



Money for nothing: How firms have financed R&D-projects since the Industrial Revolution



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ABSTRACT

We investigate the long-run historical pattern of R&D-outlays by reviewing aggregate growth rates and historical cases of particular R&D projects, following the historical-institutional approach of [Chandler \(1962\)](#), [North \(1981\)](#) and [Williamson \(1985\)](#). We find that even the earliest R&D-projects used non-insignificant cash outlays and that until the 1970s aggregate R&D outlays grew far faster than GDP, despite five well-known challenges that implied that R&D could only be financed with cash, for which no perfect market existed: the presence of sunk costs, real uncertainty, long time lags, adverse selection, and moral hazard. We then review a wide variety of organisational forms and institutional instruments that firms historically have used to overcome these financing obstacles, and without which the enormous growth of R&D outlays since the nineteenth century would not have been possible.

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1. Introduction

A key characteristic of large high-technology firms today is that they hold enormous amounts of cash. In 2012, for example, Apple held \$121bn, Google \$47bn, Facebook \$11bn and Amazon \$5bn in cash.¹ These firms may have many reasons for keeping such cash piles ([Myers and Majluf, 1984](#)); we will argue that a key reason is the importance of R&D to these firms, because it does not involve any bankable collateral, has a high degree of uncertainty, and long open-ended time lags, and faces several other challenges such as adverse selection and moral hazard. Therefore R&D has to be financed with cash rather than capital.

The R&D-financing issue that these technology giants are addressing with their cash piles is a classic problem that historically all R&D-intensive firms have had to address. Nowadays, the

scale of the cash piles that high-tech firms keep has reached enormous proportions. Apple's cash mountain, for example, is higher than the GDPs of tens of different nations. This paper aims to give long-run historical insight into how we got here.

We examine what R&D spending looked like in the very long run, since c. 1750 and how, given the substantial financing obstacles, firms have been able to incur large R&D outlays on particular, highly uncertain projects. In order to answer this question, we explore how we can conceptualise R&D-outlays to understand their long-run historical evolution and we investigate what insights we can get into the financial and organisational nature of R&D-outlays by looking into particular historical cases, not unlike [Chandler \(1962\)](#), [North \(1981\)](#) and [Williamson \(1985\)](#) did to examine, respectively, organisations, institutions, and transactions. We also aim to get comparative historical insight into the order of magnitude of the costs of these particular R&D-projects.

These research questions are worthwhile for two main reasons. First, they are important because a focus on the long run allows us to see trends and changes that are not visible in the short run. Joseph Schumpeter, for example, argued that history should be included in the training of all economists. He understood 'economic analysis' as a combination of history, statistics and theory, and he wrote late in his career that 'if, starting my work in economics afresh, I were told that I could study only one of the three but could have my

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¹ Amounts rounded to the nearest billion. "Technology giants at war," *The Economist*, 1 December 2012, p. 28. As percentage of annual revenue the cash piles were, respectively, 78, 9, 99 and 228 percent, and as percentage of the firms' market value 22, 5, 21 and 18 percent.

choice, it would be economic history that I should choose.² Innovation studies scholars such as [von Tunzelmann \(1995\)](#), [Freeman and Soete \(1997\)](#), and [Freeman and Louca \(2001\)](#), likewise have studied history. Historians and social scientists such as Chandler, North and Williamson use history to identify and examine organisational, institutional and transactional change that we cannot see if we only examine the short run. So if we want to get deep insight into how the arrangements for financing innovation can change and what might drive their dynamics, it does not suffice to study the period since the 1990s or even since the 1970s. We need to go further back in time.

Second, historical case studies can offer us unique insights, especially since each R&D-project is to some extent, almost per definition a unique, particular case that in many respects is incomparable with other projects. Much existing work on R&D is based on analysing large data-sets of aggregate annual R&D-outlays with econometric methods. In this paper we aim to show what additional insights we can gain by taking the project as the unit of analysis and studying particular cases in the long run, in a qualitative analytical-historical way following Chandler, North and Williamson's work on the dynamics of organisations, institutions, and transactions. These historical case studies can also give us an awareness of changes in scale, time lags and organisational forms in the long run.

In this paper the project is the unit of analysis, and not the organisation (Chandler), the institutional arrangement (North), the transaction (Williamson), or other parameters. Following Chandler's historical case study approach, these cases are particular, unique cases as such and are not meant to constitute a representative sample. Nevertheless, from these particular cases we can still make some inferences. A particular project with large cash outlays, for example, can potentially refute notions such as that large scale R&D was not done in the eighteenth century, or that firms in a particular country lacked the resources to carry out the largest-scale R&D projects ([Popper, 1935](#)).

Besides the historical case study method, we also use economic history methods to gain comparative insight into R&D expenditures over time, expressing them as GDP-deflated costs, as social opportunity costs and, finally, as a fraction of an intuitive non-R&D index-case.

The main empirical evidence we examine is from Britain and the United States since about 1750, though we like to emphasise that we do not endeavour to give a systematic comparison of R&D in those two countries, for which other papers can be consulted (see, for example, [Mowery and Rosenberg, 1989](#); [Edgerton and Horrocks, 1994](#)). We simply use the two countries to get broader insight into the general finance mechanisms. The United States is chosen because it is the largest country in the world in GDP-terms since the early twentieth century, and Britain because it was a technological leader in many areas until the mid-twentieth century and was never occupied during the period examined, unlike Germany, France or Japan.

We do not endeavour to give a complete and encyclopaedic review of each and every organisational form and institutional instrument that firms adopted. We merely try to review informally some main forms and provide a historical meta-narrative ([O'Brien, 2001](#)). We use a holistic approach and develop a new overarching framework, showing how all elements fit together, even if individual elements of this framework have obviously been studied previously. This is a work of history that aims to engage with the economics of technical change and innovation studies (ETIS). It does not aim to be an economic or management study, and not a standard innovation studies paper either.

This paper aims to contribute to innovation studies by showing how a long-run historical perspective, following the tradition of Nick von Tunzelmann and Chris Freeman, can give us some additional insights with respect to present-day studies. We return to very basic facts about R&D. Our approach is not economic; we focus on practical problems that firms faced and show the role of market imperfections. We aim to show how the current R&D-financing framework emerged from the past and how the factors we discuss are also important for policy and practice and for future experimentation with organisational forms and institutional instruments.

What follows first reviews the most important obstacles firms encountered when they wanted to finance R&D. In the next section we first examine growth rates in the very long run to identify trends, and then several particular historical R&D-projects for which we could trace the total cash outlays. In the subsequent section we review several organisational forms and institutional instruments that firms have historically adopted to overcome the R&D-financing problem. A final section concludes.

2. Challenges to the finance of research

We argue that the financing of R&D is made difficult by five challenges: the presence of sunk costs, real uncertainty, long and open-ended time lags between outlays and pay-offs, adverse selection, and moral hazard. We will discuss these in turn.

2.1. Sunk costs

Historically, a formidable challenge for R&D-financing has been the fact that costs are sunk ([Sutton, 1998](#)). Sunk costs are costs that must be incurred to achieve a project's aim, that are incurred once, and that cannot be recovered upon exit. R&D-costs are mostly sunk: if the outlays do not lead to a marketable product, little residual value is left. Furthermore, R&D costs are incurred 'internationally' and do not have to be incurred again with the entry of each new market, as is the case with, for example, advertising (i.e. the results of R&D costs, the successful R&D-projects, can be marketed internationally) and the results of R&D can to some extent be protected against imitation by intellectual property and trade secret law.

The small residual value of an uncompleted R&D-project also implies that there is little collateral. Given this absence of collateral, given the absence of a cash flow from which to make regular interest payments, and given that the sum needed is not precisely known ex-ante, banks generally are unwilling to provide loans for R&D. The level of sunk R&D-costs differed between industries and varied over time ([Kamien and Schwartz, 1982](#), p. 85).³ Although precise evidence is lacking, undoubtedly costs of R&D-projects increased over time and over the course of a technological trajectory. In the empirical section below we aim to gain historical understanding of the scale and growth of sunk costs in the long-run.

Technical or generic solutions to the sunk costs aspect of R&D have been developed, and most are applied nowadays by venture capital firms ([Table 1](#)). They include funding in stages, whereby initially only a limited sum is committed, until a certain milestone is reached that gives more information about the R&D-trajectory, after which a decision is made about whether to sink more money, and so on. This is not unrelated to the option approach, in which entrepreneurs see an R&D-outlay as the buying of a call option allowing them to decide at a later time whether to continue. [Hartmann and Hassan \(2006\)](#) provide a detailed study on the prevalence of this approach in the pharmaceutical industry.

² Joseph Schumpeter, as quoted in [McCraw \(2006, p. 261\)](#).

³ For historical studies of the role of sunk costs in particular industries, see [Bakker \(2005\)](#).

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