Department for
Business, Energy
& Industrial Strategy

The impact of listing on business investment

Evidence from UK corporation tax data

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Executive summary

Context and objectives of this study

Investment is a key driver of economic growth. The importance of new and productive investment has led to a policy focus on Research & Development (R&D) as part of an overall Innovation Strategy.[1] Under this Strategy, the UK Government is seeking to increase UK R&D expenditure to 2.4% of GDP by 2027, up from 1.7% in 2019.

Having a better understanding of the drivers of business investment, whether in R&D or other forms, is critical for good policymaking. One factor influencing investment may be corporate ownership structure and the incentives facing publicly listed companies, compared with private companies. The need for publicly listed companies to deliver returns to shareholders, who are not involved in the management of the company, could drive short-termism and lead to relatively lower levels of investment.

We, Frontier Economics, were commissioned by the Department for Business, Energy and Industrial Strategy (BEIS) to ascertain the effect of listing on investment. In recent years, there has been a lot of interest in the perceived lack of long-termism of UK companies. In particular, some have argued that companies return too much capital to shareholders rather than invest it for long-term growth. This 'short-termism' criticism is often aimed specifically at listed companies, and the lack of UK specific evidence in this area provided a rationale for undertaking this research.

This research contributes to the empirical evidence base on the effect of public ownership on investment. We examine this issue using company-level corporate tax data in the UK, looking at both the differential investment behaviours of public and private companies and within-company variation in investment behaviour when ownership status changes.

Theoretical basis for short-termism by publicly listed companies and existing literature

The incentives created by being publicly listed may cause listed companies to prioritise short-term outcomes. There are several theoretical reasons why publicly listed companies may invest less than comparable private companies. For example, corporate myopia may lead managers of listed companies to forgo profitable long-term investments due to pressure to improve short-term results for shareholders. Performance signalling difficulties may also lead to underinvestment, as the inability of shareholders to directly observe the performance of managers means that they may instead rely on imperfect proxies such as the company's share

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009577/uk-innovation-strategy.pdf

price. Incentivising management on this basis may encourage them to maximise share prices in the short term, potentially at the expense of higher-risk long-term investments.

Few papers have set out to address the relationship between short-termism and investment, and there does not appear to be a consensus view in the literature. Much of the existing evidence is also looking at the US, rather than the UK. This study, therefore, makes a unique contribution to the literature.

While this research is primarily interested in investment by publicly listed companies, we examine the sensitivity of our findings to considering wider definitions of 'public company', including unlisted public companies and subsidiaries, where some of the same pressures to deliver shorter-term returns may be expected to apply.

Data and approach

This study combines corporate tax data from HMRC with business-level demographic information from FAME (derived from Companies House data) and data on initial public offering (IPO) filings to create a complete and consistent dataset, which covers public and private companies over time - spanning the period 2002 to 2014:

- **HMRC tax data from the CT600 forms submitted for corporate tax filings**. This database covers corporate tax filings for all companies registered in the UK and provides consistent data on a wide range of company information and tax credit claims over time.
- **FAME data compiled by Bureau Van Dijk.** This database contains information on more than 11 million companies in the UK and Ireland, in particular on financial information such as assets, shareholders and subsidiaries, company structure, and Standard Industrial Classification (SIC) code. It is based on Companies House data. Information on company type (public or private) is only available from 2005 onwards; we therefore complement FAME with data on the date of IPOs on the LSE and AIM stock markets from the years 2000 to 2006, taken from their websites.

Our data is used to explore the relationship between ownership and investment in two ways:

- **Full sample approach.** This approach uses a linear regression to estimate whether public companies invest more or less than observably-similar private ones. We use three definitions of 'public company': listed public companies on the LSE and AIM only; all public limited companies (PLCs, including unlisted public companies); and PLCs and subsidiaries. We look at PLCs more broadly to extend the sample size available for the analysis and test the robustness of the results on a wider group of companies. Unlisted public companies are still subject to shareholder pressure due to the more stringent reporting requirements they face when compared to private companies. Including subsidiaries of PLCs further increases the number of companies in the treatment group. This widens the treatment group and captures the effects of being owned by a listed company on commercial decisions, and again tests the sensitivity of our conclusions.

- **Change in status approach.** This approach looks at the variation of public status within companies to estimate whether companies invest more or less when they are public. As a result, the regression sample used includes only those companies which change status.

Results

Our results are not consistent with the hypothesis that publicly listed companies are relatively more short-termist than private companies. Our findings are consistent with a more nuanced picture:

- **We find that publicly listed companies invest up to 1% more of their assets in R&D** when compared with similar private companies. Given that R&D is associated with the long-term, this suggests that publicly listed companies are not more short-termist than private companies. This finding is robust to different approaches to identifying comparable private companies and definitions of 'public company'.
- **We find that publicly listed companies invest up to 1.2% less of their assets in plant and machinery** (e.g., expenditure on equipment, machinery, parts of buildings considered integral, some fixtures, and vehicles kept for business use) when compared with similar private companies. This finding is robust to different approaches to identifying comparable private companies, but varies in size and significance depending on the definition of a 'public company'.
- **There is limited evidence to suggest that changes in company status have a significant impact on investment.** We find that companies which become publicly listed tend to have higher investment overall compared to when they were private, and vice-versa for when public companies become privately owned. This is consistent with the findings from the full sample approach. However, given the small number of status changes in our data, there is large variance in our results. This means most of the effects we identify are not statistically significant.

There are some limitations to the approaches used, which are important to consider. There are likely to be unobservable variables, such as risk appetite, investment decisions, managerial capability, and growth opportunities, which may be correlated with public status and may impact investment. We have also used underinvestment in R&D as a proxy for short-termism, although there are other ways in which short-termism could manifest. Finally, while our approach appears robust to selecting comparable private companies, the lack of private comparators for very large publicly listed companies means that these results may not be representative of the largest public companies. As a result, this evidence does not conclusively rule out the existence of short-termism, but the findings we have are not consistent with it.

There are several potential extensions to this work that could further enhance the literature on short-termism and listed company status. In particular, future research could explore identifying appropriate counterfactuals for investment by very large publicly listed companies, or explore individual industries of particular interest. The existing analysis could also be extended to

include stock price movements to predict short-termist pressures in the form of excess returns or reductions in stock price, or to include information from communications with investors to determine if short-termist language was used.

Literature review and institutional context

Introduction

Investment is a key driver of economic growth. Research and Development (R&D) investment yields new processes, products and services, enhancing productivity across the economy. Plant and machinery investment creates new sources of production and expands existing ones. The importance of new and productive investment has led in particular to a policy focus on R&D as part of an overall Innovation Strategy.[2] Under this Strategy, the UK Government is seeking to increase UK R&D expenditure to 2.4% of GDP by 2027, up from 1.7% in 2019.

Understanding the drivers of investment is important for meeting this target. Of particular concern is that publicly listed companies may act in a short-termist manner and under-invest relative to comparable private companies. Publicly listed companies are, on average, significantly larger than private companies, and public limited companies (PLCs, including both listed and unlisted companies) spend up to 7 times more on R&D than private companies in the UK, as shown in Figure 5.[3] According to the OECD, globally, publicly listed companies had a combined market value of about USD 84 trillion in 2017, equivalent to global GDP.[4] This means that any relative underinvestment by these companies could have significant economic consequences and make it harder to achieve policy objectives.

Objective of this research

In recent years, there has been a lot of interest in the perceived lack of long-termism of UK companies. In particular, some have argued that companies return too much capital to shareholders rather than invest it for long-term growth. This 'short-termism' criticism is often aimed specifically at listed companies, and the lack of UK specific evidence in this area provided a rationale for undertaking this research. This research complements other research commissioned by BEIS, for example the analysis on whether executive pay awards incentivised share buybacks at the expense of investment[5] or whether executive pay targets disincentivised investment[6].

We were commissioned by BEIS to ascertain the effect of publicly listed ownership on investment in 2019, following initial conversations between BEIS and HMRC on data access and scope in 2018.[7]

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[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009577/uk-innovation-strategy.pdf

[3] Based on Frontier analysis. This figure includes both publicly listed and public unlisted companies due to constraints around sample size and disclosure.

[4] https://www.oecd.org/corporate/Owners-of-the-Worlds-Listed-Companies.pdf

[5] https://www.gov.uk/government/publications/share-repurchases-executive-pay-and-investment

[6] https://www.gov.uk/government/publications/executive-pay-and-investment-in-the-uk

[7] This work contains statistical data from HMRC, which is Crown Copyright. The research datasets used may not exactly reproduce HMRC aggregates. The use of HMRC statistical data in this work does not imply the endorsement of HMRC in relation to the interpretation or analysis of the information.

The primary aim of the research is to replicate Feldman et al. (2018), or a similar study, in a UK context. This USA study uses USA corporate tax returns. Reweighing the data to generate observationally comparable sets of publicly listed and private companies, it finds evidence that publicly listed companies invest more overall, particularly driven by R&D. Exploiting within-company variation in public status, it finds that companies dedicate more of their investment to R&D following their initial public offering (IPO)[8] and reduce these investments upon going private.

The COVID-19 pandemic meant we had to pause our work on the project between March 2020 and February 2022 due to restrictions on accessing HMRC datasets. Some elements of this report were therefore completed earlier than others (e.g. a review of the existing literature), and this context should be borne in mind in reading the document. In particular, the data used to create our regression dataset only covers the period up to 2014 (the period available at the time the study was paused), and the evidence review may exclude some more recent studies.

This research contributes to the empirical evidence base on the effect of publicly listed ownership on investment. While some theoretical evidence exists concerning whether publicly listed companies invest more or less than comparable private companies, there is limited empirical evidence addressing this question. Where empirical evidence does exist, it is often contradictory. We estimate the impact of publicly listed ownership on investment using corporate tax data in the UK, looking at both the differential investment behaviours of publicly listed and private companies and within-company variation in investment behaviour when ownership status changes. We also test the robustness of these results to different definitions of public companies.

This paper is structured as follows:

- The remainder of this section addresses the theoretical and institutional context around investment by public companies, as well as evidence from the existing literature
- **Data** sets out the datasets we use to perform our analysis, including all information related to variable construction and data-cleaning to prepare this data for our regression analysis. It also includes high level information on summary statistics.
- **Analytical approach** explains our analytical approach, and the different regression specifications we use.
- **Results** summarises the results of our regression analysis, as well as any sensitivities or limitations of these results.
- **Conclusions and further research** concludes and explains the relevance of our findings for the wider policy environment and literature. It also includes a brief discussion of possible extensions to this work.

[8] An ‘initial public offering’ is a public offering in which shares of a company are sold, taking the company public.

Why do companies list on public stock exchanges?

There are a variety of reasons why companies list on public stock exchanges. From a survey of the recent literature[9], these reasons include:

- **Raising cash for investment.** While companies can also raise cash for investment through private equity or debt, a public listing may be the preferred investment capital raising option for some companies. Some evidence for this comes from Kim and Weisbach (2008), which looked at how companies spend money raised through equity issuances. They find that in the year of the initial public offering (IPO), cash reserves increased substantially, and that even four years after, the IPO cash reserves remained approximately 40 cents higher for every dollar raised. They also find an increase in investment and R&D in the first year after the IPO and a much larger increase after four years.
- **Taking advantage of over-valuation.** A company's existing owners may also choose to take a company public if they believe that it is over-valued, meaning they could make a profit from selling off their stakes. Lowry (2003) finds that more companies go public when investor sentiment is higher, which may suggest that over-valuation is an important driver of the decision to go public.
- **Capital structure adjustment.** Pagano, Panetta, and Zingales (1998) find that companies tended to list to re-balance their accounts by repaying debt to reduce their leverage after a period of high investment and growth rather than to finance future investments.
- **Owners' need for liquidity or diversification.** After a public listing, a company's existing owners can much more easily liquidate their stakes. Chemmanur, He and Nandy (2010) find that companies in industries with high average liquidity of already listed equities are more likely to go public (as well as that larger, more successful companies are more likely to go public). Listing may also allow existing owners to diversify their holdings. Looking at Swedish data for the period 1995 to 2001, Bodnaruk, Kandel, Massa, and Simonov (2008) find that private companies held by less diversified controlling owners are more likely to list publicly.
- **Being able to use stock for acquisitions and compensations.** After listing, companies can use their publicly traded stock as acquisition currency. This is likely to be particularly important in the presence of financial constraints or other market frictions which prevent them from raising cash in other ways. Similarly, the company can use stock or stock options to compensate and incentivise employees, instead of paying out cash.
- **Confidence and marketability.** The regulatory and market scrutiny associated with being publicly listed can reduce uncertainty around the value or profitability of a company and improve confidence in the company. More generally, being listed on a

[9] For a more detailed synthesis of the recent academic literature on IPOs, see Lowry, Michaely and Volka (2017) at: http://leeds-faculty.colorado.edu/bhagat/lowry-michaely-ipos.pdf

public stock exchange allows the market price to aggregate information from a wide range of investors and provide an indication of the company's true value. This can also help market the company to new investors.

Evidence on which of these reasons for a public listing are the most important is mixed. For example, Pagano (1998) finds that the most important reason for a public listing is capital structure adjustment, and investment actually decreases in Italy immediately following an IPO (although they also find that cost of credit was lower after the IPO). However, Roell (1996) finds that access to new finance for capital investment was an important reason given by companies which went public, and studies such as Kim and Weisbach (2008) also suggest investment may be a strong driver of the IPO decision.

The incentives for a public listing may also depend on company size, and this effect may have changed over time. There has been a reduction in the number of companies going public in recent years, with the number of IPOs in both the US[10] and the UK[11] falling. Gao, Ritter, and Zhu (2013) find that the decrease in the number of companies going public is particularly pronounced among smaller companies. They find that this may be due to independent smaller companies having lower profits relative to the potential profits they could generate as part of a larger organisation, making it more attractive for these companies to be acquired by larger organisations than to remain independent and undergo an IPO. Furthermore, capital has become increasingly available to private companies, allowing companies to stay private for longer.[12] Global private equity grew by a factor of nearly ten between 2000 and 2019 in terms of net asset value.[13] Following a dip in 2020, global private equity fundraising rebounded strongly in 2021 to $680 billion, just below its 2019 level.[14]

Regardless of the primary driver for public listing, it provides an important source of additional investment funding, and there is evidence that companies change their investment spending as a result of becoming publicly listed. The following section presents a brief survey of the literature exploring why listed companies might invest more or less than private companies, and the existing evidence on differences in investment by public status.

Why might publicly listed companies underinvest?

Public stock exchanges such as the London Stock Exchange (LSE) and Alternative Investment Market (AIM) provide companies with access to an important source of capital. This capital can be obtained at a relatively low cost and can spread the risk associated with large, uncertain investments amongst a large number of shareholders. However, there are reasons why publicly listed companies may invest less than comparable private companies. In particular, the

[10] Lowry, Michaely and Volka (2017).
[11] See, for example, the report by the University of Edinburgh Business School for the All-Party Parliamentary Corporate Governance Group: https://www.appcgg.co.uk/wp-content/uploads/2020/12/APPCGG-202-report-Edinburgh.pdf
[12] See, for example, Kwon, Lowry, and Qian (2017), which find that mutual fund investments have become increasingly available to private companies, and these investments allow companies to stay private for longer: https://www.nhh.no/contentassets/8f2ff1e30f4148c98860d7e38ba82ce0/kwon-lowry-qian.pdf
[13] McKinsey Global Private Markets Review 2021.
[14] McKinsey Global Private Markets Review 2022.

incentives created by being publicly listed may cause public companies to prioritise short-term outcomes.

Corporate short-termism in theory

Corporate short-termism refers to an excessive focus on short-term outcomes at the expense of long-term interests. Short-termism can result from several heuristic biases or corporate governance structures. It may result from corporate myopia, where managers of publicly listed companies forgo profitable long-term investments due to pressure to improve short-term results for shareholders. It can also result from performance signalling difficulties, as the inability of shareholders to directly observe the performance of managers means they may instead rely on imperfect proxies such as the company's share price (see e.g., Holmstrom and Milgrom, 1991). Incentivising management on this basis may encourage them to maximise share prices in the short term, potentially at the expense of higher-risk long-term investments.

Several studies draw out theoretical insights around corporate short-termism. Miller and Rock (1985) explore the implications of information asymmetry in a model where a company's managers know more about the state of a company's current earnings than outside investors. This leads to a signalling equilibrium where investment is sub-optimal because the market takes dividends as a signal of company value, creating an incentive to boost share price in the short-term by cutting back on investment.

The correlation between current and future earnings is one reason managers may cut investment to boost short-term earnings, hoping to gain in the medium term (Stein, 1989). Stock speculation can also play a role in driving this behaviour. Bolton et al. (2006) present a multi-period agent model where investors have heterogenous beliefs about the value of a company in the future. They show that speculative stock trading can push investors to incentivise managers to pursue short-termist measures to increase the speculative component of the stock price at the cost of long-term value and growth.

Another research has noted that short-termism only becomes problematic when the costs outweigh the benefits (Hackbarth et al., 2018). For companies with poor long-term growth prospects, short-termism can be an optimal strategy for shareholders. They argue that short-termism becomes a problem when it results from poorly aligned incentives in the principal-agent problem and conflicts with the objectives of investors or long-term company value.

Empirical evidence on the impact of publicly listed ownership on investment

Few papers have set out to address the relationship between short-termism and investment. Furthermore, there is no consensus view on the relationship between short-termism and investment. Some existing literature (e.g., Asker et al., 2015, and Davies et al., 2014) finds publicly listed companies underinvest relative to private ones, whilst others (e.g. Feldman et al., 2018) find the opposite.

Evidence of publicly listed companies investing less than private companies

Asker (2015) compares similar private and publicly listed companies using the nearest neighbour matching approach. They find that private companies invest more than publicly listed companies on average with respect to their gross and net investment, as well as investment in intangibles. While they test a sensitivity which includes listed companies' R&D spending, their core specification excludes R&D from the definition of investment. They find similar results when restricting their focus on companies that go public without raising capital (i.e., existing owners sell their stakes, but no new shares are created).

Davies et al. (2014) provide evidence that investors discount future returns excessively by constructing a theoretical model of investor-manager interactions. They show that if investors are myopic and discount future returns excessively, a manager will prioritise short-term profits disproportionately. This leads to sub-optimal investments, as they distribute a level of dividends disproportionately high - relative to the risk-free rate. Their model implies that myopic investors must be short-termist. They use panel data of US companies and an instrumental variable to estimate investor myopia, finding evidence of significant short-termism. They also find that private companies have larger stocks of fixed assets compared with publicly listed companies - relative to their resources. However, they do not look at comparable publicly listed and private companies, as in Asker (2015).

Evidence of publicly listed companies investing more than private ones

In contrast to these two studies, Feldman et al. (2018) find no evidence of short-termism using a time-series regression approach on U.S. corporate tax return data. They estimate several specifications, looking at different investment measures (including short-term, long-term, and R&D investment) for a subset of similar publicly listed and private companies controlling for company characteristics, such as size and industry. They find that publicly listed companies invest a statistically significant amount more than private companies. They also look at within-company variation of companies which change public listed or private status over the sample period, finding no evidence of a reduction in investment after companies list. In all cases, the authors find no evidence of short-termism and, in some specifications, find that publicly listed companies invest significantly more than similar private companies. They hypothesise that this is due to publicly listed companies having access to cheaper credit, which allows for riskier investment.

Discussion of reasons for different findings

Although Asker (2015) and Feldman et al. (2018) have a number of similarities in broad research design, there are differences in the econometric modelling, the data used, and the periods considered, which could help explain the divergence in results.

Both Asker and Feldman et al. use similar measures of investment as the dependent variables. However, there are differences in the specific variables used and what is included as an investment in their data.

- The data used by Asker does not include R&D spending, which is an important driver of the results in Feldman et al.
- Asker controls for investment opportunities, using sales growth and Tobin's Q estimates as a proxy for R&D spending. By contrast, Feldman et al. does not control for investment opportunity.
- Feldman et al. controls for profitability, while Asker controls for operating income. Unlike Asker, Feldman et al. also controls for company age, lagged asset deciles, and whether the company is a multinational corporation.

Both papers draw on large samples of USA companies and perform similar exclusions (e.g., removing financial companies and companies with negative assets). However, the time periods and sources of data differ. Asker uses a sample ranging from 2001 to 2011 and draws data on private companies from a large sample of accounting data compiled by Sageworks. By contrast, Feldman et al. uses tax filing data from 2004 to 2015 for their sample of private and publicly listed companies. Different results may partly reflect any different macroeconomic environment in the USA from 2001 to 2003 (not covered by Feldman et al.) or 2012 to 2015 (not covered by Asker).

Because of these differences in approach and findings, the existing literature is not definitive on the relationship between publicly listed ownership and investment behaviour. Moreover, it does not provide insight into whether any observed differences also apply in the UK.

Data

This section sets out the approach taken to clean and construct the dataset used in our regression specifications. Data sources have been selected to create a complete, consistent dataset that covers both public and private companies and investments by these companies and to ensure that we can observe any changes to public or private status over time.[15] We also constructed additional independent variables to control for relevant company characteristics beyond public or private status, which might be drivers of investment and short-termism, to compare public companies to observably-similar private companies.

This dataset is a unique addition to the UK literature because it captures the most complete information on company status, company financial information and yearly investment amount into plant, machinery and R&D. This is only possible by using administrative data on company tax returns and, to our knowledge, is the first time this data has been compiled and analysed.

The rest of this section explains: the underlying datasets that were combined to create our overall regression dataset, how we constructed the dependent and independent variables used in our regression specifications, and the steps taken to link these different datasets together and arrive at a clean regression sample.

- **Datasets** sets out the data sources used to construct dependent and independent variables for empirical analysis.
- **Dependent variables** describes the construction of the dependent variables.
- **Independent variables** describes the construction of the independent variables.
- **Data linking and cleaning** describes how we have linked together the separate datasets, and our approach to data cleaning and trimming.

Datasets

This study draws on evidence from three datasets:

1. **CT600 data**, an HMRC database which covers corporate tax filings for all companies registered in the UK. The CT600 data is derived from the CT600 forms submitted by companies as part of their corporate tax filings. It must be submitted for each accounting

[15] While this research is primarily interested in investment by publicly listed companies, we also explore results for alternate definitions of public companies in order to expand the sample for analysis and test the robustness of the results. As a result, in some cases in this paper, we refer to 'public' companies as opposed to 'publicly listed' companies where appropriate. Unless otherwise indicated, where the term 'public' is used in the text, it means that the content applies in general to all three definitions of public companies: listed only, PLCs (including both listed and unlisted public companies), and PLCs and their UK subsidiaries. Where this definition of 'public' needs to be changed for some statistics and figures due to sample size and disclosure constraints, we include an explanation in the accompanying text or figure.

period and contains a wide range of company information, including data on turnover and expenditure on R&D for the purposes of tax credit claims.

2. **FAME data**, which covers a wide set of UK companies based on Companies House data.
3. **IPO filings** on the date of IPOs on the LSE and AIM stock markets.

The CT600 database covers corporation tax filings for tax years 2000/01 to 2014/15 from the CT600 tax form. It contains information on a range of tax-related information, notably turnover and investment-related tax credits. As all corporations must file tax returns, this data is not subject to selection bias. Particularly important for our purposes is that the tax data covers both private and public companies (including both listed and unlisted public companies), and we can construct variables which are consistent across both company types using this data.

The FAME database is produced by Bureau Van Dijk and contains information on more than 11 million companies in the UK and Ireland,[16] with the available sample covering the period from 2001/02 to 2017/18 for most variables. While the detail of coverage varies by company, it contains data on financial information (such as turnover, operating profit, and assets), shareholders and subsidiaries, company structure, and Standard Industrial Classification (SIC). However, the FAME data we have access to only covers company type (public, private) information from 2005. FAME is derived from several underlying sources, including Companies House data.

IPO filings were extracted from LSE and AIM data and combined with Companies House data to obtain unique company names and Company Registration Numbers. This data indicates the date of IPO for companies on the LSE and AIM markets. We prepared a sample of all IPOs from the years 2000 to 2006 to account for IPOs that do not appear in the FAME data, which is only available from 2005.[17]

Dependent variables

Dependent variables construction

The variables of interest are different measures of investment as a proportion of lagged total assets. We construct investment variables using the CT600 data, while information on total assets is taken from FAME. We create three measures of investment:

1. **Research and Development (R&D) investment**. The percentage of R&D that UK companies can claim in their corporate tax filings has changed over time and differs between small- and medium-sized enterprises (SMEs) and large companies. Using the R&D claimed in the CT600 data, we account for the different rules surrounding what percentage of actual R&D investment could be claimed over time for different company

[16] As per the Bureau Van Dijk website.
[17] We collected data to 2006 to test the overlap between the FAME data and the IPO data retrieved from the stock exchange websites. We found FAME data to be generally accurate.

sizes and reverse engineer total R&D expenditure. This results in a consistent measure of actual R&D expenditure over time for companies of all sizes.

2. **Plant and Machinery (P&M) investment**. We construct a total measure of plant and machinery investment (P&M) by summing the different plant and machinery expenditure types in the CT600 data. P&M investment is expenditure on equipment, machinery, parts of buildings considered integral, some fixtures, and vehicles kept for business use.
3. **Total investment**. We construct a total investment measure by summing R&D investment and P&M investment.

As seen in Figure 1 and Figure 2, a greater proportion of public companies invest in R&D than private companies. These public companies also invest more than private companies on average in absolute terms.

Public companies are defined as public limited companies (PLCs) for the purpose of the summary statistics in this sub-section due to sample size and disclosure constraints. PLCs include both listed and unlisted public companies. Note that Figure 1 and Figure 2 do not control for drivers of these differences other than public or private status (such as company size and age) – we control for these other potential drivers using the independent variables included in our regression specifications.

Figure 1 Share of companies which invest in particular types of investment, by ownership status

Type of investment	% of public companies	% of private companies
R&D	18%	6%
P&M	74%	77%
Average number of companies (per year)	254	77,000

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: This covers all companies in our matched and cleaned dataset for the 90th-99.99th percentile of companies in terms of both mean turnover and mean assets. The average, on a per-year basis, is calculated across all years in the sample. Public companies are defined as PLCs for the purpose of this table due to constraints around sample size and disclosure.

Figure 2 Average yearly investment by company ownership type and investment type, investing companies only

Type of investment	Average public investment	Average private investment
R&D	£312,725	£72,057
P&M	£1,860,934	£703,944
Average number of companies (per year)	254	77,000

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: This covers all companies in our matched and cleaned dataset for the 90th-99.99th percentile of companies in terms of both mean turnover and mean assets. Private companies exclude companies owned by a public parent. Public companies are defined as PLCs for the purpose of this table due to constraints around sample size and disclosure. The average, on a per-year basis, is calculated across all years in the sample.

We divide these measures by the previous financial year's total assets (lagged assets) to create the **three dependent variables of interest** for the analysis:

- R&D investment as a share of lagged assets;
- P&M investment as a share of lagged assets; and
- total investment as a share of lagged assets.

Assets include both tangible assets, such as equipment and investments, and intangible assets, such as goodwill.[18] Public companies have a much larger asset base than private companies, with PLCs having over 30 times the amount of assets, as shown in Figure 5.

Once accounting for total assets, public companies invest a smaller proportion of their total assets in both R&D and P&M, as shown in Figure 3. However, R&D investment as a share of assets is similar between public and private companies, which shows the relative R&D intensive nature of public companies.

[18] There are some limitations to including goodwill in the asset base, as it cannot be sold or realised. However, due to missing observations in the breakdown between tangible and intangible assets in the FAME data, we are unable to exclude goodwill from the asset base.

Figure 3 Share of assets invested in P&M and R&D by company type - investing companies only (2014)

Type of investment	Public	Private
R&D spend per £1,000 of assets	£0.01	£0.03
P&M spend per £1,000 of assets	£0.04	£0.23

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: This covers all companies in our matched and cleaned dataset for the 90th-99.99th percentile of companies in terms of both mean turnover and mean assets. Private companies exclude companies owned by a public parent. Public companies are defined as PLCs for the purpose of this table due to constraints around sample size and disclosure.

Short-term versus long-term investment

A key motivation for this study is to provide insight into whether ownership structures have an impact on short-termism. This means that distinguishing between short-term and long-term investments is relevant.

Unlike Feldman et al. (2018), which distinguish between short-term and long-term property investments in the U.S. based on depreciation rates in the data, we are unable to distinguish between short-term and long-term P&M investments using CT600 data. However, classifying an investment as short-term or long-term based on the asset's depreciation rate is a poor measure of short-termism. Assets with long lives may be necessary investments that a company must undertake, meaning that investment in these is unlikely to be affected by short-termist pressures. Therefore, a company could invest significantly in assets with long lives and still suffer from short-termism.

Instead, investment in R&D is likely to be a better proxy for long-term investment due to the inherent uncertainty in any R&D activity as well as the impact of said investment being realised in the medium to long term.

Independent variables

Several factors are likely to affect companies' investment decisions. These include whether the company is public or not (our main independent variable of interest), and factors like industry and company age are also likely to affect investment. We control for these factors in our regression specification to avoid any omitted variable bias.

We use the following independent variables and controls in our regressions:

- public status (treatment variable);
- turnover growth;
- asset deciles, which assign companies to one of ten groups based on where their total assets sit in the overall distribution of company assets;
- company age;
- industry fixed effects based on SIC code, aggregated at the section level;[19] and
- year fixed effects.

These are addressed in turn in this section.

Public status

Our main treatment variable is whether a company is public or private in a particular year which allows us to test the hypothesis that public ownership has an impact on investment decisions. This is done by comparing similar public and private companies (between-company variation) and comparing a single company before and after it changes status from private to public or vice-versa (within-company variation).

Company ownership structures mean that there are several ways that public ownership might affect investment decisions. The primary treatment group of interest is publicly listed companies. However, we also look at PLCs more broadly (including unlisted public companies in addition to listed companies) to extend the sample size available for the analysis and test the robustness of the results on a wider group of companies. This approach was taken as unlisted public companies are still subject to shareholder pressure due to the more stringent reporting requirements they face when compared to private companies. We also test the impact of including private subsidiaries of PLCs in the set of public companies. Including subsidiaries of PLCs further increases the number of companies in the treatment group. This widens the treatment group and captures the effects of being owned by a listed company on commercial decisions, and provides further robustness testing of our conclusions.

Specifically, our definitions of public status are:

1. **Publicly listed companies** – companies listed on public stock exchanges. This includes only companies which are traded on LSE or AIM. We construct this variable using FAME and LSE data on company listing status and changes to listings from 2000 to 2015.
2. **Public Limited Companies (PLCs)** – all PLCs, including those listed on a public exchange and those unlisted (e.g., companies with public shares that are not traded on an exchange).[20] Public but unlisted companies include companies like British Airways

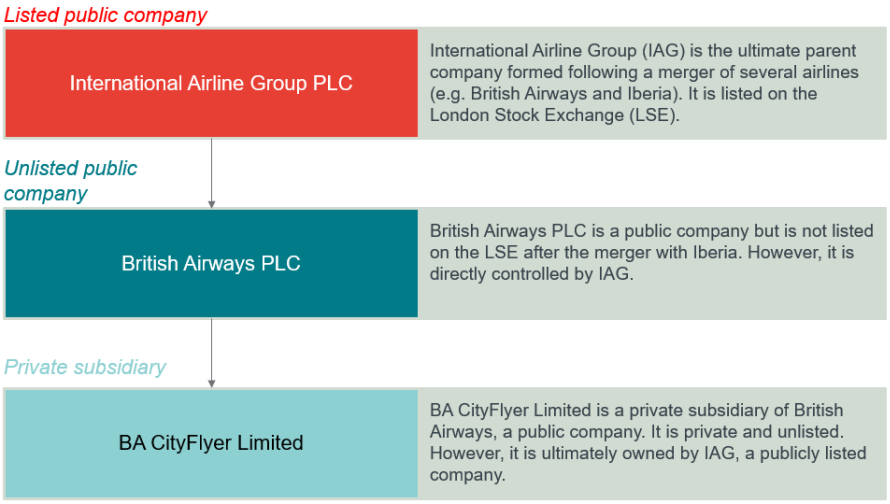
[19] A SIC section includes multiple 2-digit SIC codes. For example, SIC section A (Agriculture, Forestry, and Fishing) includes 2-digit SIC codes 01, 02, and 03.
[20] We are unable to provide information on the proportion of publicly listed and public unlisted companies in this report due to sample size constraints and disclosure concerns.

that are owned by publicly listed companies. We construct this variable using FAME data on company status and changes to their status from 2000 to 2015.

3. **PLCs and their private subsidiaries** – all PLCs as well as all of their UK-based subsidiaries. This is the widest group, which captures the impact of being public in the broadest way. We construct this variable using FAME data on company status, information on relations between companies and their subsidiaries, and changes to their status from 2000 to 2015.

Figure 4 provides an example of these three types of companies.

Figure 4 Example of public status and ownership



Source: Frontier Economics' analysis of Companies House publicly available data.

International Airlines Group (IAG) PLC is a publicly listed company which wholly owns British Airways (BA) PLC, a public but unlisted company, as well as BA CityFlyer Limited, a private limited company. This ownership structure suggests that even privately held companies which are not listed, such as BA CityFlyer, may be under the direct control of publicly listed companies.

Using listed companies and PLCs more broadly tests the hypothesis on a narrow group of companies, which are subject to stringent reporting requirements and regulatory reporting of results and targets resulting in direct shareholder pressure. For example, companies listed on the LSE must prepare their financial statements according to internationally recognised accounting standards, be audited to confirm compliance with the UK Corporate Governance Code, and maintain correct director remuneration disclosures in accordance with the Companies Act, amongst other things.[21] They generally hold quarterly earnings calls where senior leadership is questioned and regularly report strategies and targets for earnings and dividends.

[21] https://library.croneri.co.uk/cch_uk/pifrs/15-3 and https://ec.europa.eu/info/business-economy-euro/company-reporting-and-auditing/company-reporting/financial-reporting_en

Including subsidiaries of PLCs increases the number of companies in the treatment group. This widens the treatment group and captures the effects of being owned by a listed company on commercial decisions. PLCs hold a controlling interest in their subsidiaries and may be involved in the key investment decisions. However, the level of direction and control which are given to its subsidiaries may vary. Therefore, including all subsidiaries may include companies owned by a listed company but are not subject to short-termism pressure from their parent.

There are key differences in outcomes depending on the definition of a public company as shown in Figure 5.

Figure 5 Average investment and turnover amounts for companies by status (2014 mean average)

	Turnover (£m)	Assets (£m)	R&D (£m)	P&M (£m)	Company age
Private company	£14.3	£18.2	£0.05	£0.42	24
Subsidiary of a PLC	£67.4	£124.0	£0.25	£3.06	25
PLCs	£48.1	£632.0	£0.34	£2.67	43

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: This covers all companies in our matched and cleaned dataset for the 90th-99.99th percentile of companies in terms of both mean turnover and mean assets.

Private companies tend to be much smaller and younger than PLCs. However, private companies that are subsidiaries of PLCs are similar to PLCs in terms of their investment amounts. Therefore, including subsidiaries of PLCs in the public grouping will capture the indirect effects of controlling interest from a PLC. However, private subsidiaries vary from their public parents in several dimensions. They are much younger and are 5 times smaller from an asset-based perspective when compared to PLCs, as shown in Figure 5. As a result, we need to control for these differences in size and age (as well as other factors, such as industry) in our regression results to ensure we are comparing investments between similar public and private companies.

Changes in status

We use the three groupings above to determine whether a company changes its status from private to public or public to private. We define a status change in a given year according to the definition of each treatment variable group.

As shown in Figure 6, status changes are different for each type of company. For Group 1, status changes are driven only by IPOs or exchange de-listings. For Groups 2 and 3, status changes may occur when a private company is acquired or disposed of by a publicly listed company or if the company's owner changes status.

Figure 6 Status change by company type

Group	Change from private to public	Change from public to private
Publicly listed companies	IPO listing	De-listing from stock exchange
Unlisted public companies	Change in company status	Change in company status
Private subsidiaries of PLCs	Acquisition by a public company (whether listed or unlisted) or when the owner changes status	Divestment from a public company/spinoff or when the owner de-lists or gets taken private

Turnover growth

Quickly growing companies may have greater investment opportunities due to being in a rapidly growing market or by introducing new products and services. To account for this, we include turnover growth (as a % over the previous financial year) as a control in the regression.

We construct this variable using the trading turnover data in the CT600 dataset.

Asset deciles

Smaller companies may invest differently than larger companies. We control for this using lagged asset deciles from FAME. We allocate companies in our sample to one of ten equally-sized groups based on their total assets, which we call asset deciles. The bottom decile contains the 10% of companies with the lowest assets, and the top decile contains the 10% of companies with the highest assets.

Companies with large asset bases may already have made significant investments in fixed assets, meaning they require relatively smaller investments compared with their existing asset base or may operate in very capital-intensive markets. Controlling for asset deciles is consistent with the approach taken by Feldman et al. (2018).

We construct this variable using total assets data from the FAME database. Asset deciles are constructed across all companies based on average assets without controlling for the industry.

This is to avoid a proliferation of fixed effects (we control for industry separately). The asset decile variable in our regression specification is based on assets in the previous year.

Company age

Company age may also play an important role in a company's investment decisions. Younger companies may make proportionally larger investments due to having lower asset bases, to begin with, and needing to make essential investments in the early years of the business. They may also have less ability to make risky investments in R&D than older companies.

We construct this variable by creating a measure of company age for each year using the company registration date in the FAME database.

Industry fixed effects

Investment patterns are likely to differ across industries. Some industries are more capital intensive than others, while others invest far more in R&D. In general, capital-intensive companies (e.g., Mining) appear to invest the most in P&M, while capital-light but highly technical industries (e.g., Science-based industries) invest more in research and development. This is illustrated in Figure 7. Controlling for these industry differences is an important part of ensuring comparisons between similar private and public companies.

Figure 7 Rank of average investment for private companies, by industry

Rank	R&D	P&M
1	Public Administration and Defence; Compulsory Social Security	Mining and Quarrying
2	Information and Communication	Electricity, Gas, Steam, and Air-Conditioning Supply
3	Professional, Scientific, and Technical Activities	Administrative and Support Services Activities
4	Manufacturing	Wholesale and Retail Trade; Repair of Motor Vehicles
5	Mining and Quarrying	Transportation and Storage

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: This covers all companies in our matched and cleaned dataset for the 90th-99.99th percentile of companies in terms of both mean turnover and mean assets.

We create an industry variable containing each company's SIC section[22] for every year based on the SIC code associated with that company in the FAME data.

Year fixed effects

Finally, we also create variables controlling for each financial year to account for time-specific fixed effects and shocks, which are not otherwise controlled for. This is done based on the adjusted April-to-April financial years of the company, as described in the section on data cleaning.

Data linking and cleaning

To perform the analysis, we focus on companies which appear in both the CT600 data and FAME, as we require information from both databases to construct the variables of interest. We also focus on those companies for which we have complete identifier information - to avoid incorrectly matching observations across the two datasets.

Overall, we take several steps to clean and link the data. These steps are described below. We start from a dataset of 10.9 million observations and, once all data cleaning steps have been completed, end up with a final sample size of 1 million observations (where each observation is data for a company in a particular year). The stage of the cleaning process which has the largest impact is the final one, which keeps only the top decile of companies. All other steps have minimal impacts on sample size.

Normalising financial year

To account for differences in the financial year between companies, we create a normalised April-to-April financial year. Specifically, we treat companies that have financial years ending after March 31 as if they ended on March 31.

For example, if a company's financial year end is after March 31, 2004, and before April 1, 2005, we identify the year as 2004 for the purposes of the dataset.

Accounting for changes in the financial year

Some companies undergo changes in financial years over our sample period or submit tax corrections, which extend or reduce their financial year. Where this is the case, we normalise the financial results in the applicable year(s) to account for the fact that the tax period is longer or shorter than one year.

For example, if a company changes its financial year's end, which results in one year of tax filings being for a period of 1.25 years, we divide the investment and turnover figures for that year by 1.25 to account for the extended year length.

[22] SIC sections are 21 groupings of industries (e.g. Manufacturing, Transportation and Storage etc…). Each SIC section (and therefore industry) contains multiple 2-digit SIC codes.

Imputing missing values

Where we are missing data in FAME for one year, if possible, we impute the value using the immediately surrounding years' data.

For example, if we have assets data for a company in FAME for 2003 and 2005 but not 2004, we calculate the value of assets in 2004 to be the mean of the 2003 and 2005 values. In cases where we have tax data for a year but do not have any FAME data and cannot otherwise impute FAME data using the method described above, we drop this year from the dataset.

Dropping out-of-scope company types

We drop companies which are not private or public[23]based on company status in FAME and drop companies which appear to be banks, building societies, insurance companies, investment companies, or other financial concerns based on the CT600 data. This is in line with the approach taken in the rest of the literature on public investment, including Feldman et al. (2018). In papers such as Feldman et al. (2018), these company types have been excluded from the analysis due to their special organisational and tax features. We have taken this approach to ensure that our results are comparable with the literature where possible.

Dropping companies with too few observations

We also drop observations for which we cannot create lagged total assets and lagged turnover values, as these are necessary for the construction of our dependent variables and reweighting. This requires a minimum of two years' worth of observations for each company.

Stripping away the effects of inflation

To allow for comparisons across years and avoid the effect of inflation on lagged and average figures, we strip away all inflation from financial figures, with all financial figures transformed into real 2014 values.

Winsorising proportion variables

We winsorise[24] all proportion-related variables (e.g., R&D as a proportion of lagged assets) at the 98th percentile to avoid biases created by outliers with very small denominators. If not, some companies, which have positive investments but very low (or zero) total assets, can skew the results significantly.

[23] In FAME, these companies which are neither truly private or public are those with company status in the following groups: "charities", "not companies act", "other", "public investment trust", "private limited (not companies act)".

[24] Winsorising is the process of limiting extreme values in the data in order to reduce the effect of outliers. It sets all outliers to the specified percentile of the data. A 98th percentile winsorisation sets all data below the 1st percentile of the data to be equal to the value of the 1st percentile and all data above the 99th percentile to be equal to the 99th percentile.

Dropping out of scope years

The R&D tax credit scheme in the UK was extended to include large companies in April 2002. As a result, we restrict our sample to begin in the adjusted 2002 financial year (while including lagged turnover and assets data prior to 2002).

Dropping obvious outliers

Finally, we drop obvious outliers or data errors in terms of investment, where the investment figure in the tax data is not plausible given the reported turnover and assets of the company. We do this by excluding observations with investments over £100 million with a concurrent value of assets lower than £1 million.

Linking CT600, FAME, and IPO data

We merge the CT600, FAME, and IPO datasets by matching on company identifiers and year pairs. Each company in our separate datasets has an associated Companies House CRN, anonymised by HMRC for this study. For each of these companies, CT600 and FAME have separate observations for each financial year. Using these identifiers, we merge the CT600 and FAME data by matching the CRN and financial year variables.

We then append IPO data from LSE by matching the anonymised company identifier to include changes of status that occurred before the start of the FAME data series.

Keeping the top decile of companies

Our sample is restricted to include only those companies which lie within the 90th-99.99th percentile of both mean turnover and mean assets, following Yagan (2015). This is to account for the fact that public companies (both listed and PLCs - more generally) tend to be larger than private companies and clustered around the top of the distribution in terms of turnover and assets. This sample corresponds to companies with a mean turnover greater than, or equal to, £1.1 million and less than £1.8 billion and with mean assets greater than, or equal to, £1.1 million and less than £10.2 billion in 2014 pounds. We also drop SIC sections with too few observations for the DFL reweighting process described below.

The final cleaned dataset

The final cleaned dataset contains observations for the adjusted fiscal years 2002-2014 for companies which have at least 2 years’ worth of observations. We report the number of unique companies per year in Figure 8.

Figure 8 Number of companies per year in CT600 and FAME

Year	Private	Public (incl. subsidiaries)
2002	60,738	7,148
2003	55,471	6,420
2004	58,785	6,735
2005	61,928	7,055
2006	62,847	7,360
2007	73,837	8,885
2008	72,937	9,160
2009	72,129	9,445
2010	71,209	9,608
2011	70,983	9,819
2012	70,793	10,042
2013	70,821	10,193
2014	69,180	10,163
Total	871,658	112,033

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: Includes variables with missing values. 'Public', is defined as PLCs and their subsidiaries - due to constraints around sample size and disclosure.

Analytical approach

This section sets out the frameworks for our different analytical approaches. This includes information on the regression sample, the reweighting approaches used, the regression specification itself, and our approach to sensitivity tests and robustness checks.

We implemented two main regression specifications:

- **Full sample approach.** This approach estimates whether public companies invest more or less than similar private ones under three different definitions of public companies: listed public companies only; all public limited companies (PLCs, including unlisted public companies); and PLCs and subsidiaries. To test the robustness of our core specification to the reweighting approach used, we also estimate a version of the specification where propensity score matching is used to determine comparable private and public companies. The full sample regression is described in the sub-section **Full sample approach**.
- **Change in status approach.** This approach looks at the variation of public status within companies (as opposed to across companies - as in the full sample approach) to estimate whether companies invest more or less when they are public. As a result, the regression sample used includes only companies that change status. We describe the change in status approach in the sub-section **Change in status approach**.

Full sample approach

The primary regression specification estimates whether public companies invest more or less than private ones.

In order to compare public companies with similar private ones, we begin by restricting the regression sample to include only companies at the upper end of the turnover and asset distribution (where most public companies are clustered). We then reweight this sample using the approach of DiNardo, Fortin, and Lemieux (1996) so that the distribution of the target group (private companies) is the same as the distribution of the base group (public companies) for the variable of interest. This approach has been used by others in the literature, mainly Yagan (2015) and Feldman et al. (2018).

Regression specification

Our core specification is a regression which looks at the difference in investment spending between comparable public and private companies, controlling for additional factors which may influence investment. This specification broadly follows Feldman et al. (2018):

$$Y_{it} = \alpha_0 + \beta PUBLIC_{it} + X'\gamma_{it} + \delta_j + \mu_t + \epsilon_{it}$$

Where:

- Y_{it} is investment as a proportion of lagged total assets. As discussed, we test three measures of investment: total investment, R&D only, and P&M only.
- α_0 is the regression intercept.
- $PUBLIC_{it}$ is a dummy variable indicating whether the company is public in a given year. As discussed, we test three treatment definitions: listed public companies, all PLCs, and all PLCs and subsidiaries.
- X' is a matrix of company characteristics, specifically: trading turnover growth; company age; and lagged asset deciles.
- δ_j are industry fixed effects.
- μ_t are year fixed effects.
- ϵ_{it} is the regression error term.

This regression yields within industry comparisons of public and private companies across years, controlling for the impacts of company size, age, and growth.

The coefficient of interest is β. This coefficient reveals how the investment behaviour of public companies differs from that exhibited by comparable private companies, on average. It indicates the average difference in investment as a percentage of lagged total assets between public companies and private companies, once controlling for other factors. A positive and significant coefficient would suggest that public companies invest more than comparable private companies, whereas a significant negative coefficient would suggest the opposite.

Reweighting

As shown in Figure 9, public companies (both listed only and PLCs more generally) are noticeably larger than private companies, based on their turnover, even after restricting the sample to the top decile of companies. This can be seen by observing that the number of private companies with approximately £5 million in annual turnover is significantly higher than the equivalent number of public companies. Likewise, at higher levels of turnover (over approximately £40 million), there are consistently fewer private companies than public companies.

One option to control for this would be to include a variable related to the level of company turnover in the regression. However, this imposes a rigid structure on the effect of company turnover on investment. Including company turnover as a variable, strips the average impact of turnover on investment without accounting for the fact that impact may differ at varying levels of turnover. While we can introduce some nuance to this relationship by including a polynomial in company turnover, this still imposes a rigid (and arbitrary) structure for what the impact of turnover can be on investment.

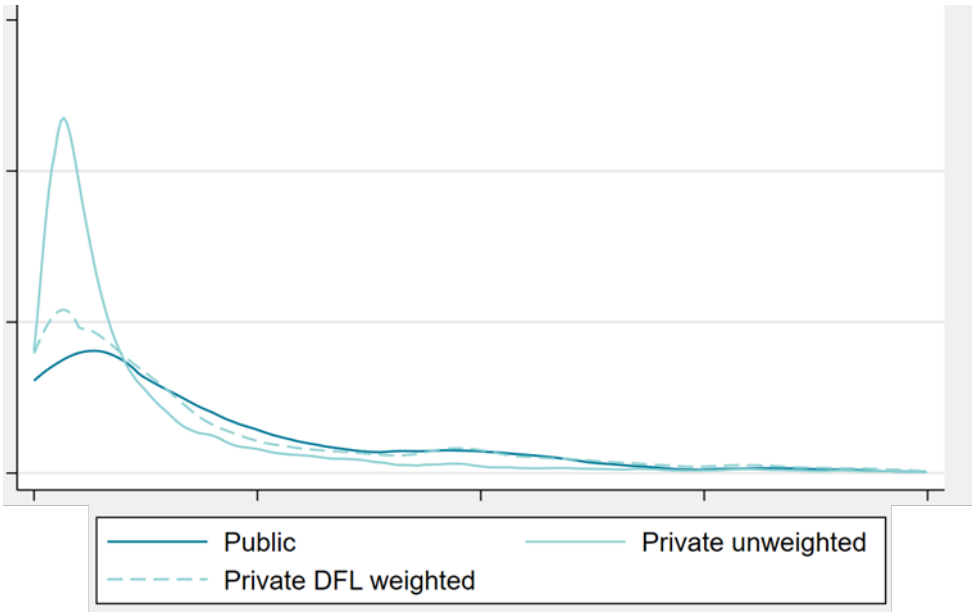
We take a more flexible approach to control for company size and reweight the regression using the DiNardo, Fortin, and Lemieux (DFL) (1996) approach. This approach is used by both Yagan (2015) and Feldman et al. (2018). When there are two distinct groups (in this case, public and private companies), the goal of DFL is to reweight the data, so the distribution of the

target group (private companies) is the same as the distribution of the base group (public companies) - for the variable of interest.

This is illustrated in Figure 9 below; the public and private distributions for a given industry and year pair are more similar after reweighting. Less weight is put on private companies with lower turnover and more on those with higher turnover when comparing their investment outcomes with those of public companies. This ensures that the comparison group of private companies appears similar to the group of public companies for the definition of public company used.

To reweight, we group companies into industries (based on SIC sections), using public companies as the base group each year. We then create an average of two-year lagged turnover for each private company[25] and construct turnover deciles for each of these base groups. Finally, we reweight the data, so the distribution of private companies more closely matches the distribution of the public base group.

Figure 9 Distribution of companies by turnover and DFL reweighting approach



Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: Shows the impact of reweighting on the distribution of companies in a given industry.

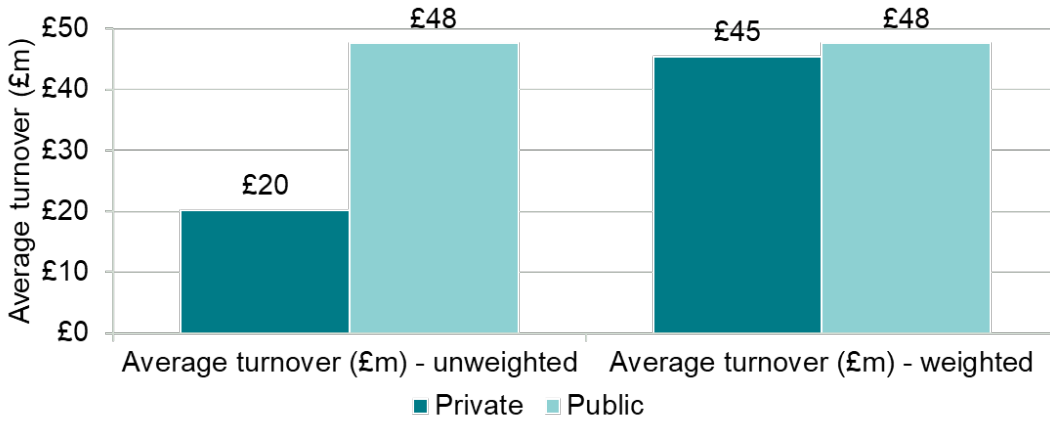
The DFL approach has some limitations. Its application is based on a univariate distribution, that is to say, only turnover is used to up- and down-weight the distribution of private companies to make it more similar to that of public companies.

[25] If two years of lagged data are unavailable, we use one year of lagged turnover instead for that observation.

As shown in Figure 10, DFL reweighting ensures average turnover is roughly equal between public and private companies for the definition of a public company used. However, important variables relevant to our analysis are not completely equalised after the DFL reweighting.

Variables, such as company age (as shown in Figure 11), do not change after reweighting. This suggests that not all variables of interest are correlated with turnover. Therefore, weighting only by turnover may miss some companies that are similar across variables of interest, which are uncorrelated with turnover.

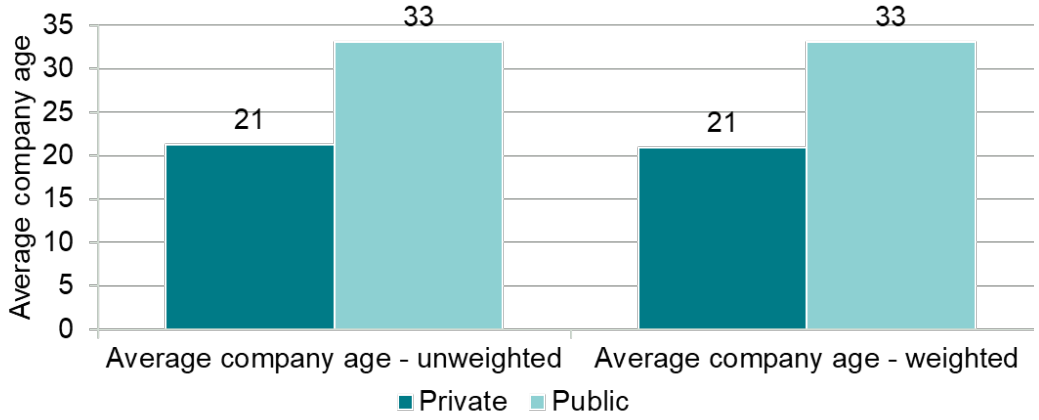
Figure 10 Average turnover before and after DFL reweighting between private and public listed companies



Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: 'Public' is defined as listed companies.

Figure 11 Average age before and after DFL reweighting between private and public listed companies



Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: 'Public' is defined as listed companies.

Covariate balance and propensity score matching

We use an alternative to create a comparable set of private companies against which to test the short-termism hypothesis: propensity score matching (PSM).[26] Feldman et al. (2018) use this as a robustness check to mirror the analysis done in Asker (2015). This demonstrates the extent to which DFL reweighting, rather than other similar methods, influences the results. We use PSM to construct a comparison group of private companies which look similar to public companies based on several variables, including company age, assets, sector, and turnover. In this way, PSM can approximate a multivariate approach to reweighting private companies.

Robustness

Alongside assessing the robustness of DFL weights with PSM, we conduct three additional robustness checks and sensitivities on the regression model specification:

1. We test modifications to the turnover and asset cut-offs. This informs whether the results are influenced by different cut-off points.
2. We test the robustness of the DFL reweighting technique by conducting the estimation without reweighting in order to quantify the influence of the DFL approach.
3. We test for multicollinearity using variance inflation factor (VIF) analysis and for any serial correlation or time dependency in the error terms.

Change in status approach

The second regression specification estimates whether companies which change their status from private to public or from public to private experience a significant change in their investment.

Regression sample

The relevant sample is the subset of companies in the (cleaned and matched) dataset that change status at some point in the period. We separate companies that change from private to public, from those that change from public to private, as significantly different business considerations are likely to be driving these changes in status. For example, a company may change status from private to public because of substantial opportunities for growth and a need to raise capital, whereas a company may change status from public to private due to financial difficulties. We exclude companies which undergo both types of change in status (those companies which list as public and then delist or are delisted and then listed again at a later date) for the same reason. The sample size of the regression sample is reported in Figure 12.

[26] DFL reweighting uses only company turnover to construct a group of private companies that look similar to listed ones. On the other hand, propensity score matching methods uses several variables to find similar companies.

Unlike the full sample approach, we do not reweight the change in the status sample. This is because this specification makes within-company comparisons as opposed to between-company comparisons.

Figure 12 Sample size for the change in status regression

Sample size	Private to public (incl. subsidiaries)	Public (incl. subsidiaries) to private
Number of observations	224	686

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: 'Public' is defined as PLCs and their subsidiaries due to constraints around sample size and disclosure.

Regression specification

We estimate a similar model to our full sample specification:

$$Y_{it} = \alpha_0 + \eta \text{Public}_{\text{it}} + X'\gamma_{it} + \delta_i + \mu_t + \epsilon_{it}$$

Where:

- Y_{it} is investment as a proportion of lagged total assets. As discussed, we test three measures of investment: total investment, R&D only, and P&M only.
- α_0 is the regression intercept.
- $PUBLIC_{it}$ is a dummy variable indicating whether the company is public in a given year. As discussed, we test three treatment definitions: listed public companies, all PLCs, and all PLCs and subsidiaries.
- X' is a matrix of company characteristics, specifically: trading turnover growth; company age; and lagged asset deciles.
- δ_i are company fixed effects.
- μ_t are year fixed effects.
- ϵ_{it} is the regression error term.

This specification has one main difference from the full sample approach: the coefficient δ_i denotes company-level fixed effects, as opposed to industry-fixed effects. The advantage of this is that we can control for fixed but unobserved factors about individual companies which might influence their investment behaviours. The disadvantage is that the effects of ownership are only identified for companies that change ownership status during the period they are observed.

η is the main coefficient of interest; denoting the impact of changes in status on investment for a given company. A statistically significant positive result would suggest companies invest more after changing their status from private to public.

Sensitivity tests and robustness

We conduct two main robustness checks on the model specification:

1. We include dummies for each year for the period around status changes. For each company, we include these indicators for up to four years before and four years after a change in status. This controls for any anticipatory effects on investment from a change in status and the persistence of the effect on investment.
2. As in the main specification, we test for multicollinearity in our regression.

Results

Our results are not consistent with the hypothesis that publicly listed companies are relatively more short-termist than private companies. We find that publicly listed companies invest up to 1% more of their assets on R&D than similar private companies, all other things being equal. Publicly listed companies invest up to 1.2% less of their assets in plant and machinery.

Taken together, total investment (R&D plus P&M) is similar to the share of assets for publicly listed and private companies, all else equal. These effects are driven by both the extensive margin (whether companies invest in R&D or P&M at all) and the intensive margin (how much is invested given that investment is positive).

We find that publicly listed companies are more likely to invest in R&D and less likely to invest in P&M, as shown in Annexe A.2. Of those that invest, R&D outlays are relatively larger, and P&M outlays are relatively smaller for publicly listed companies than for private companies.

The remainder of this section is split into three sub-sections, covering the results of the full sample approach, the results of the change in status approach, and the limitations of the conclusions that can be drawn from this analysis.

- **The full sample approach results show that publicly listed companies tend to invest more of their assets in R&D than similar private companies.** We also find that publicly listed companies invest less in plant and machinery than similar private companies. These results are robust to the definition of a public company and the reweighting approach used. This is set out in detail in the sub-section **Full sample results**.
- **There is limited evidence to suggest that changes in company status have a significant impact on investment.** We find that companies that become publicly listed tend to have higher investment overall and lower investment when publicly listed companies become private. However, given the small number of status changes in our data, there is a large variance in our results. This means most of the effects we identify are not statistically significant. This is set out in detail in the sub-section **Change in status results**.
- **There are some limitations to the conclusions that can be drawn from this analysis.** Our results are generally robust to the reweighting approach used, as well as to different definitions of a public company. However, unobservable variables and the use of underinvestment in R&D as a proxy for short-termism means that we cannot attribute a causal effect to short-termist behaviour (or lack thereof). The results may also be affected by a lack of comparable private companies for the largest publicly listed companies, and the limited sample of companies which change public listed status may also affect the precision of the change in status approach. This is set out in detail in the sub-section **Limitations of analysis**.

Full sample results

DFL reweighting results

We find that publicly listed companies tend to invest up to 1% more of their assets in R&D, but 1.2% less in plant and machinery, when compared with similar private companies after controlling for key company characteristics. This is shown in Figure 13. Given that R&D is associated with the long-term, this suggests that publicly listed companies are not more short-termist than private companies.

Figure 13 Investment as a proportion of lagged assets of public compared with private companies (DFL weighted + controls)

Variable (as a share of total assets)	Listed only	PLCs	PLCs + subsidiaries
Overall investment	-0.3%	-0.2%*	0.6%***
P&M	-1.2%***	-0.3%***	~ 0%
R&D	1.0%***	0.1%***	0.4%***

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: Results are regression coefficients and are weighted to account for company size using DFL reweighting. P-values are noted as follows: *** p<0.01, ** p<0.05, * p<0.1. Sums of P&M and R&D do not always add up to the overall investment - given rounding.

R&D investments are significantly higher for publicly listed companies even after controlling for a company's asset base, sector, and financial performance. This suggests that shareholder pressure is not reducing capital allocation to more uncertain and longer-term investments.

We find, however, that listed companies invest less in plant and machinery relative to their asset base.

Therefore, the effect on overall investment is uncertain. This effect is not statistically different from zero when subsidiaries of PLCs are excluded from the definition of a public company and positive (i.e., public companies invest more) when they are included. On balance, this evidence suggests that listed companies and their subsidiaries are not investing less than similar private companies in the long term.

Sensitivity and robustness of results

Figure 14 shows the impact of controlling for company characteristics and reweighting on the results, highlighting the importance of this as part of our preferred approach. The impact of

reweighting on the results is relatively small, with the impact of the control variables comparatively much larger.

Figure 14 Impacts of reweighting and controls on listed coefficient estimates

Public coefficient	Investment proportion	R&D proportion	P&M proportion
Comparison of means	-1.7%***	0.5%***	-2.1%***
Weighted by turnover (DFL)	-2.1%***	0.4%***	-2.2%***
Weighted and including company controls	-0.3%	1.0%***	-1.2%***

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: Results are regression coefficients. P-values are noted as follows: *** p<0.01, ** p<0.05, * p<0.1

The reweighting approach does not appear to be a significant driver of the overall regression results and conclusions.

A simple comparison of the means in the raw data (without controlling for any factors beyond public listed or private status) suggests that overall investment, as a share of assets, is around 1.7% lower for public listed companies than private companies (and statistically significantly different zero). In terms of R&D, under this specification, we find that public listed companies invest 0.5% more as a share of assets than private companies.

When reweighting the data, the coefficients of public listed investment in the regression change very little. Running the regression on the reweighted sample, but prior to controlling for additional company characteristics, leads to an estimate that overall investment as a share of assets is 2.1% lower for listed public companies than private companies, similar to the results in the unweighted sample with no controls. The impacts on the R&D and P&M coefficients are even more minor. Therefore, we can rule out that the weighting approach itself (as compared to a no weighting approach) has a significant influence on our results.

The inclusion of control variables has a larger impact. When including additional controls on; turnover growth, asset deciles, company age, and industry and year fixed effects, the impact of public listed status on overall investment as a share of assets is not statistically insignificant. The impact on R&D investment of public listed status materially increases when controlling for these factors, rising to 1% of the share of assets, double the impact in the unweighted specification with no controls, with a similar scale of impact on the P&M coefficient.

Furthermore, as illustrated in Figure 14, differences in R&D investment intensity are not driven by the characteristics of publicly listed companies. If anything, once these are accounted for, the differences in R&D investments become larger between publicly listed and private companies.

The results we report look similar if we include only listed companies in our definition of public companies, include both listed companies and PLCs that are not listed on a stock exchange, or include all public companies and their private subsidiaries. This lends robustness to our analysis, as shown in Annexe A.1. However, there are some limitations in interpreting these results.

First, while our results are consistent in direction and significance across all groups, the size of the impacts differs somewhat depending on our definition of a public company. Changes to the definition of a public company affect the types of private companies that are up-weighted as part of the DFL reweighting process. For example, defining public companies as: 'only those which are listed' implies similar private companies will have very large amounts of turnover. Therefore, mid-size and small private companies are down-weighted. However, if public companies are defined to include private subsidiaries, mid-size private companies may be more similar and will be less down-weighted.

Second, the differences between publicly listed and private investment patterns may be caused by factors other than (the lack of) short-termism if there are unobserved factors affecting investment, which differ between private and publicly listed companies. For example, differences in the cost of raising capital for these companies or differences in risk appetite. These unobservable, omitted variables are explored in more detail in the sub-section **Limitations of analysis**.

Probability of being a public company and investing in certain assets

PLCs are much more likely to invest in R&D (18% compared with 7%) and less likely to invest in P&M (74% compared with 76%), as shown in Figure 15. Full results in Annexe A.1 show that the probability of investment depends on a company's size and sector. In fact, companies with larger assets have a higher likelihood of investing in both R&D and P&M. R&D investment has become more common over time and is done significantly more by manufacturing and information and communication sectors, among others.

Figure 15 Probability of investment by company status

Company status	Probability of investing in R&D	Probability of investing in P&M
Private	7%	76%
PLCs, including listed and unlisted companies	18%	74%

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: Results from regression analysis excluding control variables. Coefficients converted from log odds into probabilities.

Company characteristics also relate to which companies tend to become public. We estimate the probability of a company being public based on its characteristics and on its holding constant financial and other factors. As shown in Annexe A.3, public companies are more likely to be in certain capital-intensive sectors, such as public administration and defence, information and communication, and professional, scientific, and technical. They are more likely to have larger asset bases and, holding all else equal, lower amounts of turnover.

Propensity score matching

The results above were used to find the factors that were associated with the propensity of a company to be public. They were used to match public companies with private ones that had a similar propensity score. We find similar results to the DFL approach when using propensity score matching to test for the existence of short-termism. R&D tends to be higher as a share of assets for public companies relative to private, and P&M investment tends to be lower. The magnitude of the effects is also similar, albeit somewhat smaller than the previous results, as shown in Figure 16.

Figure 16 Investment as a proportion of lagged assets of public compared with private companies (Propensity score matching)

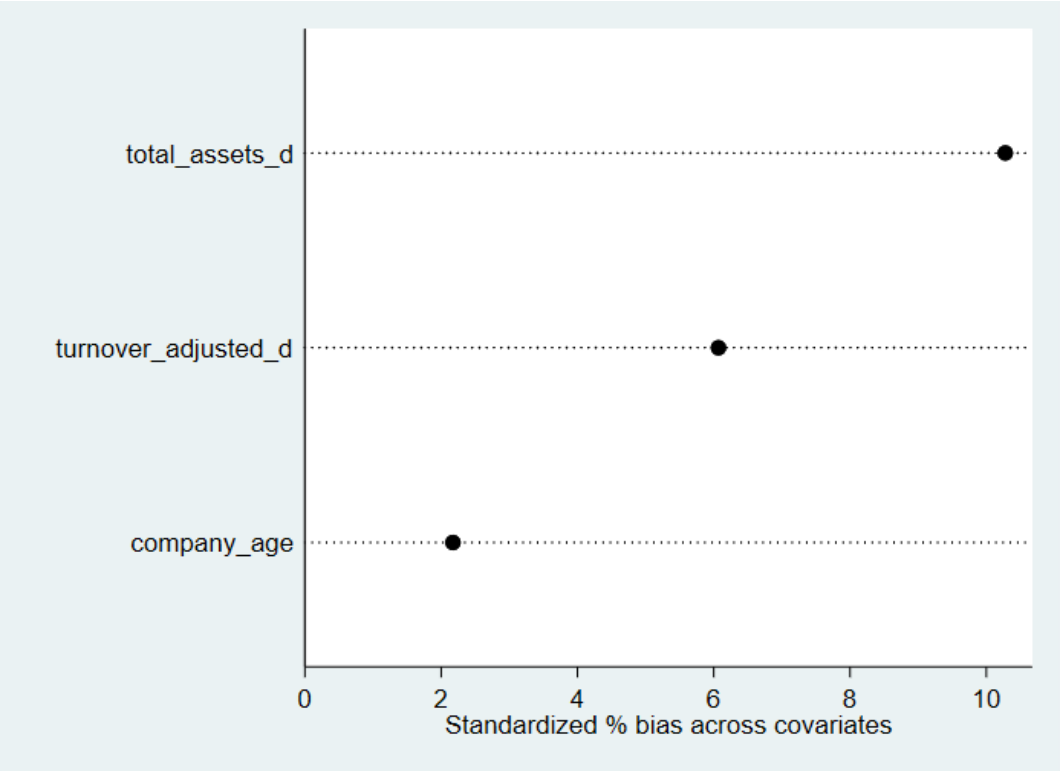
Variable (as a share of total assets)	Listed only	PLCs	PLCs + subsidiaries
Overall investment	-0.9%***	-0.7%***	0.3%***
P&M	-1.3%***	-0.7%***	-0.1%***
R&D	0.5%***	0.1%***	0.3%***

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: Results are regression coefficients and are weighted to account for company size using DFL reweighting. P-values are noted as follows: *** p<0.01, ** p<0.05, * p<0.1

Using propensity score matching, rather than DFL reweighting improves the similarity across all dimensions between private and public companies for a given definition of a public company, as shown in Figure 17. However, there were still significant differences in private and public companies with respect to their asset base and turnover, even after matching. Public companies (defined as PLCs and their subsidiaries) had around 10% higher asset bases, 6% higher turnover and 2% higher age compared to similar private companies that were matched on a similar propensity score. This suggests that there are some differences between private and public companies which cannot be completely controlled for in our analysis.

Figure 17 Difference between treatment and control covariates from Propensity Score Matching methods

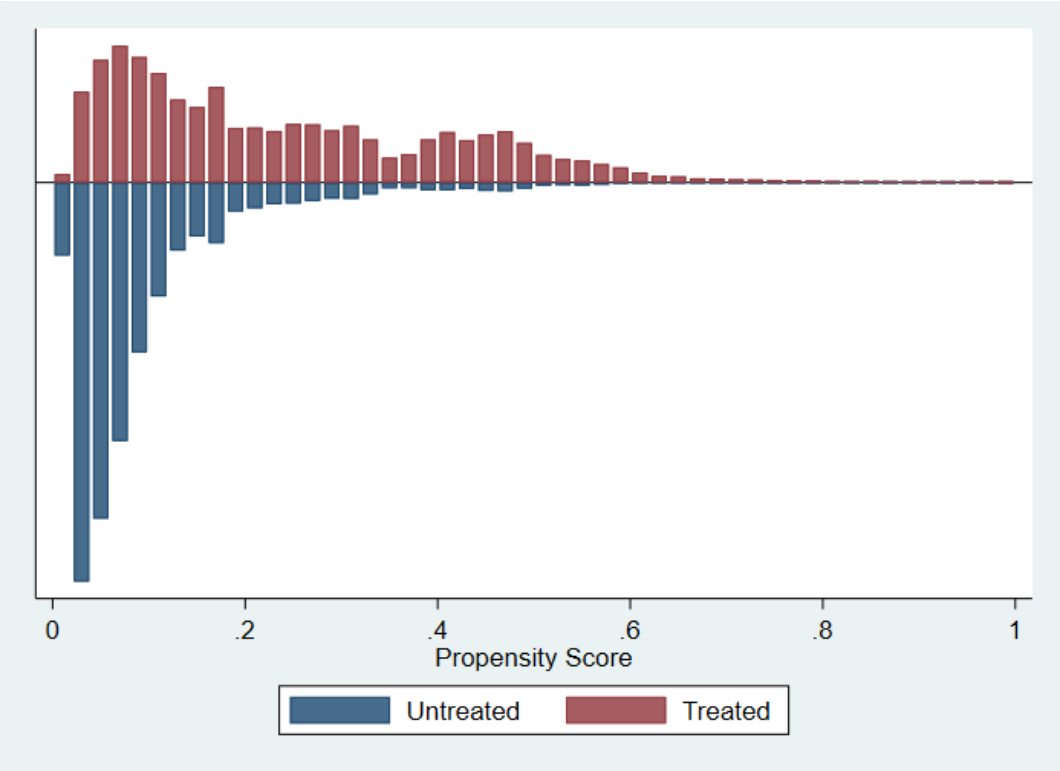


Source: Frontier Economics' calculations based on HMRC administrative datasets.

Another limitation of propensity score matching focuses on the types of public companies that are compared with similar private ones. This is likely due to the differences between private and public companies.

For very large public companies, it is very challenging to find similar private companies. As shown in Figure 18, there is only one-quarter of public companies (defined as PLCs and their subsidiaries) with a propensity score above 40% and less than 5% of private companies. This implies that the estimated effect of the propensity score matching is mostly based on public companies which exhibit characteristics that are not associated with public companies. In fact, these companies tend to be smaller than the average public company and younger.

Figure 18 Distribution of public (e.g., treated) and private (e.g., untreated) companies by their propensity score



Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: The propensity score represents the probability assigned to a company that it is public based on its characteristics. The graph shows two distributions. The y-axis above the horizontal line plots the number of public companies by propensity score. The y-axis below the horizontal line plots the number of private companies by propensity score (using a negative number to compare with the distribution of public companies above the horizontal line). Public companies are defined as PLCs and their subsidiaries.

Comparison with the wider literature

As shown in Figure 19, we find a positive relationship between R&D and publicly listed status, which is consistent with Feldman et al. (2018). However, in contrast to Feldman et al. (2018), we find an overall negative impact of publicly listed status on plant and machinery investment. Our results are consistent with Asker (2015), which finds lower investment in fixed assets for publicly listed companies relative to their private counterparts.

On balance, our findings are not consistent with short-termism. This is consistent with Feldman et al. (2018). This result, however, is driven by our results on differences in R&D spending between private and publicly listed companies and our use of R&D as a proxy for long-term investment.

Figure 19 Comparing estimates of R&D and investment for public companies (compared with private ones) across the literature

Correlation between variables and public status	Frontier (2022) estimates	Asker (2015) estimates	Feldman (2018) estimates
R&D	**Positive**	N/A	Positive
Investment	**Negative**	Negative	Positive
Total investment	**Insignificant**	Negative	Positive

Source: Frontier Economics.

Note: Results are not strictly comparable due to differences in methodology.

It is worth noting that the point estimates we produce are not directly comparable to both Asker (2015) and Feldman et al. (2018) due to differences in methodology. Definitions of investments also vary across the literature, reducing the comparability of our study with others. In fact, Feldman et al. (2018) model plant and machinery investment as property-based investments, whilst Asker (2015) uses fixed assets.

Changes in status results

Core specification

There is limited robust and consistent evidence to suggest that changes in company status have a significant impact on investment.

We find that companies which become publicly listed tend to have higher investment overall compared to when they were private, and vice-versa for public companies that become privately owned. This is shown in Figure 20. However, given the small number of status changes in our data, there is a large variance in our results. This means most of the effects we identify are not statistically significant.

We observe positive and significant effects for PLCs that change status. This result is driven by a small number of companies that are public but unlisted and change status, likely following a merger. However, since other results are insignificant, there is not enough evidence to claim that changes to status significantly impact investment amounts.

Figure 20 Results from regression on change in status

Variable (as a share of total assets)	Listed only – public to private	Listed only – private to public	PLCs – public to private	PLCs– private to public	PLCs + subsidiaries – public to private	PLCs + subsidiaries – private to public
Overall investment	-0.7%	2.9%	-0.9%***	2.9%**	-0.7%	4.7%*
P&M	-0.1%	1.3%	-0.7%***	2.8%***	-0.1%	1.7%
R&D	-0.5%*	0.2%	-0.2%**	~0%	-0.5%*	0.4%

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: Results from fixed effects regression comparing investment following a change in status. Differences in sign reflect an increase in investment when going public and a reduction in investment when going private.

Sensitivity and robustness of results

The results are sensitive to the exact nature of how public companies are defined, as explained above. This is due to the small sample sizes of companies that change status, which mean that introducing one company with a relatively large increase in investment following a change in status will influence the regression results.

More broadly, we find that investment increases in both R&D and P&M, whereas previous results suggested public companies invest more in R&D but less in P&M. This is likely due to a bias linked to changes in status which reflect other factors associated with short-termism.

Companies that change status may do so either to raise capital on public markets or as part of an acquisition or merger. In both cases, the company may increase investment with the capital raised or injected into the company. While the approach we use controls for company fixed effects, it is not able to strip out this possibility. Therefore, we are unable to determine whether increases in investment are due to factors associated with the timing of when a company changes status.

Limitations of the analysis

Our results are similar when using the DFL and PSM methodology, which shows that our results are robust to the reweighting approach. We also find similar results when using different definitions of whether a company is public.

However, limitations to our analysis mean we cannot rule out that some of the estimated effects are due to selection bias, especially given there are still significant differences in characteristics between the treatment and control groups after having applied DFL and PSM. We set out the key limitations below.

Unobservable variables and identifying the causal effect of short-termism

There are a number of other factors that might potentially be drivers of investment decisions and short-termist behaviours but are not observable in the data. This limits our ability to identify a causal effect of short-termism from this analysis.

In the full sample approach, these factors could include differences in managerial capability, human capital investment, risk appetite and opportunities for growth. To the extent that these are correlated both with company status and with investment behaviours, it is possible that our results are subject to some bias. For example, if publicly listed companies tend to have ‘better’ managerial capability, and managerial capability is positively correlated with long-term investment in R&D, then part of the positive relationship we observe between public status and R&D investment relative to assets could be explained by this omitted variable.

Similarly, in the change in status approach, we cannot observe why company ownership status changes; these reasons may be related to investment decisions. For example, a company might choose to become publicly listed in order to raise investment capital at a lower rate than they would have been able to, had they remained private, in order to make planned R&D investments. In this case, becoming publicly listed would not increase the propensity to invest in R&D, but rather a higher willingness to invest would have led the company to list publicly, suggesting a reverse causality. Similarly, companies that go from publicly listed to private and invest in R&D at a lower rate may do so due to more significant underlying business difficulties that we cannot observe in the data.

R&D as a proxy for short-termism

Our approach uses R&D spending as a proportion of assets as a proxy for short-termism. Underinvestment in R&D is one important potential consequence of short-termism, as R&D is a means of generating long-term value by incurring immediate expenses. However, short-termist actions can also take other forms. Short-termist companies may also underinvest in long-lived physical capital (such as new factories and equipment) that take years to be completed and generate returns, fail to prepare long-term business strategies, or underinvest in managing social and environmental risks to their business.

Overall, while R&D is an important type of long-term investment, it is not the only form of long-term investment and serves as a proxy for short-termism as opposed to a direct measure.

Lack of comparable private companies for the largest publicly listed companies

To compare similar public and private companies and limit the potential impact of outliers on our regression results, we have reweighted our sample following the approach of DiNardo, Fortin, and Lemieux (1996). This approach gives more weight to mid-sized public companies and comparable private companies, as opposed to the very large public companies at the tail of the distribution. Similarly, the PSM approach matches similar public and private companies and is affected by the lack of comparators ('neighbours') for large public companies. This means our findings may not be representative of very large publicly listed companies, which are particularly important sources of global R&D investments.[27]

Limited sample of change in status specification

The change in status results is based on very small samples. Given the small number of status changes in our data, there is a large variance in our results. This means most of the effects we identify are not statistically significant, although the findings are consistent with (and therefore help to reinforce) the conclusions of the full sample approach.

27 https://researchbriefings.files.parliament.uk/documents/SN04223/SN04223.pdf

Conclusions and further research

Conclusions

Our results are not consistent with the hypothesis that publicly listed companies are short-termist in their investment behaviour. R&D investments for publicly listed companies tend to be higher than similar private UK companies, holding all else constant. R&D investment can be considered a proxy for longer-term investments, given their lengthy and uncertain payback periods.

We find that investment in plant and machinery is lower for publicly listed companies than similar private UK companies, holding all else constant, and overall investment amounts (combining R&D and P&M) are similar across similar publicly listed and private companies. This result could be driven by a range of factors, including some unrelated to short-termism.

These findings are robust to different empirical methodologies. Whilst findings differ slightly based on the definition of a ‘public’ company, the broad direction of results is similar.

We find limited evidence that changes in a company’s status influence its R&D investment. However, this is driven by the limited sample size available for this regression, with only a small number of companies which change status in our sample. Therefore, the results, whilst generally not statistically significant, are subject to more uncertainty.

Caveats

There are a few key caveats for interpreting these results. In particular, we are unable to definitively identify a causal relationship between public company status and a lack of short-termism.

- There are unobservable variables that may have a causal relationship with investment decisions that we are unable to control for as part of our approach.
- We do not have a true measure of short-termism in company investments, meaning we must rely on the share of assets spent on R&D as a proxy.
- There is a lack of comparable private companies for the largest publicly listed companies. The DFL reweighting approach leads the results to be driven by mid-sized publicly listed companies and subsidiaries rather than very large public companies. However, while they may not be representative of the largest public companies, our results are generally robust to reweighting.
- The change in status result is based on very small samples.

Relevance for policy and the wider literature

This research contributes to the existing literature on corporate short-termism. The evidence in this report is not consistent with the view that the current corporate governance environment and policy gives rise to significant short-termism, as measured by R&D investment, in publicly listed companies.

However, other factors such as barriers to R&D investment may explain why private companies invest less of their assets in R&D. Therefore, this evidence does not rule out the existence of short-termism, as controlling for these unobservable differences across publicly listed and private status may change the findings of this report. These unobservable factors may include differences in:

- cost of capital;
- managerial capability and capital;
- risk appetite; and
- growth opportunities.

Extensions

There are several potential extensions to this work that could further enhance the literature on short-termism and publicly listed company status. Significant differences between private and publicly listed companies mean it is challenging to find counterfactuals to large publicly listed companies. Further work could be undertaken to develop alternative counterfactuals.

Detailed industry studies could be used to measure short-termism influence on investment, in particular for industries which are deemed critical from a policy perspective. For example, comparing the types of investments that similar companies in an industry are undertaking could determine whether listed companies are more short-termist than their private peers. For example, listed software companies invest relatively more in promotions and relatively less in new, unproven future technologies. This would be very challenging in practice as it would require detailed data on the types of investment made by all companies in a sector.

Another extension to our analysis would be to include stock price movements, as done in Asker et al. (2015), to include information about the correlation between a company's earnings per share and its stock price. Companies with a high correlation can be expected to face more short-termism pressure to influence earnings per share which, in turn, will impact their share price. Therefore, this analysis could be refined to test whether companies which have a share price that is more sensitive to earnings exhibit more evidence of short-termism.

Finally, researchers could analyse the language used by company executives on quarterly calls with investors to inform whether short-termism language is being used. This could be, for example, language promising or strongly hinting at future positive earnings performance or language, which is likely to be correlated with a short-termist stance (e.g., we are prioritising

near-term growth). This approach is novel and is likely to require advanced Natural Language Processing capabilities to predict and classify large amounts of text into whether or not it is “short-termist”. This data could then be used to determine whether companies that use more “short-termist” language invest less in longer-term projects. This analysis, however, can only be done on listed companies rather than private ones. However, it will be able to refine whether some companies are short-termist and, if so, what their main characteristics are.

However, even with these extensions, there will still be significant limitations to researching the relationship between company status and short-termism. Without a group of very large private companies, which are similar in size and age to listed companies, it will be challenging to define a counterfactual group to all publicly listed companies.

Annexe A – Detailed regression results

A.1 Summary of regression results excluding unlisted public companies

These results are similar to Figure 13 but exclude public unlisted companies.

Figure 21 Investment as a proportion of lagged assets of public compared with private companies (DFL weighted + controls)

Variable (as a share of total assets)	PLCs + subsidiaries (excluding public unlisted)
Overall investment	0.5%***
P&M	~0%
R&D	0.4%***

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Note: Results are regression coefficients and are weighted to account for company size using DFL reweighting. P-values are noted as follows: *** p<0.01, ** p<0.05, * p<0.1. Sums of P&M and R&D do not always add up to overall investment - given rounding.

A.2 Probability of investing in R&D, P&M and overall investment for a public company (compared to a private one)

These are results from a logistic regression on the probability of investing for public companies, including both listed and unlisted companies. This analysis is discussed in the sub-section **Full sample results** of the report. Results are reported in odds so they must be converted to estimate marginal effects. Marginal effects differ substantially based on the individual sector considered and other control variables, and as a result, we have not converted all the estimates into marginal effects.

Figure 22 Probability of investing for public companies

	Probability of investing in R&D	Probability of investing in R&D - w/ control variables	Probability of investing in P&M	Probability of investing in P&M - w/ control variables
public	1.083***	0.602***	-0.132***	-0.234***
	(0.0471)	(0.0525)	(0.0403)	(0.0419)
Asset Decile - 1		-0.894*		-0.187
		(0.471)		(0.296)
Asset Decile - 2		-0.973**		0.337
		(0.471)		(0.296)
Asset Decile - 3		-0.821*		0.405
		(0.471)		(0.296)
Asset Decile - 4		-0.680		0.441
		(0.471)		(0.296)
Asset Decile - 5		-0.579		0.470
		(0.471)		(0.296)
Asset Decile - 6		-0.459		0.527*

	Probability of investing in R&D	Probability of investing in R&D - w/ control variables	Probability of investing in P&M	Probability of investing in P&M - w/ control variables
		(0.471)		(0.296)
Asset Decile - 7		-0.328		0.564*
		(0.471)		(0.296)
Asset Decile - 8		-0.184		0.557*
		(0.471)		(0.296)
Asset Decile - 9		-0.140		0.489*
		(0.471)		(0.296)
Asset Decile - 10		0.0305		0.388
		(0.471)		(0.296)
2003 dummy		0.205***		-0.0453***
		(0.0324)		(0.0154)
2004 dummy		0.264***		-0.161***
		(0.0316)		(0.0149)
2005 dummy		0.223***		-0.248***
		(0.0316)		(0.0146)
2006 dummy		0.296***		-0.301***

	Probability of investing in R&D	Probability of investing in R&D - w/ control variables	Probability of investing in P&M	Probability of investing in P&M - w/ control variables
		(0.0310)		(0.0145)
2007 dummy		0.474***		-0.349***
		(0.0292)		(0.0139)
2008 dummy		0.623***		-0.550***
		(0.0286)		(0.0137)
2009 dummy		0.813***		-0.774***
		(0.0280)		(0.0135)
2010 dummy		1.054***		-0.726***
		(0.0274)		(0.0136)
2011 dummy		1.250***		-0.754***
		(0.0269)		(0.0136)
2012 dummy		1.417***		-0.752***
		(0.0266)		(0.0136)
2013 dummy		1.583***		-0.777***
		(0.0264)		(0.0136)
2014 dummy		1.578***		-0.818***
		(0.0264)		(0.0136)

	Probability of investing in R&D	Probability of investing in R&D - w/ control variables	Probability of investing in P&M	Probability of investing in P&M - w/ control variables
Mining and Quarrying		1.052***		-0.684***
		(0.108)		(0.0413)
Manufacturing		2.343***		-0.0482
		(0.0972)		(0.0322)
Electricity and Gas		0.510***		-0.997***
		(0.119)		(0.0447)
Water & Sewerage		0.913***		-0.00818
		(0.111)		(0.0455)
Construction		0.130		-0.661***
		(0.0997)		(0.0325)
Wholesale & Retail		0.104		-0.451***
		(0.0982)		(0.0321)
Transportation and Storage		-0.407***		-0.465***
		(0.104)		(0.0334)

	Probability of investing in R&D	Probability of investing in R&D - w/ control variables	Probability of investing in P&M	Probability of investing in P&M - w/ control variables
Accommodation and Food Services		-1.832***		-0.0939***
		(0.131)		(0.0347)
Information and Communication		2.618***		-0.367***
		(0.0978)		(0.0339)
Finance and Insurance		-0.145		-1.453***
		(0.105)		(0.0338)
Real Estate		-2.501***		-2.150***
		(0.149)		(0.0332)
Professional, Scientific and Technical		1.169***		-0.855***
		(0.0978)		(0.0322)
Admin and support services		-0.116		-0.100**
		(0.118)		(0.0404)

	Probability of investing in R&D	Probability of investing in R&D - w/ control variables	Probability of investing in P&M	Probability of investing in P&M - w/ control variables
Public administration and defence		1.527***		-1.314***
		(0.141)		(0.0699)
Education		-0.650***		-1.050***
		(0.207)		(0.0453)
Human health and social work		0.233**		-0.463***
		(0.107)		(0.0360)
Arts, entertainment and recreation		-0.174		-0.803***
		(0.110)		(0.0351)
Other service activities		0.533***		-0.793***
		(0.103)		(0.0346)
Constant	-2.674***	-4.386***	1.184***	1.908***
	(0.00413)	(0.481)	(0.00240)	(0.298)
Obs.	974,016	974,016	974,016	974,016
Pseudo R-squared	0.000887	0.185	9.84e-06	0.0592

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Figure 23 Probability of investing (P&M and R&D) for public companies

	Probability of investing (P&M and R&D)	Probability of investing – w/ control variables
public	-0.107***	-0.208***
	(0.0409)	(0.0426)
Asset Decile – 1		-0.238
		(0.300)
Asset Decile – 2		0.286
		(0.300)
Asset Decile – 3		0.361
		(0.300)
Asset Decile – 4		0.404
		(0.300)
Asset Decile – 5		0.429
		(0.300)
Asset Decile – 6		0.487
		(0.300)
Asset Decile – 7		0.520*

	Probability of investing (P&M and R&D)	Probability of investing – w/ control variables
		(0.300)
Asset Decile – 8		0.513*
		(0.300)
Asset Decile – 9		0.433
		(0.300)
Asset Decile – 10		0.329
		(0.300)
2003 dummy		-0.0434***
		(0.0155)
2004 dummy		-0.159***
		(0.0150)
2005 dummy		-0.246***
		(0.0147)
2006 dummy		-0.302***
		(0.0145)
2007 dummy		-0.343***
		(0.0140)

	Probability of investing (P&M and R&D)	Probability of investing – w/ control variables
2008 dummy		-0.541***
		(0.0138)
2009 dummy		-0.758***
		(0.0136)
2010 dummy		-0.698***
		(0.0137)
2011 dummy		-0.713***
		(0.0137)
2012 dummy		-0.707***
		(0.0137)
2013 dummy		-0.724***
		(0.0137)
2014 dummy		-0.760***
		(0.0137)
Mining and Quarrying		-0.676***
		(0.0414)
Manufacturing		0.0466

	Probability of investing (P&M and R&D)	Probability of investing – w/ control variables
		(0.0323)
Electricity and Gas		-1.002***
		(0.0447)
Water & Sewerage		-0.0104
		(0.0457)
Construction		-0.661***
		(0.0325)
Wholesale & Retail		-0.456***
		(0.0321)
Transportation and Storage		-0.476***
		(0.0335)
Accommodation and Food Services		-0.113***
		(0.0348)
Information and Communication		-0.263***
		(0.0341)
Finance and Insurance		-1.460***
		(0.0338)

	Probability of investing (P&M and R&D)	Probability of investing – w/ control variables
Real Estate		-2.162***
		(0.0332)
Professional, Scientific and Technical		-0.840***
		(0.0322)
Admin and support services		-0.111***
		(0.0405)
Public administration and defence		-1.319***
		(0.0699)
Education		-1.052***
		(0.0454)
Human health and social work		-0.457***
		(0.0361)
Arts, entertainment and recreation		-0.813***
		(0.0351)
Other service activities		-0.792***
		(0.0346)
Constant	1.218***	1.951***

	Probability of investing (P&M and R&D)	Probability of investing – w/ control variables
	(0.00242)	(0.302)
Observations	974,016	974,016
Pseudo R-squared	6.46e-06	0.0617

Source: Frontier Economics' calculations based on HMRC administrative datasets.

A.3 Probability of being a public company

These are results from a logistic regression on the probability of being public, including both unlisted companies and private companies that are a subsidiary of a public company. This analysis is discussed in the sub-section **Full sample results** of the report. The results are reported in odds and must be converted to estimate marginal effects. Marginal effects differ substantially based on the individual sector considered and other control variables, and as a result, we have not converted all the estimates into marginal effects.

Figure 24 Odds of a company being public

	Odds of being public	Odds of being public
Change in turnover	1.55e-09***	1.63e-09***
	(0)	(0)
Asset Decile - 1	2.191***	
	(0.119)	
Asset Decile - 2	1.722***	
	(0.120)	
Asset Decile - 3	1.831***	

	Odds of being public	Odds of being public
	(0.120)	
Asset Decile - 4	2.000***	
	(0.119)	
Asset Decile - 5	2.159***	
	(0.119)	
Asset Decile - 6	2.384***	
	(0.119)	
Asset Decile - 7	2.724***	
	(0.119)	
Asset Decile - 8	3.113***	
	(0.119)	
Asset Decile - 9	3.598***	
	(0.119)	
Asset Decile - 10	4.257***	
	(0.119)	
Mining and Quarrying	2.808***	2.918***
	(0.0713)	(0.0716)
Manufacturing	2.291***	2.278***

	Odds of being public	Odds of being public
	(0.0662)	(0.0663)
Electricity and Gas	2.782***	3.027***
	(0.0739)	(0.0745)
Water & Sewerage	1.990***	1.959***
	(0.0771)	(0.0773)
Construction	1.385***	1.290***
	(0.0675)	(0.0676)
Wholesale & Retail	1.674***	1.619***
	(0.0664)	(0.0665)
Transportation and Storage	1.886***	1.891***
	(0.0677)	(0.0678)
Accommodation and Food Services	1.260***	1.353***
	(0.0695)	(0.0697)
Information and Communication	2.922***	2.912***
	(0.0671)	(0.0672)
Finance and Insurance	2.609***	2.741***
	(0.0675)	(0.0677)
Real Estate	1.149***	1.399***

	Odds of being public	Odds of being public
	(0.0687)	(0.0689)
Professional, Scientific and Technical	2.530***	2.521***
	(0.0664)	(0.0665)
Admin and support services	1.897***	1.952***
	(0.0725)	(0.0727)
Public administration and defence	3.127***	3.260***
	(0.0967)	(0.0958)
Education	1.739***	1.752***
	(0.0807)	(0.0804)
Human health and social work	1.670***	1.686***
	(0.0712)	(0.0713)
Arts, entertainment and recreation	1.990***	2.025***
	(0.0694)	(0.0696)
Other service activities	2.057***	2.019***
	(0.0692)	(0.0692)
2003 dummy	-0.0227	-0.0221
	(0.0193)	(0.0190)
2004 dummy	-0.0445**	-0.0400**

	Odds of being public	Odds of being public
	(0.0190)	(0.0188)
2005 dummy	-0.0509***	-0.0419**
	(0.0188)	(0.0186)
2006 dummy	-0.0463**	-0.0263
	(0.0187)	(0.0185)
2007 dummy	-0.0463***	-0.0112
	(0.0179)	(0.0177)
2008 dummy	-0.0208	0.0195
	(0.0178)	(0.0176)
2009 dummy	0.0431**	0.0673***
	(0.0177)	(0.0175)
2010 dummy	0.0568***	0.0892***
	(0.0177)	(0.0175)
2011 dummy	0.0728***	0.109***
	(0.0177)	(0.0174)
2012 dummy	0.0998***	0.136***
	(0.0176)	(0.0173)
2013 dummy	0.102***	0.148***

	Odds of being public	Odds of being public
	(0.0176)	(0.0173)
2014 dummy	0.112***	0.167***
	(0.0176)	(0.0174)
Company Age	-0.00716***	-0.000849*
	(0.000468)	(0.000467)
Age Squared	6.76e-05***	2.93e-05***
	(4.91e-06)	(5.03e-06)
Change in total assets		1.51e-08***
		(1.04e-10)
Constant	-6.918***	-4.483***
	(0.136)	(0.0676)
Observations	983,594	973,567
Pseudo R-squared	0.160	0.115

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Annexe B – Accessibility tables

Figure 25 Accessibility table for average turnover before and after DFL weighting between private and listed public companies (Figure 10)

Average turnover before and after DFL weighting between private and listed public companies - £m	Average turnover £m - unweighted	Average turnover £m - weighted
Private	20	45
Public	48	48

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Figure 26 Accessibility table for average company age before and after DFL weighting between private and listed public companies (Figure 11)

Average company age before and after DFL weighting between private and listed public companies	Average company age - unweighted	Average company age - weighted
Private	21	21
Public	33	33

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Figure 27 Accessibility table for difference between treatment and control covariates from Propensity Score Matching methods (Figure 17)

Variable	Standardised % bias across covariates
Total assets	10.30%
Turnover	6%
Company age	2.20%

Source: Frontier Economics' calculations based on HMRC administrative datasets.

Peer review and work cited

The Impact of listing on business investment. BEIS Research Paper

Commentary by Ron Smith, July 2022

There has been considerable concern about “short-termism” in British industry. Investigating this question is hampered by lack of agreement about what is meant by short-termism and how to measure it. Short-termism can be interpreted as firms having a higher discount rate than either the profit maximising rate or the socially optimal rate and this higher discount rate causes them to invest less. It has been suggested that pressure for a higher discount rate might come from shareholders and this causes publicly listed companies to invest less than private companies. Whereas measuring discount rates from observational data is difficult, one can compare investment between listed public firms and unlisted private firms.

This BEIS research paper is a careful analysis of the effect of public listing on investment by UK companies over the period 2002-2014, controlling for a range of other factors. The study benefits from having exceptionally good firm-level data, obtained by combining administrative data from CT600 company tax returns with Companies House records and Initial Public Offerings, IPO, filings. Companies are included if they have two or more years of data and the number of private companies is between 55 and 73 thousand and of public companies between 6 and 10 thousand. In consequence, over the sample as a whole, the panel has almost a million observations.

Most of the work on this topic has been done on the US and the paper follows the methodology of a 2018 US Federal Reserve study which also used corporate tax return data. The US study found that public firms invest more in long term assets, particularly innovation, than private firms.

The dependent variables being explained in the paper are total investment as a share of lagged assets and its two components, research and development, R&D, investment and plant and machinery, P&M, investment. The paper investigates both the probability of doing investment, and the amount of investment done.

A central issue in such an analysis is the problem of a counterfactual. One would like to know what a particular public company would have invested in a particular year had it been a private company. But one cannot know this, since one only observes the company as being either public or private. To try and infer the effect on investment the paper considers two separate questions. One is between firms: are listed companies different from private companies with respect to investment? The other is within firms: does listing change the investment behaviour of a company? With respect to the first question, the study finds that listed companies invest up to 1% more of their assets in R&D but up to 1.2% less in P&M. Since R&D investment can be seen as long-term this higher investment by public companies is not consistent with listing inducing short-termism. With respect to the second question, they find that listing raises

investment and going private reduces it but because of the small number of status changes in the data the results are not significant.

The panel regressions control for a variety of influences: turnover growth, company age, size measured by asset deciles as well as industry and year effects.

The paper reports a wide range of robustness checks to establish the sensitivity of the results to the assumptions made and is suitably qualified about limitations to the interpretation. The robustness checks include looking a number of different definitions of being a public company: listed public, all public limited companies (PLCs, including unlisted ones) and PLCs and subsidiaries.

A major difficulty facing any analysis is that listed and unlisted companies differ in many ways both observed and unobserved. In particular public companies are larger than private companies. One way adopted to deal with this issue is reweighting the data are so that the distribution of turnover by private companies more closely matches the distribution of the public ones. While this equalises by turnover it does not equalise for other variables. Another way is to use propensity scores to match public companies with similar private companies. The two procedures gave similar results. However, there were still significant differences between public and private companies after matching. While it is reassuring that reweighting and propensity score matching give similar results but, as the paper notes, for very large public companies, it is very challenging to find similar private companies to provide comparators.

The paper concludes with a list of possible extensions, further research that might illuminate the link between listing and investment in longer term projects.

This is a careful study, using excellent data and appropriate statistical methods, which conducts a range of robustness checks and draws suitably qualified conclusions. My judgement is that it is a valuable piece of work that sheds considerable light of the patterns of investment by publicly listed and private firms.

Ron Smith is Professor of Applied Economics at Birkbeck, University of London, where he teaches econometrics and statistics. He has published extensively on a range of topics in applied econometrics and public policy and his work has been widely cited (over 25,000 Google Scholar citations). He has been elected a Fellow of the International Association for Applied Econometrics.

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