicago
Cronin B, Shaw D, Barre KL (2004) Visible, less visible, and invisible work: patterns of collaboration in 20th century chemistry. J Am Soc Inf Sci Technol 55 (2):160–168. https://doi.org/10.1002/asi.10353
Direction de l'Information Scientifique et Technique, CNRS (2015) Financer la publication scientifique. Le "lecteur" et/ou "l'auteur"? Evolutions, alternatives. Observations de la DIST. Retrieved from Centre National de la Recherche Scientifique (CNRS) website: http://www.cnrs.fr/dist/z-outils/documents/Distinfo2/DISTetude3_09.2016-final.pdf
Eelend B, Smith C (2016) Open APC Sweden. A national open repository of publication costs for open access articles. Retrieved from National Library of Sweden website: http://www.kb.se/dokument/open%20access/Open_APC_Sweden_English_LAST.pdf
European Commission, Directorate-General for Research & Innovation (2017) H2020 Programme. Guidelines to the Rules on Open Access to Scientific Publications and Open Access to Research Data in Horizon 2020. Retrieved from European Commission website: https://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-pilot-guide_en.pdf
Finez J (2014) La construction des prix à la SNCF, une socio-histoire de la tarification: De la péréquation au yield management (1938-2012). Revue française de sociologie 55(1):5. https://doi.org/10.3917/rfs.551.0005
Fyfe A, Coate K, Curry S, Lawson S, Moxham N, Røstvik CM (2017) Untangling Academic Publishing: a history of the relationship between commercial interests, academic prestige and the circulation of research. https://doi.org/10.5281/ZENODO.546100
Gläser J (2006) Wissenschaftliche Produktionsgemeinschaften: Die soziale Ordnung der Forschung. Campus, Frankfurt/Main; New York, NY
Gulledge E, Roscoe P, Townley B (2015) Economizing habitus: material calculation and 'the rules of the game' in the publishing industry. J Cult Econ 8 (6):637–654. https://doi.org/10.1080/17530350.2015.1047785
Hilgartner S (1995) Biomolecular databases: new communication regimes for biology? Sci Commun 17(2):240–263. https://doi.org/10.1177/1075547095017002009
Hilgartner S (2017) Reordering life: knowledge and control in the genomics revolution. The MIT Press, Cambridge, Massachusetts
Karpik L (2007) L'économie des singularités. Gallimard, Paris
Karpik L (2011) What is the price of a scientific paper? In The worth of goods. valuation and pricing in the economy. Oxford University Press, Oxford, pp. 63–85
Kauffman GB (1986) The ACS style guide: a manual for authors and editors (Dodd, Janet S; Brogan, Marianne C). J Chem Educ 63(7):A181. https://doi.org/10.1021/ed063pA181.2
Khoo SY-S (2019) Article processing charge hyperinflation and price insensitivity: an open access sequel to the serials crisis. LIBER Quart 29(1):1. https://doi.org/10.18352/lq.10280
King DW, Alvarado-Albertorio FM (2008) Pricing and other means of charging for scholarly journals: a literature review and commentary. Learn Publ 21 (4):248–272. https://doi.org/10.1087/095315108X356680
Kuney JH (1968) American Chemical Society information program. In Encyclopedia of Library and Information Science, vol I (A to Associac.). Marcel Dekker Inc, New York-Basel, pp. 247–264
Laitinen HA (1967) Editorial-Handbook for authors. Anal Chem 39 (14):1681–1681. https://doi.org/10.1021/ac50157a025
Lara, K. (2014) Open Access Library Survey. An investigation of the role of libraries in open access funding and support within institutions. Retrieved from Publishers Communication Group website: http://www.pcgplus.com/wp-content/uploads/2014/09/PCG-Open-Access-Library-Survey-2014.pdf
Latour B, Woolgar S (1986) Laboratory life: the construction of scientific facts. Princeton University Press, Princeton, N.J.
Lécuyer C (2015) Manager l'innovation. In Histoire des Sciences et des Savoirs. Tome 3: Le siècle des technosciences. Seuil, Paris
Muniesa F, Millo Y, Callon M (2007) An introduction to market devices. Sociol Rev 55(2_suppl):1–12. https://doi.org/10.1111/j.1467-954X.2007.00727.x
Nye MJ (1999) Before big science: the pursuit of modern chemistry and physics, 1800-1940 (1 paperback ed). Harvard University Press, Cambridge, Mass
Paye S, Renisio Y (2017) Un gouvernement à distance des modes de production savante? L'articlisation de 36 disciplines au prisme du Research Excellence Framework (Royaume-Uni, 1992-2014). In Le gouvernement des disciplines académiques: Acteurs, dynamiques, instruments, échelles. Edition des Archives Contemporaines, Paris
Pieper D, Broschinski C (2018) OpenAPC: a contribution to a transparent and reproducible monitoring of fee-based open access publishing across institutions and nations. Insights: UKSG J 31:39. https://doi.org/10.1629/uksg.439
Reese KM (2002) The American Chemical Society at 125: a recent history, 1976-2001. The Society, Washington
Samuel Reich E (2012) Chemical society tried to block business competitor. Nature 489(7417):482–483. https://doi.org/10.1038/489482a
Scheiding T (2009) Paying for knowledge one page at a time: the author fee in physics in twentieth-century America. Hist Stud Nat Sci 39(2):219–247. https://doi.org/10.1525/hsns.2009.39.2.219
Scheiding, T (2011) Boundary Institutions for Reconciliation of Academic Chemistry to Industry: Germany vs. The United States (SSRN Scholarly Paper No. ID 1912161). Retrieved from Social Science Research Network website: https://papers.ssrn.com/abstract=1912161
Schimmer R, Geschuhn KK, Vogler A (2015) Disrupting the subscription journals' business model for the necessary large-scale transformation to open access. A Max Planck Digital Library Open Access Policy White Paper. Retrieved from https://pure.mpg.de/rest/items/item_2148961_7/component/file_2149096/content
Skolnik H (1982) The literature matrix of chemistry. Wiley, New York, NY
Steiner P (2010) La transplantation d'organes: Un commerce nouveau entre les êtres humains. Gallimard
Strasser BJ, Edwards P (2016) Open access: publishing, commerce, and the scientific ethos. Swiss Science and Innovation Council, Bern
Tenopir C, Dalton E, Christian L, Jones M, McCabe M, Smith M, Fish A (2017) Imagining a gold open access future: attitudes, behaviors, and funding scenarios among authors of academic scholarship. Coll Res Libr, 78(6). https://doi.org/10.5860/crl.78.6.824
Tesnière V (2014) Histoire et actualité de la revue. Revue de Synthèse 135 (2–3):167–174. https://doi.org/10.1007/s11873-014-0257-8
Thackray A (1988) Chemistry in America, 1876-1976: historical indicators. D. Reidel Publishing Company, Dordrecht/Boston/Lancaster
White HC, Eccles RG (1987) Producers' markets. In: Palgrave Macmillan (ed.), The new palgrave dictionary of economics (p. 1-6). Palgrave Macmillan UK
Zbaracki MJ, Bergen M (2004) Pricing structure and structuring price. Annual Meeting of the American Sociological Association, San Francisco, CA

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