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Do Pension Fund Investments Make a Difference? Effects on Firm Productivity*

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1 Introduction

Global assets in retirement savings plans amounted to over USD 56 trillion for the first time at the end of 2020 (OECD, 2021). A large part of these savings is accumulated in pension funds, making them key investors in global financial markets. Given their rising importance, it is not surprising that funded pensions have attracted the attention of policymakers and researchers alike. For example, the G20 has identified pension funds as a key source of long-term capital to finance growth and development (OECD, 2019).[1]

Against this backdrop, a natural question that arises is whether and how pension funds affect the economy at large. However, the understanding of the economic implications of pension funds is still rather limited. This study aims to reduce this gap by providing empirical evidence on the effects of pension funds' investments with high-quality data, which offer three main advantages. First, they are based on a large and comprehensive sample of firms drawn from Danish administrative registers. Second, they include detailed information on the complete ownership structure of the firms involved in the analysis, which allows us to cover both listed and unlisted companies. Third, they carefully identify domestic pension funds' investments in Danish firms. Armed with these data, we find that firms experience a productivity increase after they receive a pension fund investment.[2] We also provide suggestive evidence that the effect of productivity tends to be larger the larger the investment in the firm and the longer its duration. Finally, we find that unlisted firms benefit more from pension fund investment than do listed firms. These results suggest two main economic channels through which pension funds help firms improve their productivity: long-term investment commitment and capital provision.

We use the Danish matched employer–employee dataset for the period 2003–2019, combined with a comprehensive ownership dataset. Denmark is a fitting setting for this type of analysis for two main reasons. First, the unique features of the Danish data allow us to link pension funds' investments to both listed and unlisted firms' characteristics. To the best of our knowledge, most previous studies analyzing similar research questions focus mainly on listed firms. Second, Danish pension funds play an important role in the domestic economy. At the end of 2020, assets in retirement savings plans in Denmark were the largest as a share of GDP among the OECD countries, standing at almost 230% (OECD, 2021). Furthermore, the Danish pension system is frequently described as one of the best in the world (Mercer, 2021) and serves as an example of a well-functioning system largely reliant on a funded pension pillar. Since an increasing number of countries are shifting from pay-as-you-go pension schemes towards funded pension arrangements, our findings are relevant beyond the Danish

[1] See also, for example, Andonov et al. (2021).

[2] In this paper, "pension fund investment" always refers to equity investment by Danish pension funds, unless explicitly noted otherwise.

context.

It is important to note that while our data do not include information on debt financing, focusing on equity investments should be not a major limitation, because equity is by and large the most important source of financing of Danish non-financial companies.[3] Whereas the previous literature has suggested that both equity and debt financing affect productivity, equity seems to be a more relevant driver of productivity increases, because it is more likely to finance risky projects such as R&D intensive investments that are crucial for productivity growth.[4]

A major challenge in investigating the effect of investors on the firms that they invest in is that investors may carefully select the latter. The issue of selection is relevant in our case if pension funds choose to invest in firms that are already relatively productive to start with, because this selection effect would confound with the observed productivity increases implied by the pension fund investment itself. While controlling for selection is empirically difficult without any exogenous variation, we adopt the following strategies to isolate the causal effect of pension funds' investment net of selection. First, we show with a simple event study that "treated" (through a pension fund's investment) and control firms share almost identical pre-trends in productivity. The same analysis provides suggestive evidence of a positive relationship between a pension fund's investment and firm productivity in the period after the investment event. We argue that this positive trend is consistent with a whole host of benefits that pension funds bring to the table, such as an improvement in corporate governance, an increase in capital availability, long-term financing commitment and a reduction in the cost of external financing.

Second, we estimate the impact of a pension fund investment directly in a structural production function framework that allows us to control for past productivity and therefore selection. Similarly to the event study, in the structural estimations, we find that a pension fund investment positively affects firm productivity. Furthermore, the concern that the estimated effects are merely driven by selection is also dismissed by our refinement analyses. For example, we find suggestive evidence that investments of long duration tend to provide even larger benefits in terms of productivity. These results are instead consistent with the hypothesis that pension funds offer a stable and long-term financing commitment that allows firms to invest in projects that are less liquid but yield a higher long-term return. Indeed, other studies have shown that pension funds tend to commit their investments for longer periods than other investors (Artiga González et al., 2020; Cremers & Pareek, 2016). Our findings resonate with previous evidence that investors' time horizon matters for corporate

[3]National accounts data show that at the end of 2019 equity and loans were the main liabilities of Danish non-financial companies, with equity accounting for 59.5% of total liabilities and loans 30.1% (Danmarks Nationalbank, 2022).

[4]See Heil (2018) for an overview of the literature on finance and productivity.

outcomes, such as the quality of corporate governance (Garel, 2017).

This paper contributes to several strands of the literature. First, we contribute to the work done on funded pensions and economic growth by investigating the hypothesis that pension investments promote productivity growth at the firm level. The literature has, to date, focused mostly on the relationship between the amount of pension savings in an economy and its economic growth, largely disregarding how these savings are invested. The conclusions have been mixed so far. Bijlsma et al. (2018) find evidence of higher output growth in sectors that strongly rely on external financing in countries with a larger pension asset pool. Altiparmakov and Nedeljkovic (2018) find no significant effect on economic growth of pension reform toward a funded system.[5] Zandberg and Spierdijk (2013) fail to find short-term effects of pension funding on economic growth when controlling for capital market returns and demographic changes, while the evidence for long-term effects is more mixed and tends to confirm only a small positive effect of pension funding.

Second, we add to the growing literature on the effects of ownership composition on corporate outcomes by explicitly investigating the role of pension funds. Our study is one of the few relating ownership to firm productivity (Bircan, 2019; Braguinsky et al., 2015; Chemmanur et al., 2011; Davis et al., 2014; Fons-Rosen et al., 2021) and the first to focus on pension funds in this regard.

Third, our new ownership data allow us to include both listed and unlisted firms in the analysis. Most of the literature on ownership and firm outcomes, particularly on ownership by institutional investors, such as pension funds, focuses only on listed firms. We provide a comprehensive set of results by looking at a larger sample of firms and by investigating whether the effects of a pension fund investment are heterogeneous across listed and unlisted firms. We also validate the analysis based on listed firms by deploying an alternative database constructed by exploiting direct information on ownership kindly provided by major Danish pension funds.

Finally, our paper adds to the extensive literature on the determinants of firm productivity. Existing work has singled out, among other factors, the importance of financial frictions (Caggese, 2019; Coricelli et al., 2012; Levine & Warusawitharana, 2021), leverage (Coricelli et al., 2012), firm size, book-to-market ratio and hiring practices (İmrohoroğlu & Tüzel, 2014; Parrotta & Pozzoli, 2012). Other studies have suggested that the threat of foreign competition (Bao & Chen, 2018), export experience (De Loecker, 2013) and workforce composition characteristics (Parrotta et al., 2014) also play an important role. We contribute by highlighting pension funds' investments as a novel and unexplored driver of productivity

[5]However, they identify a positive relationship between economic growth and pension reform in countries where pension funds invest less than 50% of assets in domestic government bonds. This finding suggests that the asset allocation of pension funds matters with regard to their macroeconomic effects, an aspect that we further explore in the present paper.

at the firm level.

The remainder of this paper is structured as follows. Section 2 describes the economic channels through which pension funds can affect firm productivity. Data and summary statistics are then discussed in section 3 and followed by the presentation of our empirical strategy in section 4. We present our empirical results in section 5, along with a series of robustness checks and heterogeneity analyses. Finally, section 6 offers concluding remarks.

2 Channels from Pension Investment to Firm Productivity

Once we control for selection, pension fund investments may directly affect firm-level productivity through a number of channels. First, as suggested by the existing literature on institutional investors, pension funds could actively engage with firms that they invest in, with the aim of improving their productivity. For example, Chemmanur et al. (2011) find that investments by venture capital (VC) funds lead to higher productivity through increased sales and lower production costs of the firms that they take a stake in. Davis et al. (2014) suggest that private equity buyouts affect firm productivity by accelerating the closure of less productive plants and the opening of more productive ones.

Second, pension funds may increase the supply of financial capital to the firm. This implies a reduction in the required rate of return on the firm's investment in (physical) capital, leading the firm to expand its investment until its demand for financing again equals the supply of financing. The additional investment could be directed towards items that raise productivity, such as advanced equipment or innovation-related items. Alvarez et al. (2018) evaluate a sample of publicly traded firms from several emerging economies. They conclude that the relationship between investment and institutional blockholding follows an inverse U-shape. Hence, when institutional blockholders own a large share of controlling rights, investment rates decline. The authors interpret this as evidence that large holdings by institutional investors translate into increased monitoring of managers and lead the firm to take a long-term view regarding investment instead of short-term capital spending, reflected in a reduction of overinvestment.

Third, beyond the direct effect of raising the supply of capital just discussed, pension fund investment in a firm can provide a positive signal about the firm to the market, thereby reducing the cost of capital, which in turn would stimulate productivity-improving investment. In particular, the presence of important institutional investors could signal well-functioning corporate governance mechanisms. Jara et al. (2019), for example, find evidence that Chilean firms that receive pension fund investments are more likely to issue bonds and pay a lower

interest rate on these bonds, crowding out bank lending. The authors attribute this effect to better corporate governance and improved information disclosure. Alvarez et al. (2018) conclude that the presence of institutional investors in a firm's shareholder mix reduces the firm's reliance on internal operating cash flow to fund capital expenditure. They interpret this as institutional investors signaling better corporate governance, leading to easier credit access.

Fourth, it is important to keep in mind that pension funds and other types of investors, such as private equity/venture capital (PE/VC) funds, differ considerably in their business model. Therefore, the channels through which these investors affect firm productivity may differ. For example, PE/VC funds are more likely to seek direct influence over the operational structure of target firms and to invest in younger firms or start-ups than pension funds. The potential effects of pension funds' investment in firms may stem instead from the fact that pension funds tend to be long-term investors and, hence, their involvement raises the security over the long-term financing of the firm. This might lead firms to invest in projects that favor long-term objectives, such as productivity enhancement, over short-term dividend payouts. The long investment horizon of pension funds is also at the center of policy discussions on their role in terms of economic growth.

While other investors such as PE/VC funds might strive to increase firm productivity through, for example, changes in management, pension funds appear generally less inclined to interfere with the organization of a firm. Therefore, we interpret any effects on productivity as a byproduct or an externality rather than a reflection of the direct objective of pension funds. Nonetheless, we cannot exclude instances in which pension funds invest in a firm with the intent of making it more productive. However, the available data do not allow us to identify these cases, which we deem rare in any case.

The channels outlined above are likely to be more salient in our context in which we focus on pension funds, which tend to be large stakeholders relative to other investors. We also expect these channels to be more relevant for privately held than for publicly listed firms. Since listed firms have, by definition, easier access to external capital and a broader investor base than nonlisted firms, we expect any productivity effect induced by pension funds to be smaller for listed firms.

3 Data

3.1 Ownership Data from Experian

We construct information on pension funds' investment in a firm based on shareholder data of all incorporated Danish firms from data provider Experian. The original dataset reflects

only direct ownership relationships between pairs of firms. To address this limitation, we proceed as follows. First, we construct a panel dataset where the unit of observation is a single firm. Second, we iterate through the ownership levels to identify the ultimate owner of each firm. The following example illustrates the main features and the salience of this procedure. Suppose that firm A owns 100% of firm B and firm B owns 100% of firm C. Here, firm A is the "ultimate owner" of firm C, meaning that firm A is not owned by any other firm. The original dataset shows only the bilateral relationships between firms A and B and firms B and C but not that firm A owns 100% of firm C through firm B. However, the relationship between firms A and C is the one that we are actually interested in for our empirical purposes. This is especially relevant if firm B is merely a legal entity with the aim of owning firm C. Therefore, we iterate through the ownership levels until all firms in the dataset are ultimate owners (i.e., they should not be owned for more than 80% by other firms) or firms that are owned.

The final result is a panel dataset where one observation identifies a relationship between two firms in a given year, or equivalently an owner–owned firm–year combination. To determine ownership by pension funds, we manually search the main CVR number (the Danish business registration number) of each domestic pension fund using public sources, notably the Danish Business Register (Virk, 2022). Finally, we consider a firm to have received a pension fund investment if any of these CVR numbers is among the shareholders of the firm.

The Experian ownership data cover all incorporated Danish firms. Therefore, we are able to identify a pension fund investment in both listed and unlisted firms. The majority of the literature on the firm-level effects of pension funds and of institutional investors more generally covers only listed firms (e.g., Aghion et al., 2013; Alvarez et al., 2018; Jara et al., 2019). Therefore, we see our inclusion of unlisted firms as a relevant contribution to the literature.

3.2 Danish Registers

Once we have obtained the ownership data we merge its anonymized version to two Danish registers, FIRE and FIRM, which provide detailed information about a firm's balance sheet, its number of employees and the sector it operates in. We now describe how we process the firm accounting data. In the remainder of this section, we define a firm's sector as the NACE Rev.2 1-digit sector based on the Danish Industry Classification (DB07).[6] The sample period covers the years 2003–2019, for which we have matching accounting and pension fund investment data. First, we exclude all firms with imputed values or missing sector information. To estimate firm productivity as described in Subsection 4.2, we exclude

[6]Table A.2 shows the sectors included in the analysis and the number of firms in each sector in the sample.

all observations with zero or missing values for capital, labor (number of employees), output, value added or intermediate inputs. We deflate output, value added, intermediate inputs and capital with sector-specific deflators.[7] To improve balance sheet consistency, we drop observations with negative equity values. Next, we drop sectors with very few firms receiving pension fund investments and firms that we observe only in a single year. Afterwards, we winsorize capital, labor, intermediate inputs and output at the 1st and 99th percentiles. Finally, Denmark has many small firms, while pension funds invest mostly in large firms. To improve comparability across firms in the treated and control groups, we restrict our analysis sample to firms that have at least 10 employees in all periods.[8]

3.3 Measures of Pension Fund Investment

In our empirical analysis, we use three different measures of pension fund investment in a firm: (i) a dummy for whether the firm received a pension fund investment in the previous year, (ii) investment intensity, which is equal to the aggregate share of a firm owned by all domestic pension funds together, and (iii) investment length, captured by the number of consecutive years (up to and including the previous year) of pension fund investment in the firm. We expect the latter variable to be relevant for the following reason. Productivity-enhancing investments are typically of a long-term nature (frequently involving new technology), because they take time to be planned and implemented and to bear fruit. Hence, for a firm to be willing to make such investments, it needs to be confident that financing will remain available for a sufficiently long period. In view of their long-term liabilities, pension funds can be long-term financiers. Precisely because the effects of pension fund investment on productivity materialize only gradually over time, we expect the length of the pension fund investment history to be relevant for current productivity.[9]

3.4 Descriptive Statistics

Our final sample consists of firms for which we can successfully compute productivity as described below.[10] This includes 102,443 firm–year observations, representing 14,968 different

[7] Deflators are compiled at the NACE Rev.2 1-digit level and sourced from Statistics Denmark.

[8] This restriction is common in the literature working with Danish register data (see, e.g., Fan et al., 2022; Parrotta et al., 2014).

[9] One main limitation of our data is that they only cover equity investments and not debt or loans. However, national accounts data (Danmarks Nationalbank, 2022) show that at the end of 2019 domestic pension funds and insurance companies held 254.6 bn DKK in equity and only 38.6bn DKK in debt and loans of Danish non-financial companies. Therefore, they are much more active as equity rather than debt investors. Danish pension funds and insurance companies held 15.7% of the total equity of non-financial companies held by domestic financial corporations and only 2.1% of debt and loans.

[10] The descriptive statistics and sample sizes discussed in this section refer to the final sample that we use to estimate equation (10) below and its variations. Since this estimation uses one-period lags of several

firms. Of these, 574 (3.8%) are treated in at least one year. Following our methodology described below in Section 4, we define treatment as a firm receiving a pension fund investment in the previous year. Descriptive statistics and definitions of all variables used in the analysis can be found in Table 1. We show statistics for four different sub-samples: (i) all firm-year observations, (ii) firm-year observations with treatment, equivalent to receiving a pension fund investment in the previous year (year $t-1$), (iii) firm-year observation without treatment, and (iv) firm-year observations without treatment in the matched sample only (the matching procedure is part of our robustness analysis and is explained in the next section). Focusing on the second sub-sample, we observe that domestic pension funds invest on average for over 4 consecutive years and hold an aggregate stake of approximately 10.4% in a firm, conditional on investing in the firm in period t.

The second panel of Table 1 reports some interesting facts about the firms that pension funds invest in. If we look at two standard measures of labor productivity, output per worker and value added per worker, firms with a pension fund investment are relatively more productive than untreated firms in the year following treatment. These firms, on average, also produce higher output (value added) with a higher consumption of inputs (labor, capital and intermediary inputs). This is in line with the observation highlighted by the previous literature that institutional investors, including pension funds, tend to invest in larger firms (Ferreira & Matos, 2008). Pension funds also tend to invest in older firms: the average age of a firm one year after treatment exceeds that of untreated firms in the sample by more than three years. On average, pension funds start to invest in a firm in its 21st year of existence.

Furthermore, 48% of the firms that receive a pension fund investment do so in 2003, the first year for which we have pension fund data. Therefore, the variable that measures the length of the investment is left-censored by construction, given that we do not observe ownership data before 2003. For 62% of the firms that pension funds invest in, the first investment coincides with the first year that the firm is in the sample. This is again the result of the left-censoring of the investment tenure variable. Furthermore, we record 347 instances of pension funds fully divesting from a firm, meaning that at least one pension fund invests in the firm in some year $t-1$ but none invests in it in year t. Table A.2 in the appendix shows the number of firms in the sample per NACE Rev.2 1-digit sector. Pension fund investment is clearly concentrated within the manufacturing sector, with 49% of all firms receiving a pension fund investment being in this sector.

variables, the final estimation period starts in 2004 and ends in 2019.

Table 1: Descriptive Statistics

		All		Treatment		No Treatment		No Treatment (matched sample)	
Variable	**Definition**	**Mean**		**Mean**		**Mean**		**Mean**	
Pension Fund Investment Variables									
$DPFI_{it-1}$	dummy = 1 if a pension fund invested in the firm	0.022	(0.148)	1.000	(0.000)				
$Length_{it-1}$	duration of current episode of pension fund investment (years)	0.093	(0.788)	4.156	(3.294)				
$Intensity_{it-1}$	total ownership by domestic pension funds (%)	0.233	(2.391)	10.393	(12.250)				
Firm Variables									
Output/worker	output per worker per worker (DKK, log)	7.375	(0.717)	7.589	(0.794)	7.370	(0.715)	7.491	(0.752)
VA/worker	value added per worker (DKK, log)	6.306	(0.414)	6.435	(0.486)	6.303	(0.411)	6.360	(0.408)
Value added	(DKK,log)	10.035	(1.141)	11.411	(1.207)	10.003	(1.119)	10.550	(1.050)
Labour	number of full-time employees (log)	3.729	(0.999)	4.976	(1.113)	3.701	(0.978)	4.191	(0.955)
Capital	fixed capital (DKK, log)	8.995	(1.747)	10.697	(1.727)	8.956	(1.728)	9.609	(1.638)
Intermediary inputs	(DKK, log)	10.540	(1.474)	12.043	(1.477)	10.506	(1.456)	11.142	(1.435)
Age	firm age (years)	24.463	(18.888)	28.135	(21.080)	24.377	(18.824)	25.779	(18.591)
Capital Intensity	capital stock per worker (DKK, log)	5.265	(1.310)	5.721	(1.255)	5.255	(1.310)	5.418	(1.249)
Observations		102,443		2,292		100,151		46,262	

Notes: All descriptive statistics are calculated as averages over the 2004–2019 period. Variables in DKK are in real Danish kroner (using 2010 as the base year). Since pension fund investment enters our estimations lagged by one year, we choose to report lagged pension fund investment variables. The table presents means and standard deviations in parentheses for four different subsamples: (i) all firm-year observations, (ii) firm-year observations with treatment, equivalent to receiving a pension fund investment in the previous year (year $t-1$), (iii) firm-year observations without treatment, and (iv) firm-year observations without treatment in the matched sample only. Values for subsample (ii) are reported conditional on the firm receiving a pension fund investment in the previous year $t-1$.

Our hypothesis that pension funds can affect firm productivity through long-term investments is inspired by the assumptions that pension funds seek to match their long-term liabilities with long-term assets (Beyer et al., 2014; Della Croce et al., 2011). Empirical evidence supports the notion that pension funds typically have a longer investment horizon than other institutional investors (Cella et al., 2013; Cremers & Pareek, 2016; Döring et al., 2021; Harford et al., 2018). Our data confirms this trend. In the appendix, Table A.1 compares the length of the investment period of domestic pension funds with that of other investors in the domestic financial industry. We classify other investors based on their 6-digit industry code (and 3-digit code for insurance companies). Panel A of Table A.1 reports the mean investment horizon of each investor group, conditional on investing in firm i at time $t-1$, as well as the difference from the average investment horizon of pension funds for that firm and the p-value of a simple difference-in-means t-test. On average, pension funds invest in a firm for 0.89 years longer than banks. While this difference may seem small, it represents more than 20% of the mean investment horizon of pension funds, making it relatively important.[11] Our data show that, among domestic investors, pension funds feature a longer investment horizon than all other sectors except for non-financial holding companies.[12] Moreover, the differences in the length of the investment horizon between pension funds and other investor types are statistically significant for all sectors except investment companies. Panel B of Table A.1 shows that, prior to divestment, pension funds invested in firms for a larger number of consecutive years than any other investor type.[13] These differences are mostly statistically significant at the 1% level and always at least at the 10% level. To conclude, our data show domestic pension funds to exhibit a longer investment horizon than other domestic investors.

4 Methodology

In this section, we describe the methods used to address selection and the identification of the impact of a pension fund investment on firms' productivity.

[11] Small absolute differences are also consistent with the empirical finance literature on investor horizon (see e.g. Cella et al., 2013).

[12] Non-financial holding companies correspond to DB07 sector 642020. According to Statistics Denmark, this sector includes holding companies whose main activity is to hold controlling stakes in other non-financial companies. Therefore, this sector does not include outside investors in the sense of asset managers, and therefore it is not surprising that they have a long investment horizon.

[13] In Panel B, the length variable is the number of consecutive years of investment in firm i by at least one investor of each type in year $t-1$ conditional on no investor of that specific type invest in the firm in period t. This condition addresses the concern that the length variable is right-truncated, as investment by an investor type might continue after 2019 or the firm exits the sample due to our sampling conditions.

4.1 Addressing Selection

Selection may confound the causal impact of a pension fund investment on productivity, as pension funds may actively select firms with certain characteristics that make them more productive to begin with. This is a very pervasive issue in the literature looking at the effects of investors on target firms (see, e.g., Aghion et al., 2013; Fons-Rosen et al., 2021; Garel, 2017; Lerner et al., 2011; Levine & Warusawitharana, 2021). A common approach is to use the inclusion of a firm in a large index as an exogenous event (Aghion et al., 2013), which exposes the firm to investment by certain institutional investors. For our case, this is not a suitable approach since 1) the indices on Danish listed equity instruments include only a small number of firms and 2) the composition of the indices does not vary much over time, resulting in very low exogenous variation that can be exploited to tease out causality in our analysis. Furthermore, to the best of our knowledge, there are no other events in our sample period, such as a regulatory change, that would clearly affect the propensity of Danish pension funds to invest in domestic equity. We therefore adopt two strategies to account for selection effects.

First, we take an event study approach that allows us to check for differential pre-trends, i.e., to assess whether, before the treatment occurs, firms eventually treated with a pension fund investment differ in terms of productivity from their counterparts that do not receive a pension fund investment. A number of recent studies have highlighted concerns with the traditional event study design when units, in our case firms, receive treatment at different points in time (see, e.g., de Chaisemartin & D'Haultfoeuille, 2022; Goodman-Bacon, 2021). This issue is important in our context since pension funds start investing in firms in different years. Therefore, we use the estimator suggested by Sun and Abraham (2021) that is robust to treatment heterogeneity with respect to the timing of the treatment. For this event study, we use two different measures of labor productivity — i) value added per worker and ii) output per worker — and control for year by NACE Rev. 2 1-digit sector fixed effects. We also include the following control variables: firm age, firm size, a dummy for whether the firm is listed, and capital intensity, defined as the capital-to-labor ratio.

Second, we implement a structural estimation approach developed by Bøler et al. (2015) and Doraszelski and Jaumandreu (2013) that allows us to explicitly attenuate the issue of selection by controlling for past productivity and thus firm-level heterogeneity. The next subsection describes this procedure in detail.

4.2 Structural Productivity Estimation

Firm productivity is often defined as total factor productivity (TFP), the residual from a regression of firm output on input factors, usually formed by capital and labor. The main

advantage of TFP over labor productivity measures such as output per employee is that it captures productivity changes after variation in input factors is accounted for (Chemmanur et al., 2011). This is particularly important in our case, since pension fund investments in a company may imply an injection of new capital and thus an increase in one of the inputs of the production function. We are interested in the productivity changes in response to pension fund investments that are not explained by changes in the amounts of inputs used in the production process.

A key concern in estimating TFP relates to potential simultaneity bias: changes in productivity may affect not only output (the dependent variable) but also the input mix that the firm chooses (the explanatory variables). Based on Ackerberg et al. (2015), we illustrate this problem using a Cobb–Douglas production function in logs:

$$y_{it} = \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \varepsilon_{it} \tag{1}$$

where lower case letters denote logs and y_{it} is the value added of firm i at time t, k_{it} is its capital stock and l_{it} is its labor input.[14] Furthermore, ε_{it} is an i.i.d. unobservable shock to production (or a measurement error), while ω_{it} is a shock to production that cannot be observed by the econometrician but that can be anticipated by the firm and is a source of potential endogeneity problems.[15] Simultaneity bias can arise because the firm may choose its capital and labor inputs as a function of its prediction of the future productivity shock that is unobservable to the econometrician. Hence, the choice of the inputs (l_{it}, k_{it}) and ω_{it} may be correlated, resulting in biased OLS estimates of the coefficients on the inputs (Ackerberg et al., 2015).

The use of proxy variables has recently become a popular approach to address this endogeneity issue. The approach uses available information to proxy for the unobservable ω_{it}.[16] Popular estimation techniques include Olley and Pakes (1996), Levinsohn and Petrin (2003), Wooldridge (2009) and Ackerberg et al. (2015) (henceforth OP, LP, Wooldridge and ACF, respectively). OP uses an inverted demand function for investment as a proxy variable, while LP, ACF and Wooldridge use an inverted demand function for intermediate inputs since investment is often zero for a large share of observations. We follow Bøler et al. (2015),

[14] Industry subscripts are omitted for ease of reading. We define capital as the total value of tangible fixed assets (including real estate), calculated with the perpetual inventory method. Labor is the total number of employees, whereas intermediate inputs equal the sum of the following items: raw materials, consumables, goods for resale, finished goods and packaging (excluding purchases of energy), energy purchases, value of subcontracts, rental and leasing costs. All monetary variables are deflated with sector-specific deflators published by Statistics Denmark.

[15] More precisely, the firm does not observe ω_{it} until time t and has information $p(\omega_{it+1}|\omega_{it})$ about the conditional distribution of the future shock.

[16] For an overview and discussion on the identification assumptions, see Ackerberg et al. (2015).

Doraszelski and Jaumandreu (2013), and Fan et al. (2022) and estimate the impact of a pension fund investment by using a control function approach in two steps. This structural estimation attenuates the selection issue discussed above. Furthermore, this approach addresses the concern that a firm receiving a pension fund investment may alter the use of inputs in a way that may bias the estimation of productivity. De Loecker (2013) finds that controlling for endogeneity is important for the correct estimation of firm productivity. While factors impacting productivity can be the result of firm decisions such as export or R&D expenditure choices (Bøler et al., 2015; De Loecker, 2013; Doraszelski & Jaumandreu, 2013; Fan et al., 2022), changes in the ownership structure have also been found to be important for firm productivity (Bircan, 2019; Braguinsky et al., 2015).

Productivity is obtained from a Cobb–Douglas production function containing value added, labor and capital. Following ACF in a setup described by equation (1), we assume that:

$$E\left(\varepsilon_{it} \mid l_{it}, k_{it}, m_{it}, l_{it-1}, k_{it-1,}, m_{it-1}, ..., l_{i1}, k_{i1}, m_{i1}\right) = 0 \tag{2}$$

where m refers to our proxy variable (materials). Because past values of ε_{it} are not included in the conditioning set, we allow for serial dependence in the pure shock term. However, we need to restrict the dynamics of the productivity process:

$$E\left(\omega_{it} \mid \omega_{it-1}, \omega_{it-2}, ..., \omega_{i1}\right) = E\left(\omega_{it} \mid \omega_{it-1}\right) = g\left(\omega_{it-1}\right) \tag{3}$$

for a given function $g\left(\cdot\right)$. As in ACF, for the timing of the choice of the inputs, we assume the following: i) k_t is a function of k_{t-1} and new investment at $t-1$, so it is fully determined by choices made at $t-1$ or earlier; ii) l_t is chosen between $t-1$ and t; and iii) m_t is chosen at time t. As a result, material demand is a function not only of capital and productivity but also of labor:

$$m_{it} = f(k_{it}, l_{it}, \omega_{it}) \tag{4}$$

Moreover, following the standard assumption in the literature that the material demand function is strictly monotonic in the productivity shock ω_{it} , we can invert the function in (4) to obtain ω_{it} as a function of k_{it}, l_{it} and m_{it}:

$$\omega_{it} = \tilde{h}(k_{it}, m_{it}, l_{it}) \tag{5}$$

Plugging $\tilde{h}\left(.\right)$ into production function (1), we obtain:

$$y_{it} = h\left(k_{it}, m_{it}, l_{it}\right) + \varepsilon_{it} \tag{6}$$

where the linear terms in capital and labor in the production function have been subsumed in the new function $h(.)$. The goal of this (first-stage) equation is solely to predict output net of measurement error or unanticipated shocks, hence to separate ω_{it} from ε_{it}. We operationalize the first stage by approximating $h(.)$ using a second-degree polynomial of capital, labor and intermediate inputs with full interaction terms.[17] We then estimate the following equation separately by each NACE 1-digit sector s via OLS:

$$y_{ist} = \delta_s + \kappa_t + h\left(k_{it}, m_{it}, l_{it}\right) + \varepsilon_{it} \tag{7}$$

where δ_s and κ_t capture sector and year fixed effects, respectively. We then define $\hat{h}_{it}$ as the predicted output net of sector and year fixed effects. The predicted output from the first stage $\hat{h}_{it}$ is then used to identify the input elasticities in the second stage.

To obtain the second-stage estimation equation, it is important to note that productivity ω_{it} follows a first-order Markov process. In the standard ACF approach, this Markov process is exogenous to the firm, meaning that the firm cannot affect it. Therefore, the firm can only react to changes in productivity but cannot influence how it evolves. Following Bøler et al. (2015), De Loecker (2013), and Doraszelski and Jaumandreu (2013), we relax this exogeneity assumption by augmenting the Markov process with our endogenous variable of interest, pension fund investment at time $t-1$. In other terms, pension fund investment enters as a shifter in the evolution of productivity ω_{it} over time. We prefer this approach to the inclusion of pension fund investment directly as an input in the production function (1) since pension fund investments in a given firm are not only determined by the firm in question, as it is the case for capital and labor. They are in fact the outcome of a complex decision-making process that involves both the investor and the firm. Formally, we assume that productivity ω_{it} depends on firm i receiving a pension fund investment through the following law of motion:

$$\omega_{it} = \rho\omega_{it-1} + \gamma PFI_{it-1} + \xi_{it} \tag{8}$$

where PFI_{it-1} denotes a pension fund investment in firm i at time $t-1$. Furthermore, ξ_{it}

[17] The results are unaffected when we use an alternative specification of the first stage – see the discussion of robustness in Section 6 below.

is an idiosyncratic error term uncorrelated with the other right-hand-side variables.[18]

Rewriting productivity in terms of predicted output $\hat{h}_{it}$ from the first stage yields:

$$\hat{\omega}_{it} = \hat{h}_{it} - \beta_k k_{it} - \beta_l l_{it} \tag{9}$$

Integrating the law of motion (8) into (9) yields the estimating equation for the second stage:

$$\hat{h}_{it} = \alpha + \beta_k k_{it} + \beta_l l_{it} + \rho\left(\hat{h}_{it-1} - \beta_k k_{it-1} - \beta_l l_{it-1}\right) + \gamma PFI_{it-1} + \xi_{it} \tag{10}$$

where we have added the constant α to arrive at the empirical specification. We estimate (10) by the generalized method of moments (GMM).[19] Following the standard ACF approach, we use k_{it} and l_{it-1} as instruments. Since $\hat{h}_{it-1}$, k_{it-1}, k_{it} and PFI_{it-1} are determined at time $t-1$ or earlier, they are orthogonal to the error term ξ_{it} and can be used to form the necessary moment conditions. Labor l_{it}, however, is chosen after $t-1$, given our timing assumptions, so we instrument it with l_{it-1}. Finally, we allow the constant α to vary by industry by including sector dummies in the estimation, using these dummies as their own instruments. The instrument set thus contains l_{it-1}, $\hat{h}_{it-1}$, k_{it}, PFI_{it-1} and the industry dummies. The error term ξ_{it} is uncorrelated with the instrument set since it is uncorrelated with all the information at time $t-1$ and, hence also, current capital k_{it}.

The coefficient γ in equation (10) captures the effect of a past pension fund investment on firm productivity. We identify this effect in the second stage by exploiting variation in past pension fund investment PFI_{it-1} conditional on lagged productivity ω_{it-1}. The literature on the effect of ownership on productivity (see, e.g., Bircan, 2019; Braguinsky et al., 2015; Fons-Rosen et al., 2021) mostly uses a three-stage approach that consists of first estimating the elasticities of capital and labor in two steps to produce TFP estimates and then regressing the latter on the variables of interest and firm control variables. However, retrieving the effect of interest directly from the law of motion of productivity as we do allows us to control for past productivity and to address more explicitly the issue of selection.

[18] PFI_{t-1} and earlier pension fund investment therefore indirectly enter the production function (1) through ω_{it}. Relating this to our timing assumptions, input choices at time t can depend on pension fund investment since it is in the information set at time t.

[19] For the identification of the production function elasticities, our approach requires variation in these inputs conditionally on ω_{it}. Put it differently, our approach requires either exogenous input price differences across firms or differences in input dynamics across firms. However, we obtain similar results (available upon request from the authors) when we include average wages at the firm-level in the $\tilde{h}(.)$ function and we rule out variation in the price of the quasi-flexible inputs across firms.

4.3 Matching

To address the fact that the firms in the control group tend to differ on average in terms of observable characteristics (such as size and industry) from treated firms, we construct a matched sample using a propensity score approach. First, we estimate the probability of a firm receiving a pension fund investment with a logit regression of the dummy variable $DPFI_{it}$ on valued added, labor, capital and an indicator for whether firm i is listed (all at time $t-1$).[20] We calculate propensity scores using this method by sector–year and then drop firms that have a propensity score below the sector–year-specific 25th percentile in at least one year.[21] We therefore proceed very conservatively and keep only firms in the matched control group that are likely to receive a pension fund investment over the sample period. Furthermore, while the specification for the propensity score is very parsimonious, estimating it separately for each sector–year alleviates concerns over mis-specification.

5 Empirical Analysis

5.1 Event Study

Figure 1 presents the effect of a pension fund investment on two measures of firm productivity, output per worker and value added per worker, using the methodology described in Subsection 4.1. We show the impact on these two straightforward measures of firm productivity instead of deriving the latter from structural estimation for two reasons: 1) we explore the selection hypothesis by testing for the presence of differential pre-trends, and this can be feasibly done only with standard measures of productivity, and 2) the justification for extrapolating the productivity term outside the production function and using it as a dependent variable in a separate regression is not theoretically obvious (Ackerberg et al., 2015).[22] Figures 1a and 1b indicate that there are no significant pre-existing differences in productivity trends between treated and non-treated firms prior to the first pension fund investment in the firm (which we refer to as the "event" date).[23] However, we do observe a positive effect on productivity in the first few years following the event date, as shown in the figures. To further explore this effect, we use a structural estimation approach in the next

[20] Using base year values instead of one-period lags yields very similar results.

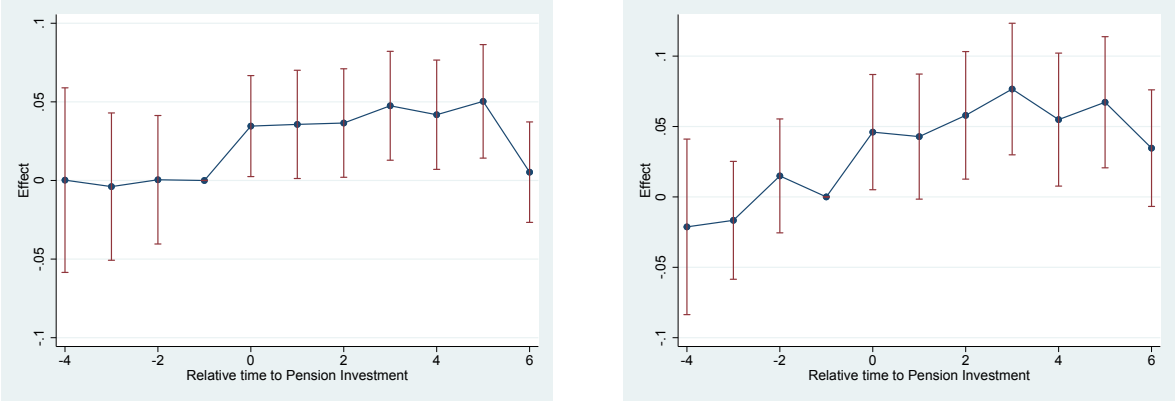
[21] Sectors are here defined as the standard DB07 36-industry grouping. The 25th percentile is calculated only among firms that do not receive a pension fund investment in any year. We keep firms for which a propensity score could be computed in at least one year. Excluding firms with missing propensity scores from the matched control group does not change our results.

[22] In fact, the possibility of computing the effect of a pension fund investment directly in the productivity estimation is one of the main reasons that we choose this approach rather than the more traditional three-stage analysis used in the literature (e.g., Bircan, 2019; Braguinsky et al., 2015).

[23] This is consistent with the method proposed by de Chaisemartin and D'Haultfoeuille, 2022, which also suggests that there are no pre-trends.

section. We find that our event study results are robust to alternative specifications and sample restrictions. Specifically, we obtain qualitatively similar results in the event study analysis when we: 1) use a matched sample, 2) use an alternative measure of output, 3) include the share of R&D workers among the control variables, or 4) omit all control variables from the event study regressions. Moreover, our findings remain consistent when we focus on events where only one pension fund invests in a given firm over the sample period or when we exclude pension fund investments that last for fewer than five consecutive years.[24]

Figure 1: Event Study Results



(a) Output per worker

(b) Value added per worker

Notes: The outcome variable is output or value added per worker. This figure presents point estimates and 95% confidence intervals of an event study specification using the estimator proposed by Sun and Abraham (2021). The following controls enter the specification: firm age, a dummy for the firm being listed in the base year, firm size (number of employees), and capital intensity. We also include year by NACE Rev.2 1-digit sector fixed effects.

5.2 Main Results

All results reported in this section are obtained from the estimation of equation (10) using the log of the firm's value added as a measure of output y_{it}. We report the results for the baseline sample and the sample resulting from the matching procedure described in Subsection 4.3. For convenience, we report the coefficient estimates of the pension fund investment variable and the related standard errors multiplied by 100.

Table 2 presents the results for the model in which the pension fund investment is included through a dummy variable. Columns 1 and 5 show estimates for the case in which the law of motion of the exogenous productivity process is specified without the pension fund investment variable. Columns 2 and 6 introduce the pension fund dummy in the law of motion. Columns 3 and 7 restrict the pension fund investment dummy to take a value of 1 only if the aggregate holding by all Danish pension funds in firm i is at least 5%. This

[24]These results are reported in the on-line Appendix.

allows us to abstract from those cases in which investment by pension funds constitutes only a negligible source of capital for the firm. Moreover, there are good reasons to assume that a non-negligible equity stake provides a stronger signal of commitment and a stronger signal to the rest of the financial market. Previous literature found that export status is important in the estimation of productivity (De Loecker, 2013). Columns 4 and 8 therefore report the results including a dummy in equation (10) taking a value of 1 if firm i is an exporter at $t-1$.

We observe a positive and significant effect of a pension fund investment in all specifications. Receiving a pension fund investment in the previous year is associated with an increase in productivity ranging from 3.0% to 4.6%, depending on the specification. As expected, the effect is slightly stronger when we restrict the pension fund investment dummy to take a value of 1 only when aggregate ownership of pension funds in the company is at least 5%. We also find a stronger effect when we select the matched sample. Interestingly, including the export dummy hardly affects the estimate of the pension investment dummy, suggesting that the effects of exporting and receiving a pension investment on productivity are independent.

Although we do not control for a large number of firm characteristics, the structural approach that we employ has the advantage of controlling for past productivity. In this way, we control for selection effects driven by heterogeneity, particularly for pension funds selecting firms based on their productivity. Hence, even controlling for such a potential selection effect, we find robust positive and significant effects of a pension fund investment on firm productivity.

Table 2: Productivity Estimates: Pension Fund Dummy

	Whole sample				Matched sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
β_l	0.954***	0.953***	0.953***	0.950***	0.912***	0.910***	0.910***	0.908***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)	(0.008)
β_k	0.085***	0.085***	0.085***	0.084***	0.092***	0.092***	0.092***	0.091***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.006)	(0.005)
$DPFI_{it-1}$		3.361***	3.460***	2.969***		4.401***	4.638***	3.981***
		(0.992)	(1.129)	(0.989)		(0.975)	(1.067)	(0.979)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	No	Yes	No	No	No	Yes	No
Export_{it-1}	No	No	No	Yes	No	No	No	Yes
Obs.	102,443	102,443	102,443	102,443	48,554	48,554	48,554	48,554
Obs. PF	2,292	2,292	1,730	2,292	2,292	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	14,968	7,468	7,468	7,468	7,468
# Firms PF	574	574	429	574	574	574	429	574

Notes: This table presents the results from the estimation of equation (10). $DPFI_{it-1}$ is a dummy taking a value of 1 if at least one domestic pension fund invested in firm i in year $t-1$. Coefficient estimates and standard errors for $DPFI_{it-1}$ are multiplied by 100. The estimated coefficient of $DPFI_{it-1}$ measures its effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 3 and 8, $DPFI_{it-1}$ equals 1 if the aggregate holding of all pension funds in firm i in year $t-1$ was at least equal to 5%. In columns 4 and 8, we include a dummy equal to 1 if firm i is an exporter in year $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment in year $t-1$. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

Next, we investigate whether the size of the pension fund investment matters by defining pension fund investment in equation (10) as the total share of firm i (in percent) held by all domestic pension funds. Table 3 presents the results of this specification. On average, an increase of 1 percentage point in pension fund investment is associated with a TFP increase of approximately 0.2%. Note that the estimated coefficient on $Intensity_{it-1}$ combines the effect due to the extensive margin (i.e., receiving a pension fund investment at all) with the one induced by the intensive margin (i.e., the size of the investment).[25]

[25]Unfortunately, we lack the statistical power to distinguish between these two effects due to a limited number of treated observations.

Table 3: Productivity Estimates: Pension Fund Investment Intensity

	Whole sample			Matched sample		
	(1)	(2)	(3)	(4)	(5)	(6)
β_l	0.953***	0.953***	0.950***	0.911***	0.911***	0.909***
	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)
β_k	0.085***	0.085***	0.084***	0.092***	0.092***	0.091***
	(0.003)	(0.003)	(0.003)	(0.006)	(0.006)	(0.005)
$Intensity_{it-1}$	0.220***	0.219***	0.208**	0.243***	0.242***	0.230***
	(0.084)	(0.084)	(0.081)	(0.086)	(0.086)	(0.083)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	Yes	No	No	Yes	No
Export_{it-1}	No	No	Yes	No	No	Yes
Obs.	102,443	102,443	102,443	48,554	48,554	48,554
Obs. PF	2,292	1,730	2,292	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	7,468	7,468	7,468
# Firms PF	574	429	574	574	429	574

Notes: This table presents results from the estimation of equation (10). $Intensity_{it-1}$ is the aggregate share of firm i (in percent) held by domestic pension funds in year $t-1$. Coefficient estimates and standard errors for $Intensity_{it-1}$ are multiplied by 100. The estimated coefficient of $Intensity_{it-1}$ measures its effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 2 and 5, $Intensity_{it-1}$ is equal to 0 if the aggregate holding of all domestic pension funds in firm i at time $t-1$ is less than 5%. In columns 3 and 6, we include a dummy taking value 1 if firm i is an exporter at time $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment at time $t-1$ in the sample. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

One of the main differences between pension funds and most other types of investors is their long investment horizon. Therefore, pension funds can provide long-term financing security and stimulate firms to make productivity-enhancing investments (often using new technology). Hence, we now investigate whether the holding period of a pension fund investment makes a difference by capturing the pension fund investment in equation (10) with the variable $Length_{it-1}$, which measures the number of consecutive years that firm i has received pension fund investment up to year $t-1$. Table 4 shows that an additional year of a pension fund investment is associated with a highly significant increase in productivity in the range of 0.4%–0.6%, depending on the specification. Hence, this finding lends support

to the hypothesized mechanism.

These results on duration should be interpreted with caution due to the following two caveats. First, like in the intensity results, the coefficients estimated on the variable $Length_{it-1}$ capture the impact of both the extensive and intensive margins. Although we do not have enough power to separate the two effects, we are confident that the duration of the investment matters for productivity. The event study provides in fact suggestive evidence for a positive effect in productivity not only in the first year of the investment but also some years after the investment starts. Furthermore, regression results based on equation (10) including $Length_{it-1}$ and its square, as reported in Table C.2 of the online Appendix, suggest a non-linear relationship between productivity and our length variable. This supports the hypothesis that not all of the estimated effects in Table 4 are driven by the extensive margin. Second, the length variable may be a downward-biased estimate of the actual length of the investment history in the firm, because our sample starts only in 2003. However, because of this truncation at the start of the sample period and the associated measurement error, we are likely to underestimate the effect of investment tenure, and the estimates reported in Table 4 likely represent a lower bound on the true effect of investment tenure.

Table 4: Productivity Estimates: Pension Fund Investment Length

	Whole sample			Matched sample		
	(1)	(2)	(3)	(4)	(5)	(6)
β_l	0.953***	0.953***	0.950***	0.911***	0.911***	0.909***
	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)
β_k	0.085***	0.085***	0.084***	0.092***	0.092***	0.091***
	(0.003)	(0.003)	(0.003)	(0.006)	(0.006)	(0.005)
$Length_{it-1}$	0.469**	0.486**	0.414**	0.589***	0.639***	0.527***
	(0.203)	(0.242)	(0.203)	(0.188)	(0.213)	(0.188)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	Yes	No	No	Yes	No
Export_{it-1}	No	No	Yes	No	No	Yes
Obs.	102,443	102,443	102,443	48,554	48,554	48,554
Obs. PF	2,292	1,730	2,292	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	7,468	7,468	7,468
# Firms PF	574	429	574	574	429	574

Notes: This table presents the results from the estimation of equation (10). $Length_{it-1}$ is the number of consecutive years that firm i received investment from any pension fund up to year $t-1$ included. Coefficient estimates and standard errors for $Length_{it-1}$ are multiplied by 100. The estimated coefficient of $Length_{it-1}$ measures its effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 2 and 5, $Length_{it-1}$ includes only the years when aggregate investment by domestic pension funds in the firm is at least 5%. In columns 3 and 6, we include a dummy taking value 1 if firm i is an exporter at time $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment at time $t-1$ in the sample. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.3 Robustness Checks

In this section, we discuss the robustness of our main results. First, we explore the robustness of our results to different levels of sectoral classification. In the baseline analysis, we estimate our production function separately by NACE 1-digit industry, which is a rather aggregated classification. To check whether this level of aggregation affects our main results, we re-estimate the productivity effect of a pension investment at a more granular level (i.e., at the DB07 36-industry group level instead of the NACE 1-digit level). This classification can be seen as an intermediary level between the NACE 1-digit and 2-digit levels. Our

baseline results could be affected by the facts that (i) we estimate the first stage across very broadly defined industries and (ii) we therefore allow the constant term in the second stage to vary across broad industry categories that may mask substantial variation existing across more narrowly defined sectors. The second robustness check addresses data limitations with respect to firm ownership. Our baseline estimations use a control group based on all firms in Denmark. However, we have ownership data only for firms that are at least partly owned by one other firm or more. Therefore, the set of firms that receive a pension fund investment is a subset of the latter. To verify that our results are not driven by the inclusion of firms for which ownership data are unavailable, we repeat our baseline exercise excluding these firms.

Table 5 presents the results of both of these checks. The left-hand part of the table includes sector fixed effects at the DB07 36-industry level, while the right-hand part excludes firms without ownership information from the sample.[26] When we use a more granular sector classification, the magnitudes of the coefficients on all pension fund investment variables slightly decrease, while they slightly increase when we include only firms with ownership data. Notwithstanding these small changes, our baseline results are confirmed for both checks.

As a third robustness check, Appendix B shows that our results and interpretations are largely robust to the use of a gross output–based instead of a value added–based production function. Even though the coefficients estimated on our pension fund investment variables are generally not precisely estimated, they remain positive and far from zero.

[26]The specifications of the models estimated for each variant in Table 5 correspond to those in Column 2 in Table 2 and Column 1 in Tables 3 and 4.

Table 5: Productivity Estimates: Robustness Checks

	36-industry grouping			Excl. firms without ownership data		
	(1)	(2)	(3)	(4)	(5)	(6)
β_l	0.949***	0.949***	0.949***	0.933***	0.933***	0.933***
	(0.520)	(0.515)	(0.518)	(0.562)	(0.562)	(0.560)
β_k	0.087***	0.087***	0.087***	0.093***	0.093***	0.093***
	(0.350)	(0.350)	(0.350)	(0.395)	(0.396)	(0.396)
$DPFI_{it-1}$	3.289***			4.472***		
	(1.131)			(0.992)		
$Intensity_{it-1}$		0.228***			0.269***	
		(0.081)			(0.079)	
$Length_{it-1}$			0.450**			0.639***
			(0.229)			(0.200)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	No	No	No	No	No
Export_{it-1}	No	No	No	No	No	No
Obs.	102,443	102,443	102,443	73,309	73,309	73,309
Obs. PF	2,292	2,292	2,292	2,236	2,236	2,236
# Firms	14,968	14,968	14,968	10,803	10,803	10,803
# Firms PF	574	574	574	564	564	564

Notes: This table presents the results from the estimation of equation (10). $DPFI_{it-1}$ is a dummy taking a value of 1 if at least one domestic pension fund invested in firm i in period $t-1$. $Intensity_{it-1}$ is the aggregate share of firm i (in percent) held by domestic pension funds in year $t-1$. $Length_{it-1}$ is the number of consecutive years that firm i received investment from any pension fund up to year $t-1$ included. Coefficient estimates and standard errors for $DPFI_{it-1}$, $Length_{it-1}$ and $Intensity_{it-1}$ are multiplied by 100. The coefficient estimates measure the effect of these variables on productivity. Columns 1–3 include industry fixed effects at the DB07 36-industry level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. Columns 4–6 include industry fixed effects at the NACE Rev. 2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment at time $t-1$. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

We proceed this subsection with a number of extra robustness checks. First, jointly including the investment intensity and its square yields positive coefficients on the linear term that remain significant for the matched sample, but lose significance for the full sample, although their magnitude is not far from their original magnitude (Table C.1, online

Appendix). We attribute this loss of significance to the low number of treatment observations. Jointly including the holding period and its square yields a highly significant positive coefficient on the former and a (highly) significant negative coefficient on the latter (Table C.2, online Appendix), providing an indication of a potential nonlinear relationship between productivity and holding period.

Second, we explore whether including co-investments by other parties from the financial sector in our regressions affect our coefficients of interest. There is in fact the concern that if pension funds invested in a firm always in conjunction with other investors (such as private equity or insurance companies), then it would be misleading to interpret the positive estimated coefficients reported in the previous tables as the effects on productivity exclusively attributable to the presence of pension fund investments in a firm. We therefore augment our baseline specification from Column 2 of Table 2 by adding a dummy that captures investments by any other financial party and report the results in Table 6.[27] These additional results allow us to dismiss the concern that the estimated effects reported in the baseline analysis are confounded by the presence of other investors. Table 6 shows in fact that no matter how we measure the other investor dummy, our central variable capturing pension fund investments remains positive and significant, with a coefficient estimate ranging between 2.0 and 3.5.

[27] We construct this additional variable on the basis of the indicated sub-sector of the domestic financial industry.

Table 6: Other Investors Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
β_l	0.953***	0.953***	0.953***	0.953***	0.953***	0.953***	0.953***	0.953***	0.953***	0.953***	0.953***	0.953***	0.953***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
β_k	0.085***	0.085***	0.085***	0.085***	0.085***	0.085***	0.085***	0.085***	0.085***	0.085***	0.085***	0.085***	0.085***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$DPFI_{it-1}$	3.283***	3.277***	3.000***	3.363***	3.272***	3.362***	2.815***	3.252***	3.041***	3.352***	2.079*	3.349***	3.356***
	(0.989)	(0.989)	(1.086)	(0.994)	(1.006)	(0.994)	(1.020)	(1.053)	(0.990)	(1.214)	(1.115)	(1.038)	(0.990)
$Other_{it-1}$	0.176	0.192	1.260	-0.005	0.301	-0.003	1.422**	1.346	1.406**	0.030	2.545***	0.151	0.663
	(0.287)	(0.286)	(1.548)	(0.282)	(0.710)	(0.287)	(0.658)	(1.932)	(0.693)	(1.408)	(0.903)	(1.699)	(1.865)
Obs.	102,443	102,443	102,443	102,443	102,443	102,443	102,443	102,443	102,443	102,443	102,443	102,443	102,443
Obs. PF	2,292	2,292	2,292	2,292	2,292	2,292	2,292	2,292	2,292	2,292	2,292	2,292	2,292
# Firms	14,968	14,968	14,968	14,968	14,968	14,968	14,968	14,968	14,968	14,968	14,968	14,968	14,968
# Firms PF	574	574	574	574	574	574	574	574	574	574	574	574	574
Obs. other	40,994	40,852	959	37,207	3,478	35,156	4,219	290	3,622	919	3,441	229	81
# Firms other	7,384	7,367	315	6,893	973	6,582	1,050	136	909	279	923	88	32
Obs. both	2,020	2,008	664	1,659	738	1,524	990	190	627	706	1,234	180	18
# Firms both	540	539	234	478	258	450	312	100	219	216	358	72	7

Notes: This table presents the results from the estimation of equation (10), the baseline variant in Column 2 of Table 2, adding a dummy for domestic investors that are not pension funds. $DPFI_{it-1}$ is a dummy equal to 1 if at least one domestic pension fund invested in firm i in year $t-1$. $Other_{it-1}$ is a dummy equal to 1 if at least one non-pension fund investor from a specific part (as indicated in the following) of the domestic financial industry, according to the 6 digit DB sector classification, invested in firm i in year $t-1$. This dummy takes value 1 as follows. Column 1: any investor from the domestic financial industry, except for pension funds. (The next columns concern subsets of this column.) Column 2: banking and financing activities, except insurance and pensions. Column 3: banks, savings banks and cooperative banks. Column 4: holding company. Column 5: financial holding company. Column 6: non-financial holding company. Column 7: investment associations, investment companies etc. Column 8: money market associations. Column 9: investment companies. Column 10: venture companies and capital funds. Column 11: other financial intermediaries except insurance and pension insurance. Column 12: insurance companies. Column 13: asset management. Coefficient estimates and standard errors for $DPFI_{it-1}$ and $Other_{it-1}$ are multiplied by 100. The coefficient estimate of $DPFI_{it-1}$ measures its effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment at time $t-1$. The line "Obs. other" ("# Firms other") gives the number of observations (number of firms) with an investment from the indicated part of the financial sector at time $t-1$. The line "Obs. both" ("# Firms both") gives the number of observations (number of firms) with a simultaneous investment by a pension fund and a firm from the indicated part of the financial sector at time $t-1$. Finally, * $p<0.1$, ** $p<0.05$, and *** $p<0.01$.

We now conclude this robustness checks section by discussing additional results that for brevity are not reported in the paper but are available on request from the authors. First, limiting the definition of pension fund investment to include only direct pension fund investments in a firm reduces precision, because the number of firms with a pension fund investment falls substantially.[28] Nevertheless, the coefficient on the pension fund investment dummy remains close to its baseline value, while the coefficient on the intensity of the investment remains positive and is significant at the 10% level when we use the matched control sample.

Second, we exclude from the sample firms whose outstanding number of shares increased in any sample year. Firms that increase capital may experience a productivity increase regardless of whether a pension fund invests, which would complicate our interpretation of the effect of a pension fund investment. However, excluding these firms confirms our baseline results for the investment dummy and intensity, with positive and highly significant coefficients in all models. The coefficient on investment length remains positive in all models and significant when we use the matched control sample. Third, we replace the pension fund investment dummy with the number of pension funds investing in a firm and obtain a positive and highly significant coefficient. However, as mentioned in the previous section when we discussed the results on the intensity and length variables, the positive effect estimated on the number of pension funds is due to changes at both the extensive and the intensive margin of investment. The limited number of treated observations does not allow to separate out the two effects. Fourth, our main findings are robust to defining capital as the book value of fixed assets instead of the value obtained via the perpetual inventory method as in our baseline results. Fifth, our results remain unaffected if we approximate the function $h(.)$ in the first-stage equation (7) by a third-degree polynomial in labor, capital, intermediary inputs, average wage and investment rate (following Fan et al. (2022)).

5.4 Heterogeneity Analysis

In this subsection, we explore whether the impact of a pension fund investment is heterogeneous across firms.

5.4.1 Listed and Unlisted Firms

One of the strengths of our dataset is that it includes information on pension fund investments for both listed and unlisted firms. In this subsection, we explore whether the effect of a pension fund investment differs between these two categories of firms. We define a firm as

[28] Direct pension fund investments are defined as cases where the direct owner is a pension fund. This differs from the investments as defined in the full sample, which also include cases in which a firm is owned by a pension fund indirectly through another firm.

listed if it issued an equity instrument listed on the Copenhagen Stock Exchange over the sample period. Furthermore, we apply business group mapping to expand the group of listed firms as follows. Using the KONC register published by Statistics Denmark, we map firms that belong to the same business group. If one firm in a business group is listed in a given year, we define all firms in the business group as listed in that year. We apply the same logic to our pension fund investment measures. Therefore, if one company in a business group receives a pension fund investment in a given year, we assume that all companies in the business group receive a pension fund investment in that year.[29]

This mapping addresses two issues: i) the number of individual listed firms in Denmark is very low, and therefore, the mapping allows us to increase the sample size to allow a meaningful analysis; and ii) the actual equity instrument is often issued by a headquarters company, for example, a holding company, that has only administrative tasks in the business group. However, this type of firm is not the ideal object for productivity analysis. The drawback of the approach proposed here would be that any analysis of investment intensity would necessitate the additional stronger assumption that the amount invested in one firm in the business group is equivalent for all firms in the business group. A similar argument holds for the investment length. We refrain from making these assumptions and therefore restrict the analysis in this subsection to the pension fund investment dummy variable.

As a first exercise, we modify equation (10) as follows:

$$\begin{aligned}\widehat{h}_{it} =& \alpha + \beta_k k_{it} + \beta_l l_{it} + \rho\left(\widehat{h}_{it-1} - \beta_k k_{it-1} - \beta_l l_{it-1}\right) + \gamma_1 PFI_{it-1} \\ &+ \gamma_2 List_i + \gamma_3 PFI_{it-1} \times List_i + \xi_{it}\end{aligned} \tag{11}$$

where $List_i$ is a dummy equal to 1 if firm i is part of a business group that included at least one firm listed on the Copenhagen Stock Exchange in at least one year during 2003–2019. The coefficient $\widehat{\gamma_3}$ indicates whether the effect of a pension fund investment is different for listed and unlisted firms. Table 7 reports the results of this specification. While listed firms overall seem to be more productive, as indicated by the positive sign of the coefficient $\widehat{\gamma_2}$, the coefficient $\widehat{\gamma_3}$ reveals that the pension fund investment effect is stronger for unlisted firms by 6–7 percentage points. Therefore, we find that unlisted firms indeed benefit more from pension fund investment than do listed firms. This finding is consistent with the

[29]To illustrate the mapping with an example, let firms A and B belong to the same business group. Firm A receives a pension fund investment at time $t-1$, while firm B does not. Furthermore, firm B is publicly listed, while firm A is not. In Tables 7 and 8, both firms A and B are defined as treated and publicly listed, since they belong to the same business group. In our baseline results, only firm A is defined as treated, because we do not use business group mapping. However, the baseline results are robust to using the mapping and defining both A and B as treated.

hypothesis that pension fund investment raises productivity through the capital provision channel. Listed firms typically have easier access to third-party capital compared to unlisted firms. As a result, an investment from a particular investor, such as a pension fund, may have a greater impact on unlisted firms.

Table 7: Productivity Estimates: Listed vs. Unlisted Firms

	(1)	(2)
β_l	0.951***	0.947***
	(0.005)	(0.005)
β_k	0.084***	0.083***
	(0.003)	(0.003)
$DPFI_{it-1}$	3.869***	3.474***
	(1.151)	(1.140)
$List_i$	7.921***	7.842***
	(1.761)	(1.741)
$DPFI_{it-1} \times List_i$	-6.822***	-6.568***
	(2.224)	(2.214)
Industry FE	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	No
Export_{it-1}	No	Yes
Obs.	102,443	102,443
Obs. PF	2,753	2,753
# Firms	14,968	14,968
# Firms PF	712	712

Notes: This table presents the results from the estimation of equation (11). $DPFI_{it-1}$ is a dummy equal to 1 if at least one domestic pension fund invested in firm i in year $t-1$. $List_i$ is a dummy equal to 1 if firm i was part of a business group including at least one firm listed on the Copenhagen Stock Exchange in at least one sample year. Coefficient estimates and standard errors for $DPFI_{it-1}$, $List_i$ and their interaction term are multiplied by 100. The coefficient estimates on these regressors measure their effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In column 2, we include a dummy equal to 1 if firm i was an exporter in year $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment in year $t-1$. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

For the set of listed firms, we have the possibility of verifying our findings using another dataset. This second dataset, which we henceforth refer to as "Collected Data", is the result of an original data collection effort in which we obtain investment data directly from six large Danish pension funds, which at the end of 2019 together managed approximately 70% of assets in the Danish pension sector. We use only data on listed equity holdings of these funds during the period from 2005 through 2019 due to data availability constraints.

Table 8 shows the results using this alternative source of pension fund investment data. Since the Collected Data only includes pension fund investment information for publicly listed firms, we exclude privately held firm from this exercise. The positive coefficient on the pension fund investment variable supports our main conclusions, and its magnitude is even larger than that from our baseline specifications. However, the results obtained from this additional refinement have to be interpreted with some caution due to the small sample size.

Table 8: Productivity Estimates: Listed Firms from Collected Data

	(1)	(2)	(3)
β_l	0.785***	0.775***	0.771***
	(0.037)	(0.038)	(0.039)
β_k	0.145***	0.144***	0.144***
	(0.025)	(0.025)	(0.025)
$DPFI_{it-1}$		8.165**	8.017**
		(3.274)	(3.245)
Industry FE	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	No	No
Export_{it-1}	No	No	Yes
Obs.	2,802	2,802	2,802
Obs. PF	1,330	1,330	1,330
# Firms	348	348	348
# Firms PF	222	222	222

Notes: This table presents the results from the estimation of equation (10) using data on domestic listed equity holdings collected directly from a subset of Danish pension funds. $DPFI_{it-1}$ is a dummy equal to 1 if at least one domestic pension fund invested in firm i in year $t-1$. Coefficient estimates and standard errors for $DPFI_{it-1}$ are multiplied by 100. The coefficient estimate of $DPFI_{it-1}$ measures its effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In column 3, we include a dummy equal to 1 if firm i is an exporter in year $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment at time $t-1$. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.4.2 Further Heterogeneity Analysis

We further explore heterogeneity along the following dimensions: firm size, age and labor productivity. For each of those variables, we construct a dummy indicator. Specifically, the dummy $small_i$ equals 1 if firm i's employment, defined as the number of employees, in its base year is below the sample median employment.[30] Furthermore, the dummy $young_i$ is 1 if the number of years since firm i was established is below the sample median. Finally, $hlprod_i$ equals 1 if firm i's base year output per worker is above the sample median.[31]

[30] The base year is defined as the first year in which we observe a firm in our sample.

[31] When we calculate these dummies on the basis of year-specific medians, we obtain similar results, which are available upon request.

Whereas age of the firm does not matter for the effect of a pension fund investment, we find evidence that smaller firms benefit more from a pension fund investment. This larger effect for small firms is in line with the notion that pension fund investment is relatively more important as a source of funding for small firms, which are more likely to be non-listed firms and therefore companies with fewer possibilities of turning to alternative financing sources. Finally, base year output per worker does not matter for the effect of a pension fund investment. However, it is noteworthy that the coefficient on the pension fund investment variable is still significant after we control for high base year productivity, supporting the notion that the pension fund investment effect that we estimate is not specifically due to the selection of highly-productive firms by pension funds when they start their investment.

Table 9: Productivity Estimates: Heterogeneity Analysis

	Age			Size			$\frac{output}{worker}$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
β_l	0.953***	0.953***	0.950***	0.950***	0.950***	0.948***	0.950***	0.950***	0.948***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
β_k	0.085***	0.085***	0.084***	0.085***	0.085***	0.084***	0.076***	0.076***	0.075***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
$DPFI_{it-1}$	5.238***	4.582***	4.610***	2.083**	2.590**	1.718*	3.145***	3.372***	2.822***
	(1.632)	(1.634)	(1.596)	(0.961)	(1.138)	(0.966)	(0.980)	(1.128)	(0.961)
$young_i$	-0.050	-0.084	-0.425						
	(0.398)	(0.397)	(0.390)						
$DPFI_{it-1} \times young_i$	-2.996	-1.765	-2.622						
	(1.826)	(1.893)	(1.804)						
$small_i$				-0.945	-0.914	-0.637			
				(0.576)	(0.576)	(0.577)			
$DPFI_{it-1} \times small_i$				10.052**	8.681**	9.731**			
				(4.085)	(4.310)	(4.101)			
$hlprod_i$							17.980***	17.980***	17.650***
							(0.665)	(0.664)	(0.657)
$DPFI_{it-1} \times hlprod_i$							-1.886	-2.388	-1.673
							(1.904)	(2.058)	(1.893)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	Yes	No	No	Yes	No	No	Yes	No
Export_{it-1}	No	No	Yes	No	No	Yes	No	No	Yes
Obs.	102,443	102,443	102,443	102,443	102,443	102,443	102,443	102,443	102,443
Obs. PF	2,292	1,730	2,292	2,292	1,730	2,292	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	14,968	14,968	14,968	14,968	14,968	14,968
# Firms PF	574	429	574	574	429	574	574	429	574

Notes: This table presents the results from estimations of a specification analogous to that in (11) using dummies for young firms ($young_i$=1 if firm age in the base year is below the sample median), small firms ($small_i$=1 if firm size in the base year is below the sample median), and labor productivity ($hlprod_i$=1 if labor productivity in the base year is above the sample median). $DPFI_{it-1}$ is a dummy taking a value of 1 if at least one domestic pension fund invested in firm i in year $t-1$. Coefficient estimates and standard errors for all variables except β_k and β_l are multiplied by 100. The coefficient estimates on the other regressors measure their effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 2, 5 and 8, $DPFI_{it-1}$ equals 1 if the aggregate holding of all domestic pension funds in firm i in year $t-1$ was at least equal to 5%. In columns 3, 6 and 9, we include a dummy equal to 1 if firm i is an exporter in year $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment at time $t-1$. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

6 Discussion and Conclusion

Among a multitude of potential initiatives to raise productivity, this paper has focused on the role of investments operating through funded pension schemes. In recent decades, funded pension savings have increased significantly across the globe, and countries with high levels of pension savings relative to GDP typically top the international ranking of pension systems. For example, Mercer (2021) ranks pension systems in terms of adequacy, sustainability and integrity. The three countries with the best-rated pension systems, Iceland, the Netherlands and Denmark, also have the highest pension assets to GDP ratios among OECD countries (OECD, 2021). However, while pension funds are potential financiers of firms, it is largely an unresolved question whether and to what extent pension fund investments affect firms' productivity.

In this paper, we have highlighted several possible channels for a positive effect of a pension fund investment on firms' productivity. For example, by channeling savings toward firms, pension funds can raise the supply of capital, thereby reducing its cost and hence stimulating investment by firms. Additionally, pension funds are long-term investors in the sense that they try to match their long-term liabilities with long-term assets. Investment by a pension fund may thus be taken as a long-term financing commitment. Presumably, such "long-termism" could give firms the assurance they need when undertaking investments that raise productivity in the long run rather than focusing on short-term gains. Furthermore, pension funds could play a role in monitoring firm management, although they tend to be less engaged than some types of activist shareholders, such as private equity firms.

Since which firms receive a pension fund investment may not be a random group, it is important to control for selection when estimating the impact of these investments on productivity. We dealt with this issue as follows. First, we conducted an event study that made us confident that there were no differential pre-trends. We then proceeded by implementing a structural estimation approach in which we explicitly controlled for selection. An added advantage of the structural estimation was that it addressed omitted variable bias issues by fully controlling for firms' heterogeneity in terms of past productivity.

We deployed three main sources of Danish data. The first was firm register data. In particular, we constructed a dataset at the individual firm level for Denmark with information on inputs, output, and other individual firm-level characteristics. The second was a dataset that we constructed covering pension fund investment in listed and unlisted Danish firms. The third source was data on domestic listed equity holdings that we collected directly from six large Danish pension funds.

We found that pension fund investment has a highly significant and quantitatively substantial positive effect on firms' productivity. This finding was highly robust. It was robust

to, for example, controlling for whether a firm exports, suggesting that the effects of pension fund investment and exporting are additive. We also found suggestive evidence that the productivity effect was stronger the larger the pension funds' stake in a firm and the longer the pension fund had been investing in a firm. Although these results combine the impact of the extensive margin with the one of the intensive margin of a pension fund investment, we believe that the long-term financing commitment is an important mechanism behind our main results. Finally, the effects of pension fund investment are larger for non-listed than for publicly listed firms, in line with the notion that listed firms have more alternative sources of financing.

Our findings may provide leads for policies aimed at increasing firms' productivity. On the one hand, this is important in an era where potential GDP growth has gradually fallen over several decades in the industrialized world. This naturally raises the question of how to reverse this development. On the other hand, many emerging and developing countries are facing the dual challenge of fostering economic development while designing sustainable pension systems for a growing population. The challenge of boosting productivity growth becomes even more important in view of the prospect of ageing populations and other contemporary challenges. At the same time, there is a global trend towards more pension funding, increasing the importance of pension funds for the global economy. Against this backdrop, our results at the micro level have the potential to inform policymakers on the macroeconomic implications of funded pension systems and the potential of pension funds to support the real economy.

Specifically, a positive effect of a pension fund investment on productivity could support the introduction, or enlargement, of funded pension schemes, or even making participation in a funded pension scheme mandatory.[32] To the extent that the productivity effect is driven by pension funds' long-term financing commitment, this is an argument for restricting early withdrawal of accumulated pension savings to avoid a danger of premature liquidation of pension investment in firms.[33] Other policies aimed at increasing pension savings and investment could also support domestic productivity. Such policies could rely on tax incentives by, for example, allowing pension contributions to be deducted from taxable income or increasing the maximum deduction limit. Another measure would make the tax rate on capital gain a declining function of the length of the holding period of equities. Although our paper focuses on the impact of pension fund investments, larger equity holdings held by other long-term institutional investors, such as insurance companies, may also have a positive effect on firms' productivity. Investigating the impact of these institutional investors on productivity,

[32]For example, in the Netherlands most employees are obliged to participate in the pension fund of their sector or company.

[33]See Beetsma et al. (2012) on the sustainability of non-mandatory funded pensions and Brown et al. (2022) on take-up trends of retirement income in the U.S.

and how it varies across different types of investors, would be an interesting area for future research.

Our findings may also have consequences for the supervision of institutional investors, particularly pension funds, as well as other investors with long-term liabilities, such as insurance companies. Typically, supervision focuses on the protection of savings held by individual institutions. However, an "excessive" quest for safety at the level of individual institutions may have adverse macroeconomic implications, as it could undermine the availability of long-term financing for firms and the real economy more broadly. On a related point, our conclusion that the effect of pension fund investment is more pronounced for unlisted than listed firms could be understood as an argument to support more investment by pension funds into unlisted assets and potentially more broadly alternative asset classes. While we do find a positive effect of pension fund investment on productivity, it is important to stress that regulation needs to strike a careful balance between the benefits and the risks for pension savers. Investigation of this trade-off between the risks at the level of individual pension fund participants through fund ownership of firms and the macroeconomic benefits in terms of higher productivity constitutes interesting opportunities for future research.

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Appendix A Additional Statistics

Table A.1: Investment Length Pension Funds and Other Investors

Investor sector	N	Mean $Length_{it-1}$	Difference	Difference p-value
Panel A				
Pension funds	2,292	4.16	.	.
Banks, savings banks and cooperative banks	959	3.26	0.89	0.00
Financial holding companies	3,478	3.53	0.63	0.00
Non-financial holding companies	35,156	4.82	-0.67	0.00
Investment associations	290	1.91	2.25	0.00
Investment companies	3,622	4.10	0.05	0.54
Venture companies and capital funds	919	3.27	0.88	0.00
Other financial intermediation except insurance and pension insurance	3,441	3.73	0.43	0.00
Asset management	81	3.22	0.93	0.01
Insurance companies	229	2.76	1.39	0.00
Panel B				
Pension funds	347	4.41	.	.
Banks, savings banks and cooperative banks	219	3.36	1.06	0.00
Financial holding companies	527	2.94	1.47	0.00
Non-financial holding companies	2,098	3.99	0.42	0.03
Investment associations	103	2.26	2.15	0.00
Investment companies	521	3.54	0.87	0.00
Venture companies and capital funds	164	3.85	0.56	0.06
Other financial intermediation except insurance and pension insurance	529	3.32	1.09	0.00
Asset management	13	1.92	2.49	0.01
Insurance companies	79	2.32	2.10	0.00

Notes: This table shows the average value of our treatment variable measuring investment length, $Length_{it-1}$, for the six-digit investor sectors included in table 6 and insurance companies (three-digit sector), as well as pension funds. The table also includes results from t-tests, the difference in means of the length variable between each investor sector and pension funds, and the p-value of the difference. All results are conditional on at least one investor of the sector investing in firm i at time $t-1$. In panel A, all such observations are considered. In panel B, we additionally condition on observing active divestment of the sector, so on at least one investor of the sector investing in firm i at time $t-1$ and no investment by the investor sector in company i in period t.

Table A.2: Number of Firms per NACE Rev.2 1-Digit Sector

Sector	Firms with PFI	Firms without PFI
Manufacturing	283	3,391
Construction	37	2,383
Wholesale and retail trade; repair of motor vehicles and motorcycles	87	4,374
Transportation and storage	28	1,154
Information and communication	73	707
Real estate activities	12	219
Professional, scientific and technical activities	34	1,345
Administrative and support service activities	20	821
Total	**574**	**14,394**

Notes: This table illustrates the sector distribution among firms in the sample. Since a firm is "treated" if it received a pension fund investment in the previous year, this table splits the sample into firms that are treated at least once over the sample period (left column) and firms that are never treated (right column). "PFI" denotes "pension fund investment".

Appendix B Gross Output Production Function

In our main specifications, we use a value added production function. An alternative approach is to model the production function with a gross output production function. The main difference is that in a gross output production function, intermediate inputs enter the right-hand side of the production function. Formally, the production function in logs is:

$$y_{it} = \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \omega_{it} + \varepsilon_{it} \tag{B.1}$$

and the second-stage equation, analogous to equation (10), is:

$$\begin{aligned} \widehat{h}_{it} =& \alpha + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} \\ &+ \rho \left(\widehat{h}_{it-1} - \beta_k k_{it-1} - \beta_l l_{it-1} - \beta_m m_{it-1} \right) + \gamma PFI_{it-1} + \xi_{it} \end{aligned} \tag{B.2}$$

where all variables are defined as in the main text. Ackerberg et al. (2015) conclude that the lagged value of intermediate inputs m_{it-1} is not a suitable instrument for the input m_{it} in the context of gross output production functions; therefore, the parameter β_m cannot be estimated as in our main approach. To address this, we exploit the firms' first-order

condition for intermediate inputs following (Gandhi et al., 2020) and Fan et al. (2022). In particular, Fan et al. (2022) show that the following condition holds:

$$\frac{P_{mt} \times \exp(m_{it})}{\exp(y_{it})} \times \exp(\tilde{\varepsilon}_{it}) = \widehat{\beta}_m \tag{B.3}$$

where P_{mt} is the price of material inputs and $\tilde{\varepsilon}_{it}$ is the estimated residual from the first stage of the estimation procedure. The first term on the left-hand side of equation (B.3) is the share of intermediate inputs in revenue (output) of the firm. With that share readable from the data and $\tilde{\varepsilon}_{it}$ in hand from the first-stage estimation, we follow Fan et al. (2022) and estimate the $\widehat{\beta_m}$ equation (B.3) by the method of moments, assuming that $\exp(\tilde{\varepsilon}_{it})$ has a mean of 1. We then plug $\widehat{\beta_m}$ into equation (B.2) and estimate all other parameters via GMM as in our baseline approach. Tables B.1–4 are the counterparts to Tables 2–4, which display the main results using a gross output production function. This alternative specification confirms our results regarding the dummy and the investment length. However, contrary to our baseline results, the coefficient of the investment intensity variable is no longer statistically significant. Therefore, using a gross output production function, the amount that pension funds invest does not seem to have a significant impact on firm productivity. The amount invested, however, is a noisy measure, and we are able to confirm our baseline results for two out of the three dimensions of pension fund investment that we investigate.

Table B.1: Pension Fund Dummy Results, Gross Output Production Function

	Whole sample				Matched sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
β_l	0.414***	0.414***	0.413***	0.413***	0.400***	0.399***	0.399***	0.399***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.008)	(0.008)	(0.008)
β_k	0.030***	0.030***	0.030***	0.030***	0.033***	0.032***	0.032***	0.032***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
β_m	0.605***	0.605***	0.605***	0.605***	0.618***	0.618***	0.618***	0.618***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$DPFI_{it-1}$		2.111*	3.490**	1.990		2.054	3.493**	1.966
		(1.226)	(1.493)	(1.225)		(1.307)	(1.622)	(1.305)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	No	Yes	No	No	No	Yes	No
Export_{it-1}	No	No	No	Yes	No	No	No	Yes
Obs.	102,443	102,443	102,443	102,443	48,554	48,554	48,554	48,554
Obs. PF	2,203	2,292	1,730	2,292	2,203	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	14,968	7,468	7,468	7,468	7,468
# Firms PF	570	574	429	574	570	574	429	574

Notes: This table presents the results from the estimation of equation (B.2). $DPFI_{it-1}$ is a dummy equal to 1 if at least one domestic pension fund invested in firm i in year $t-1$. Coefficient estimates and standard errors for $DPFI_{it-1}$ are multiplied by 100. The estimated coefficient of $DPFI_{it-1}$ measures its effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 3 and 7, $DPFI_{it-1}$ equals 1 if the aggregate holding of all domestic pension funds in firm i in year $t-1$ was at least equal to 5%. In columns 4 and 8, we include a dummy equal to 1 if firm i is exporter in year $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment at time $t-1$. Finally, * $p<0.1$, ** $p<0.05$, and *** $p<0.01$.

Table B.2: Pension Fund Investment Intensity Results, Gross Output Production Function

	Whole sample			Matched sample		
	(1)	(2)	(3)	(4)	(5)	(6)
β_l	0.414***	0.414***	0.413***	0.400***	0.400***	0.399***
	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)
β_k	0.030***	0.030***	0.030***	0.033***	0.033***	0.032***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
β_m	0.605***	0.605***	0.605***	0.618***	0.618***	0.618***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Intensity_{it-1}$	0.061	0.064	0.057	0.052	0.056	0.049
	(0.084)	(0.084)	(0.082)	(0.099)	(0.099)	(0.098)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	Yes	No	No	Yes	No
Export_{it-1}	No	No	Yes	No	No	Yes
Obs.	102,443	102,443	102,443	48,554	48,554	48,554
Obs. PF	2,292	1,730	2,292	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	7,468	7,468	7,468
# Firms PF	574	429	574	574	429	574

Notes: This table presents the results from the estimation of equation (B.2). $Intensity_{it-1}$ is the aggregate share of firm i (in percent) held by domestic pension funds in year $t-1$. Coefficient estimates and standard errors for $Intensity_{it-1}$ are multiplied by 100. The estimated coefficient of $Intensity_{it-1}$ measures its effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 2 and 5, $Intensity_{it-1}$ equals 0 if the aggregate holding of all domestic pension funds in firm i in year $t-1$ is less than 5%. In columns 3 and 6, we include a dummy equal to 1 if firm i is an exporter in year $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment at time $t-1$. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

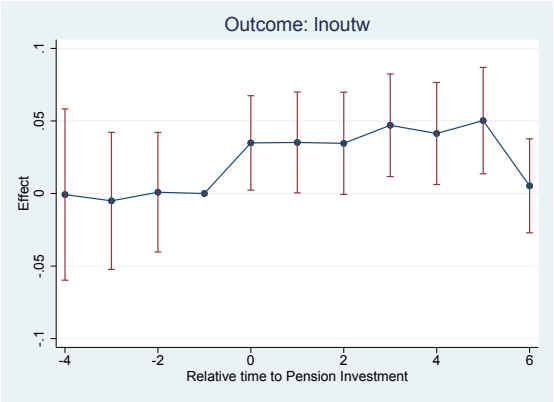
Table B.3: Pension Fund Investment Length Results, Gross Output Production Function

	Whole sample			Matched sample		
	(1)	(2)	(3)	(4)	(5)	(6)
β_l	0.414***	0.414***	0.413***	0.400***	0.399***	0.399***
	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)
β_k	0.030***	0.030***	0.030***	0.032***	0.032***	0.032***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
β_m	0.605***	0.605***	0.605***	0.618***	0.618***	0.618***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Length_{it-1}$	0.326	0.522*	0.309	0.264	0.467	0.250
	(0.248)	(0.305)	(0.248)	(0.252)	(0.335)	(0.252)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	Yes	No	No	Yes	No
Export_{it-1}	No	No	Yes	No	No	Yes
Obs.	102,443	102,443	102,443	48,554	48,554	48,554
Obs. PF	2,292	1,730	2,292	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	7,468	7,468	7,468
# Firms PF	574	429	574	574	429	574

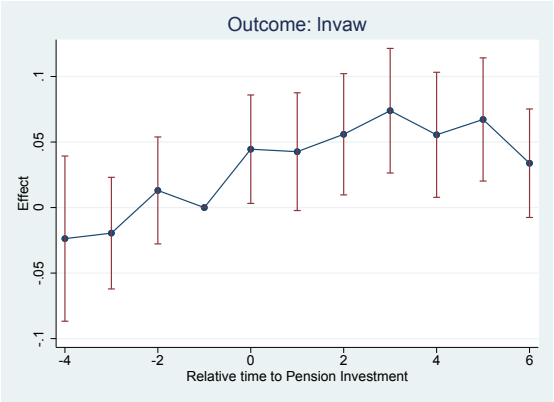
Notes: This table presents results from the estimation of equation (B.2). $Length_{it-1}$ is the number of consecutive years that firm i received an investment from any pension fund up to year $t-1$ included. Coefficient estimates and standard errors for $Length_{it-1}$ are multiplied by 100. The estimated coefficient of $Length_{it-1}$ measures its effect on productivity. All specifications include industry fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 2 and 5, $Length_{it-1}$ includes only the years when aggregate investment by domestic pension funds in the firm is at least 5%. In columns 3 and 6, we include a dummy taking value 1 if firm i is an exporter in year $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with a pension fund investment in year $t-1$ in the sample. Finally, * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

Online Appendix (not for publication): Additional Results

Figure 2: Event Study Results, Matched Sample



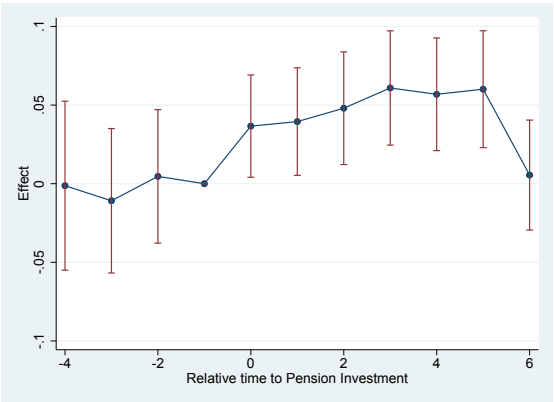
(a) Output per worker



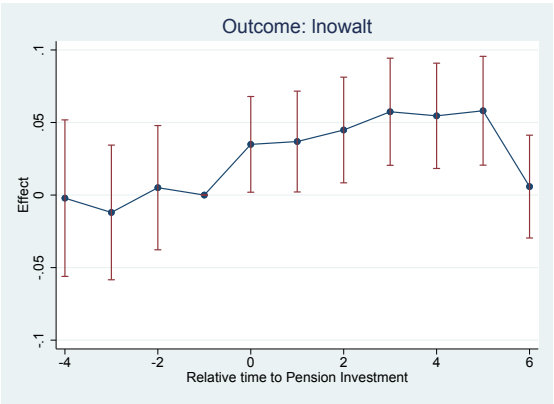
(b) Value added per worker

Notes: Results obtained with the matched sample. The outcome variable is output or value added per worker. This figure presents point estimates and 95% confidence intervals of an event study specification using the estimator proposed by Sun and Abraham (2021). The following controls enter the specification: firm age, a dummy for the firm being listed in the base year, firm size (number of employees), and capital intensity. We also include year by industry (NACE Rev.2 1-digit) fixed effects.

Figure 3: Event Study Results, Alternative Measure of Output



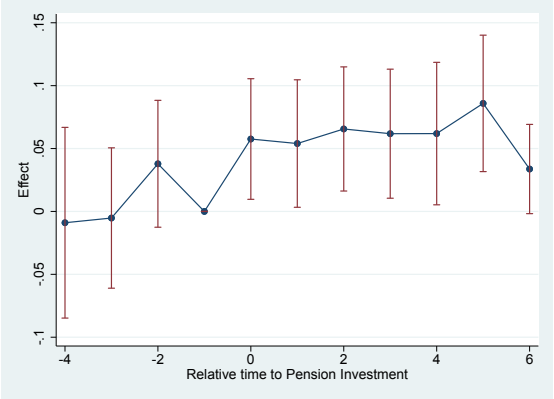
(a) Output per worker (alt. def.)



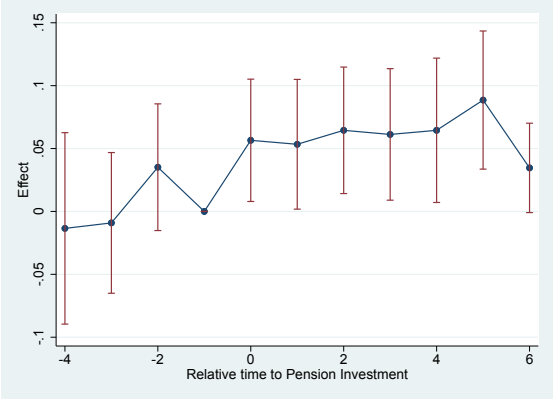
(b) Output per worker (alt. def.) and Matched Sample

Notes: The outcome variable is output per worker (alternate definition). Results in the second panel obtained with the matched sample. This figure presents point estimates and 95% confidence intervals of an event study specification using the estimator proposed by Sun and Abraham (2021). The following controls enter the specification: firm age, a dummy for the firm being listed in the base year, firm size (number of employees), and capital intensity. We also include year by industry (NACE Rev.2 1-digit) fixed effects.

Figure 4: Event Study Results, Specification without Control Variables



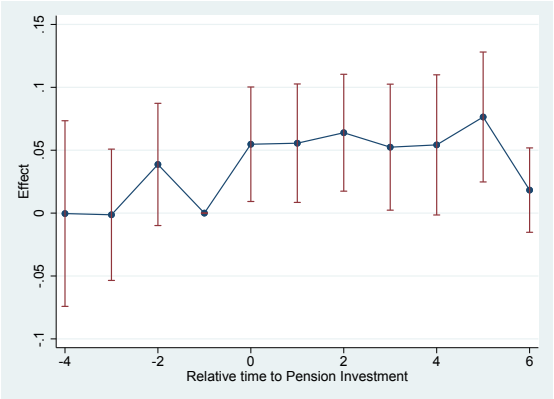
(a) Value added per worker



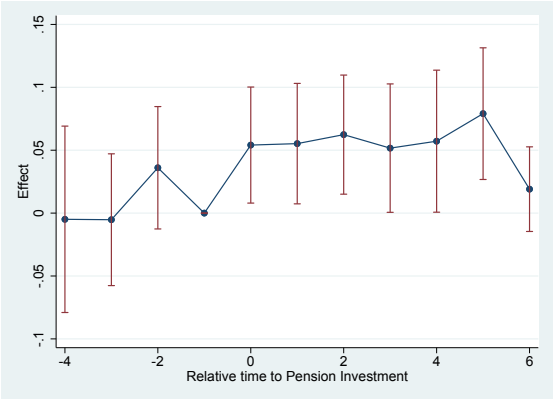
(b) Value added per worker and Matched Sample

Notes: The outcome variable is value-added per worker. Results in the second panel obtained with the matched sample. This figure presents point estimates and 95% confidence intervals of an event study specification using the estimator proposed by Sun and Abraham (2021). We only include year by industry (NACE Rev.2 1-digit) fixed effects.

Figure 5: Event Study Results, Controlling for the Share of R&D Workers



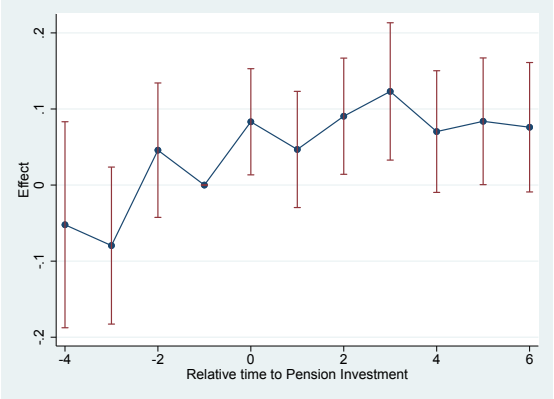
(a) Value added per worker



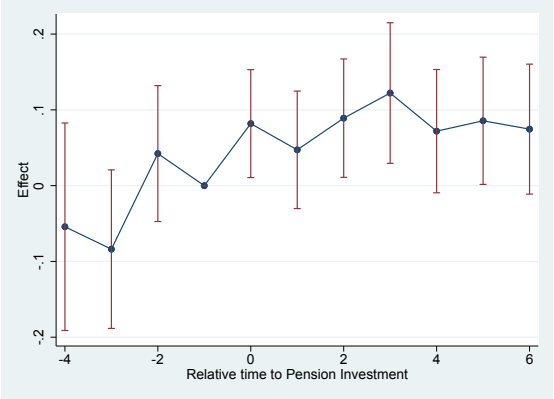
(b) Value added per worker and Matched Sample

Notes: The outcome variable is value-added per worker. Results in the second panel obtained with the matched sample. This figure presents point estimates and 95% confidence intervals of an event study specification using the estimator proposed by Sun and Abraham (2021). We add to the control variables the share of *R&D* workers. We also include year by industry (NACE Rev.2 1-digit) fixed effects.

Figure 6: Event Study Results, Excl. Multiple Investments



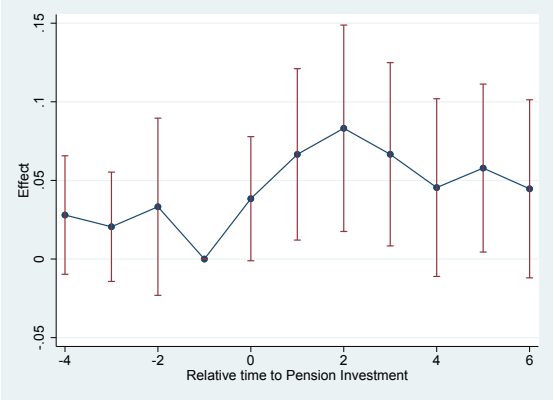
(a) Value added per worker



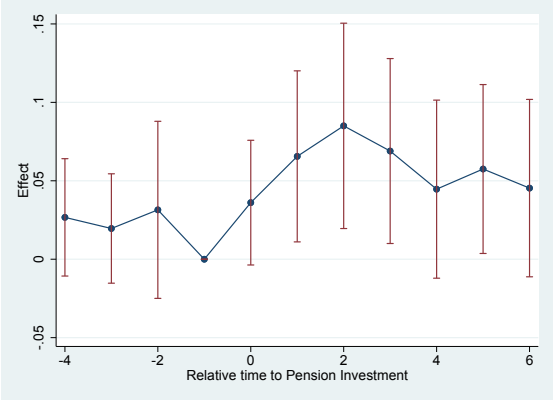
(b) Value added per worker and Matched Sample

Notes: The outcome variable is value-added per worker. Results in the second panel obtained with the matched sample. This figure presents point estimates and 95% confidence intervals of an event study specification using the estimator proposed by Sun and Abraham (2021). We focus on events in which only one pension fund invests in a given firm over the sample period. The following controls enter the specification: firm age, a dummy for the firm being listed in the base year, firm size (number of employees), and capital intensity. We also include year by industry (NACE Rev.2 1-digit) fixed effects.

Figure 7: Event Study Results, Excl. Short Investments



(a) Value added per worker



(b) Value added per worker and Matched Sample

Notes: The outcome variable is value-added per worker. Results in the second panel obtained with the matched sample. This figure presents point estimates and 95% confidence intervals of an event study specification using the estimator proposed by Sun and Abraham (2021). We exclude pension fund investments that last for fewer than 5 consecutive years. The following controls enter the specification: firm age, a dummy for the firm being listed in the base year, firm size (number of employees), and capital intensity. We also include year by industry (NACE Rev.2 1-digit) fixed effects.

Table C.1: Including Investment Intensity and Intensity Squared

	Whole sample			Matched sample		
	(1)	(2)	(3)	(4)	(5)	(6)
β_l	0.953***	0.953***	0.950***	0.911***	0.911***	0.909***
	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)
β_k	0.085***	0.085***	0.084***	0.092***	0.092***	0.091***
	(0.003)	(0.003)	(0.003)	(0.006)	(0.006)	(0.005)
$Intensity_{it-1}$	0.190	0.188	0.144	0.278**	0.276**	0.231*
	(0.143)	(0.144)	(0.142)	(0.131)	(0.131)	(0.130)
$Intensity^2_{it-1}$	0.001	0.001	0.001	-0.001	-0.001	-0.000
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	Yes	No	No	Yes	No
Export_{it-1}	No	No	Yes	No	No	Yes
Obs.	102,443	102,443	102,443	48,554	48,554	48,554
Obs. PF	2,292	1,730	2,292	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	7,468	7,468	7,468
# Firms PF	574	429	574	574	429	574

Notes: This table presents results from the estimation of equation (10) including $Intensity_{it-1}$ and $Intensity^2_{it-1}$. $Intensity_{it-1}$ is the aggregate share of firm i (in percentage points) held by domestic pension funds in year $t-1$. Coefficient estimates and standard errors for $Intensity_{it-1}$ and $Intensity^2_{it-1}$ are multiplied by 100. All specifications include industry-fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 2 and 5, $Intensity_{it-1}$ is equal to 0 if the aggregate holding of all domestic pension funds in firm i at time $t-1$ is less than 5%. In columns 3 and 6 we include a dummy taking value 1 if firm i is an exporter at time $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with pension fund investment at time $t-1$. Finally, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Finally, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.2: Including Investment Length and Length Squared

	Whole sample			Matched sample		
	(1)	(2)	(3)	(4)	(5)	(6)
β_l	0.953***	0.953***	0.950***	0.911***	0.911***	0.909***
	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)
β_k	0.085***	0.085***	0.084***	0.092***	0.092***	0.091***
	(0.003)	(0.003)	(0.003)	(0.006)	(0.006)	(0.005)
$Length_{it-1}$	1.197***	1.199***	1.018**	1.583***	1.666***	1.398***
	(0.399)	(0.452)	(0.396)	(0.396)	(0.426)	(0.398)
$Length^2_{it-1}$	-0.081**	-0.079*	-0.067*	-0.109***	-0.114***	-0.096***
	(0.035)	(0.041)	(0.035)	(0.036)	(0.039)	(0.036)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
$PFI_{it-1} \geq 5\%$	No	Yes	No	No	Yes	No
Export_{it-1}	No	No	Yes	No	No	Yes
Obs.	102,443	102,443	102,443	48,554	48,554	48,554
Obs. PF	2,292	1,730	2,292	2,292	1,730	2,292
# Firms	14,968	14,968	14,968	7,468	7,468	7,468
# Firms PF	574	429	574	574	429	574

Notes: This table presents results from the estimation of equation (10) including $Length_{it-1}$ and $Length^2_{it-1}$. $Length_{it-1}$ is the number of consecutive years that firm i received investment from any pension fund up to year $t-1$ included. Coefficient estimates and standard errors for $Length_{it-1}$ and $Length^2_{it-1}$ are multiplied by 100. All specifications include industry-fixed effects at the NACE Rev.2 1-digit level. Bootstrapped standard errors, clustered by firm, with 200 repetitions in parentheses. In columns 2 and 5, $Length_{it-1}$ only includes the years when aggregate investment by domestic pension funds in the firm is at least 5%. In columns 3 and 6 we include a dummy taking value 1 if firm i is an exporter at time $t-1$. The line "Obs. PF" ("# Firms PF") gives the number of observations (number of firms) with pension fund investment at time $t-1$ in the sample. Finally, * $p<0.1$, ** $p<0.05$, *** $p<0.01$.