ISSN 2042-2695

CENTRE for ECONOMIC PERFORMANCE

CEP Discussion Paper No 1580

October 2018

Labor Specialization as a Source of Market Frictions

Maria Molina-Domene

LSE THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Abstract
This paper investigates why labor specialization brings additional frictions to the labor market. The intuition is that labor specialized firms rely on complementarity and firm-specific human capital, assigning high value to the worker-employer match. Consistent with employees' importance, the findings show that specialized firms preserve their workforce: these firms labor hoard and increase wages during slow-downs. Additionally, when specialized firms unexpectedly face a labor supply shock | albeit managing to decrease the wages of the remaining co-workers, they become less productive. Overall, the empirical evidence suggests that frictions introduce bilateral monopoly rents.

Key words: labor specialization, market frictions, division of labor, human capital
JEL Codes: J24; J42; J63

This paper was produced as part of the Centre's Labour Markets Programme. The Centre for Economic Performance is financed by the Economic and Social Research Council.

I thank Jörn-Steffen Pischke for his continuous advice and support. Thanks also to Philippe Aghion, Michael Amior, Diego Battiston, Pawel Bukowski, Leonardo Bursztyn, Giulia Giupponi, Kilian Huber, Simon Jäeger, Xavier Jaravel, Benjamin Jones, Edward Lazear, Ana J. López Men_endez, Stephen Machin, Alan Manning, Guy Michaels, Dana Müller, Tuomas Pekkarinen, Barbara Petrongolo, Yona Rubinstein, Jan Stuhler, Catherine Thomas and John Van Reenen, as well as participants at the CEP-LSE Labor Seminar. Remaining errors are my own.

Maria Molina-Domene, Centre for Economic Performance, London School of Economics.

Published by
Centre for Economic Performance
London School of Economics and Political Science
Houghton Street
London WC2A 2AE

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means without the prior permission in writing of the publisher nor be issued to the public or circulated in any form other than that in which it is published.

Requests for permission to reproduce any article or part of the Working Paper should be sent to the editor at the above address.

© M. Molina-Domene, submitted 2018.

1 Introduction

This paper investigates why labor specialization can bring additional frictions to the labor market. Building on Pissarides (2011), the hypothesis is that the specialized employer is keen on locating and preserving a good match because it is costly and difficult to find suitable individuals for the kind of job the specialized firm offers. Reciprocally, the specialized firm's employees have less incentives to leave the firm, because the outside labor market is thin for his idiosyncratic skills. Looking at adverse shocks, this study extends Wasmer (2006), assuming that specific human capital investments can become an employment protection.

The contribution of the paper is to provide empirical evidence that working under labor specialization may entail mutual employee-employer dependence. Hence, specialized employers do not behave as pure monopsonists. These employers reassure employees during recessions (i.e. do not dissolve the match and renegotiate wages, given that search, hiring and training are particularly costly in time and resources for these firms), taking more of a hit in terms of labor productivity when they unexpectedly face an idiosyncratic firm-specific labor supply shock — compared to generalist firms.

From a theoretical perspective, this study relates to the literature on the complementarity between employees (Becker and Murphy, 1994) — which leads to superadditivity (Rosen, 1978); as well as on an extensive body of studies on firm-specific human capital (Becker, 1962; Gibbons and Waldman, 2004; Lazear, 2009; Gathmann and Schönberg, 2010) highlighting aspects such as low substitutability of employees. It is also intersected by monopsony (Sullivan, 1989; Manning, 2003; Ashenfelter et al., 2010; Staiger et al. 2010) and search models (Mortensen and Pissarides 1994).

This study relies on two main assumptions. The first one is that working under high levels of the division of labor fosters labor productivity (conditioned for instance, on coordination costs). The second one is that employers can contract with employees on a single basis, attaining optimal matches (Jovanovic, 1979). Once the match is achieved, the specialized employer is interested in preserving it. The logic is that the single employee is precious for the specialized firm for at

least two reasons: (i) he raises the productivity of his coworkers, (ii) he works on a fairly limited number of specific and closely related tasks, being the only one who possesses information about the role (see Molina-Domene (2018) among others). Crucially, the employee becomes more important over time: the specialized firm needs him on the grounds they have already developed firm-specific human capital, obtained by learning through specialization or by training (Acemoglu and Pischke, 1998).

The empirical evidence is based on matched employee-employer data (LIAB 1993-2010) from the German Social Security, which covers all workers employed in one of the surveyed establishments[1]. This data feature is important, because it allows us to build the specialization proxy — based on the entire occupation distribution within each firm, which measures occupation concentration. To assess the business cycle, the study relies on changes in the National Account industry gross value added in Germany as a source of variation, and focuses on downturns.

The first part of the study looks at specialized firms' response to downturns. Consistent with an extensive literature (Burnside et al.,1993; Bernanke and Parkinson, 1991; Hall, 1988; Bernanke, 1986; Fair, 1985; Fay and Medoff, 1985), the results document that more specialized firms preserve their labor force during slumps, appearing less productive. There is significant evidence that generalist employers lay off employees and that their employees quit. Nevertheless, the coefficient is close to zero regarding specialized firm's changes in separations during downturns. Within our sample, a one standard deviation increase in specialization decreases labor productivity by around 0.03 percent during downturns. Additionally, specialized firms slightly increase wages by almost a 0.02 percent — to preserve, and potentially to attract new employees.

The second part of the study assesses other frictions related to the matching market. The story is about employers who face the unexpected absence of an

[1]This study uses the Linked-Employer-Employee Data (LIAB) version from the IAB. Data access was provided via on-site use at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB) and subsequently remote data access (fdz1059-1060-1061). LIAB version: longitudinal model 1993-2010 (LIAB LM 9310). Data documentation: Heining et al., (2014), Klosterhuber et al., (2013), Fischer et al., (2009)

employee. To circumvent endogeneity concerns (e.g. an employee quits because he is unsatisfied with the job experience), the paper follows previous research (Jaravel et al., 2018; Fadlon and Nielsen, 2017; Jäger, 2016; Isen, 2013; Becker and Hvide 2013; Oettl, 2012; Azoulay et al., 2010; Bennedsen et al., 2007; Jones and Olken, 2005) and uses employee's deaths as a source of variation. The setting is a quasi-experimental research design, which compares the response of firms of different levels of specialization, in terms of different labor outcomes. The results show that more specialized firms require more time to externally find a substitute for the deceased, via hiring — compared to generalist firms[2]. Nevertheless, there is some underlying heterogeneity: specialized firms fill the vacancy of high-tenured employees more promptly, conditioned on the labor market availability. Additionally, the death of an employee hits specialized firms hard: a standard deviation increase in specialization decreases firm productivity by around 0.04 percent in the second year and around 0.03 percent in the third year. This is true even if specialized employers decrease the wages of the remaining coworkers more than their counterparts generalist firms. The effects are stronger for smaller firms and extend till the third year after the death, suggesting monopsonistic power.

The remainder of the paper is organized as follows. Section 2 lays out a simple conceptual framework and Section 3 presents the data and variable description. Section 4 focuses on adverse demand shocks, outlining the empirical strategy and providing results and Section 5 concentrates on the unexpected loss of an employee, conveying the empirical strategy and results. In Section 6, I conclude by drawing some implications derived from labor specialization.

[2]Unless the labor market is a frictionless competitive one — where uniqueness is not an issue (Manning, 2003), or if the firm-specific human capital is diffused and general (Lazear, 2009), the replacement of the deceased will be challenging.

2 Conceptual Framework

2.1 Labor Specialization

At time t, the worker's skills are unknown to the firm, there is no production and firms make their organizational choice. Firms and workers are risk neutral. Generalist firms hire 'jack-of all-trades' workers, who have more balanced talents and are versed in a variety of fields. Alternatively, specialized firms hire individuals who have expertise in certain skills[3].

For simplicity, let the production line include 2 workers w (A and B)[4] and assume there are two skills S^s : S^1 and S^2. Generalist firms hire workers who are equally proficient at S^1 and S^2. Each worker possesses skills S^s_w:

$$q = \frac{1}{2}(S^1_A S^2_A, S^1_B S^2_B) \tag{1}$$

Conversely, specialized firms hire workers who possess higher dexterity in one of the skills[5] S^1 and S^2, and not in the other, and assign employees to one task where they produce at the maximum skill level $max[S_1, S_2]$ as in Lazear (2005). The specialized firm achieves complementarity and high levels of productivity (i.e. as far as the costs of coordination, communication or adaptation[6] do not outweigh the benefits of the division of labor), but in the extreme it cannot operate if one employee is missing (i.e. $q = 0$). Therefore, the specialized firm output is:

$$q = max(S^1_A S^2_B, S^2_A S^1_B) \tag{2}$$

In this setting, an employee working for a generalist employer alone divides his time equally, contributing to $q\frac{1}{2}$. Alternatively, the specialized firm is more productive

[3]Beyond the level of education attainment, specialists perform their roles at high quality as in Kremer (1993), adhering to Jones (2014) 'quality' beyond 'quantity'.

[4]As in the Roy (1951) model, individuals are different.

[5]The probability of a specialized firm's meeting an employee is independent of the number of searchers and once firms find a good match, they stop searching.

[6]For instance, Dessein and Santos (2006) suggest that rigid organizations can rely on rules and task guidelines to coordinate tasks ex ante, while adaptive organizations require task bundling and intensive communication to ensure coordination ex post.

because A and B work at their maximum skill level. Therefore, A and B become more valuable for the specialized firm than for the generalist firm and receive an income associated with applying their best skill to the task they perform[7].

At time $t+1$, the firm assigns workers to tasks (i.e. not a choice for the worker). For simplicity, assume there are two tasks, $Task^1$ and $Task^2$ that correspond to S^1 and S^2 respectively. Within specialized firms both tasks 'must be' performed (i.e. as in Becker and Murphy, 1994). Each worker maximizes income by devoting full time to $Task^1$ or $Task^2$ (see Rosen, 1978) and there are no overlaps between coworkers[8]. There are neither hold-up nor principal-agent problems, which means each worker focuses on a task and combines his output with that of another worker without compensation (Jones, 2005).

A specialized firm's production function exhibits increasing returns to tenure: the longer the employee stays in the firm, the more productive he becomes. Each worker increases his firm-specific human capital (for instance, due to high on-the-job learning by training) and does not have obvious reasons to quit his job. The employee is precious and the firm has no incentive to lay-off, because it possesses information about the employee and has invested in his human capital. Profits are given by:

$$\pi = f(q) - C \tag{3}$$

where $f(q)$ is the firm's revenue function minus the wage rate and C are search or hiring costs. Assuming the scarcity of individuals who are able to maximize one of their skills, $C > 0$ within specialized firms because these firms face search and hiring costs[9]. An ex post bilateral monopoly arises within specialized firms. These

[7]An example can be found in a watch maker production line. Typical stages are the dial assembly, the mounting of the hands, the setting into the case and the manual tests. Each of these steps requires a specialist who is an expert in his role. He is fully responsible for his task and conveys the finished piece to the next work stage. This sequence is repeated until the watch is ready to be sold. The dexterity of an individual worker determines the quality of each step, the quality of the subsequent steps of the process, and ultimately the excellence in quality of the watch.

[8]There is non-cooperation (Baumgardner, 1988) or minimum employee' interaction with peers, which implies infrequent or negligible overlap between coworkers across sets of activities (i.e. each worker is uninformed about the role of other coworkers).

[9]For instance, because specialized firms' workforce is typically scarce and valuable.

firms have some market power over their specialists and are able to set wages (i.e. the elasticity of the supply is less than infinite), even below the competitive market. Nevertheless, firms' monopsony power decreases when their employees becomes power monopolists.

2.2 The Labor Matching and the Exogenous Shocks

The value of the labor matching comes to light when firms face adverse exogenous shocks. Assume there is a surplus M^{Surp} derived from the matching. M^{Surp} splits into shares β and $1-\beta$, where β is an index of the bargaining power of the worker with $0 \leq \beta \leq 1$. Within specialized firms, this index is away from the extremes because nor the employee neither the employer possess all the bargaining power.

During downturns, the specialized employer has no incentive to lay off and instead he labor hoards — even if $M^{Surp} < 0$, due to complementarity and low level of substitutability of workers (i.e. the firm already knows the employee's personal efficiency). Plausible strategies to retain workers are to rent share and to increase of wages.

After another type of exogenous shock, like the unexpected exit of an employee, the specialized firm is unprepared (e.g. due to status quo bias) and suffers a non trivial disutility shock. The significance of this shock is determined by the missing employee' substitutability[10], which is a function of the missing employee's firm-specific human capital and the firm's level of the division of labor[11].

Conditioned on β, once the specialized firm unexpectedly loses an employee it has at least two options:

1. It internally reorganizes and invests in retraining the surviving coworkers to perform the deceased's role. This option can be nonexistent, if the firm relies on complementarity.

[10]Working with the 1990 UK Employer's Manpower and Skills Practices Surveys, Manning (2003) provides evidence that employers report problems with recruiting specialist workers. Conversely, vacancies in jobs that require general skills cause less of a problem because other workers in the firm can adjust their work patterns to mitigate the costs of the vacancy.

[11]The shock is a concave function of the difficulty to find the deceased's skill, that decreases when the skill of the deceased becomes general or common knowledge (i.e whether human capital is labeled specific or general depends on observable market parameters, as in Lazear, 2009).

2. It poaches a suitable replacement for the deceased. This entails facing search and training costs, and potentially paying a higher wage (i.e. the higher the wage, the easier to fill the vacancy).

If the specialized firm possesses ex-post monopsonist power, it puts forward option one. It may also change remaining workers' wages, conditioned on the difficulty of the replacement. If the remaining workers are powerful monopolists, the firm is already paying a competitive wage or even a wage premium and prefers option two — creating a job opportunity for a specialist (e.g. an individual who is highly productive on the deceased's role and who has low outside options).

3 Data and Variables Description

3.1 Data

Employer-employee data (LIAB LM9310) and Establishment Panel

The analysis combines German linked employer-employee data (LIAB[12] LM9310) with the waves of surveys[13] from the unbalanced IAB Establishment Panel ($1993 - 2010$). Excluding establishments with more than fifteen employees and those in Public Administration and Defense; Political Parties; Educational, Scientific and Cultural Organizations; Christian Churches and Representations of Foreign Countries, the sample consists of around 9 million observations.

National Accounts (Eurostat)

The data regarding downturns come from German National Accounts (Eurostat), which provide different national macroeconomic indicators, aiming to convey an overall view of the country's economy. In particular, the study focuses the gross value added[14] — by industry breakdowns, according to NACE Rev.2 classification,

[12]LIAB matches establishment data (BHP Establishment History Panel) to administrative biographies of individuals (IEB Integrated Employment Biographies).

[13]These surveys' sampling frame is all establishments covered by the social security system, stratified according to industry, firm size and federal state. Consequently, the data is considered representative of the German firm population.

[14]Eurostat defines gross value added as the output value (at basic prices, in euro) minus intermediate consumption (valued at purchasers' prices), and calculates it before consumption of fixed capital (http://ec.europa.eu/eurostat/web/national-accounts).

and merges this data with LIAB 9310 through the industry code.

3.2 Variables Description

3.2.1 Dependent Variables

Midpoint changes

These are changes in separations, the net employment and the variables described below.

Labor productivity

It is defined as the value added divided by the number of employees working in firm j at time t. In turn, the value added equals the business volume (sales in euro) minus intermediate inputs (e.g. all raw materials and supplies purchased, external services, rents, etc.)[15]

Average wages

The variable is computed as the average of gross daily wages (in euros) paid by firm j at time t.

Time to Replace

It is the natural logarithm of the number of days needed to hire a new employee after an employee unexpectedly dies (i.e. excludes firms that do not replace the deceased).

3.2.2 Independent Variables

Specialization Proxy (EG)

For computing the specialization proxy variable I work with all individuals, employed in one of the surveyed establishments for at least one day during the studied period. The data contains information of around 330 titles provided in the 3-digit coded Classification of Occupations (Systematic and Alphabetical Directory of Job Titles, KldB88). Employers encode an employee's occupation with the title that best defines the main activity performed (i.e. even if more than one title

[15] As productivity is computed using the current number of employees, productivity regressions include the lagged size as a control (to avoid working with a simultaneously determined regressor).

could apply to one employee), in accordance with any of the German systematic classification of occupations.

The proxy of specialization is the dynamic version of the Ellison and Glaeser Index (hereafter EG)[16] applied in this case to compute the distribution of occupations in a firm. Given its construction, one advantage of working with EG is that it tells us to what extent the firm concentration of occupations departs from the occupation concentration in a typical firm within a specific industry (see Appendix). Specialization is considered a firm pattern and is computed as the EG firm average across years.

Downturn

The $Down_{kt}$ variable is based on the industry aggregated gross value added[17] by industry breakdowns, according to NACE Rev.2 classification. The variable $Down_{kt}$ equals 1, indicating downturns if $VA_{k(t)} < VA_{k(t-1)}$ and 0 otherwise.

Dummies relative to the death

The $DRDth_{jt}$ dummies are eight — for years -3 to 5 relative to the death (e.g $DRDth_0$ is the dummy for the year of the death and $DRDth_3$ is the dummy for the third year after the death). They are based on employer's notifications to the Social Security system. These records are sent at least once a year or when there are special reasons for notification such as employment interruption, unemployment, employee's illnesses, etc.

These dummies equal one in the relevant year — for employers that meet the following conditions: (a) they sent the Social Security agencies one notification stating that the end of the spell is due to the death of an employee occurred between July 1 and June 30 of the previous year, (b) the deceased has not been lingering with any health condition (i.e. the employee who dies, does not have an employment interruption notification that entitles him to compensation for six months or more, due to illness). The $DRDth_{jt}$ dummies are zero, otherwise.

The samples exclude firms with multiple death notification within a year

[16]Dumais et al., (2002) apply the Ellison and Glaeser Index to measure the geographic concentration of industries. The original version was proposed by Ellison and Glaeser in 1997.

[17]Eurostat defines gross value added as the output value at basic prices less intermediate consumption valued at purchasers' prices and it is calculated before consumption of fixed capital (http://ec.europa.eu/eurostat/web/national-accounts).

— these are 61 firms. The logic for excluding these firms is twofold: ruling out collective accidents or disasters, and avoiding further selection bias derived from the heterogenous recovery speed after the death of an employee.

Agglomeration

It reflects the preponderance of employment in a specific occupation within a particular area (Glaeser, 2007). Specifically, high levels of local agglomeration of employees in an occupation — say for instance due to the presence of an industry cluster, can correlate with a pool of potential specialists or individuals with a specific skill in the local labor market.

In this case, the variable $Agglom_l$ reflects the availability of an occupation within a district (5-digit code *Kreis*), which represents a proxy for τ in (2). Therefore, higher agglomeration represents a higher probability of finding an individual who works in the deceased's occupation within the district where the deceased used to work. It is computed as the ratio between individuals in the deceased's occupation within the firm's district and individuals in the deceased's occupation in total employment.

Control Variables

X_{jt} are firm size or lagged firm size (i.e. in productivity regressions), calendar year dummies, sector and region; as well as individual characteristics X_{ijt} (age, age squared, school education level and vocational training such as upper secondary school, university degree, etc.), occupation status (blue-collar, white collar, trainee, apprentice, etc.) and gender.

For the demand shock regressions, additional controls are the interactions between the $Down_{kt}$ indicator variable and the other covariates. For the supply shock regressions, additional controls are the interactions between the $DRDth_{jt}$ indicator variable and the other covariates as well as the interactions and leads and lags of those interactions.

4 Labor Specialization During Downturns

4.1 Empirical Strategy

This section evaluates the interaction between an aggregate adverse shock and labor specialization. Intuitively, generalist and specialized firms adjust to transitory demand shocks differently. The reason is that a specialized firm's workforce is particularly valuable because it is quasi-fixed: specialized employees' internal value to the firm exceeds their external value in the labor market (Oi, 1983), given search, recruiting and training costs.

In line with Wasmer (2006), labor specialization and low turnover tend to reinforce each other (due to reverse causality), while generalist firms have greater turnover and a different labor market, especially during downturns. In practical terms, specialized firms' optimal strategy should be to hoard workers even above the minimum level required in order to produce a given output. Some implications for specialized employers are: (1) they are hit more in terms of labor productivity — compared to generalist firms, (2) they do not decrease wages, (3) employers do not lay off and neither do employees quit. The latter may prefer to continue working for the firm because they possess highly distinct skills (e.g. specifically trained for the firm).

To evaluate these patterns, the empirical strategy focuses on industry transitory demand shocks (via recessions)[18] and estimates the differential effect of being specialized, in terms of firm's labor productivity and other labor outcomes (wages, hires and separations[19]). The data regarding downturns come from German National Accounts (Eurostat) that provide different national macroeconomic indicators, aiming to convey an overall view of the country economy. In particular, the study looks at the gross value added[20] by industry breakdowns —according

[18]Firm's organizational choice can make firms more resilient to negative shocks. For instance, Aghion et al., (2017) find evidence that 'bad times' can be less tough for decentralized firms.

[19]An appealing derivation is that labor specialization could be a reassurance against recessionary unemployment (Michaillat, 2012). Note that separations adds up quits and layoffs, to include cases such as disguised or induced dismissals

[20]Eurostat defines gross value added as the output value at basic prices (in euro) less intermediate consumption valued at purchasers' prices and calculates it before consumption of fixed capital

to NACE Rev.2 classification and merge this data with LIAB 9310 through the industry code.

Since 2003, firms with more than 10 employees face specific procedures and costs to terminate employment relationships, otherwise the employee has to be reinstated to his former position[21]. Therefore, to work on a more homogeneous basis, we focus on a sample of firms with more than 10 employees.

The study implements a difference-in-difference specification, which is:

$$\begin{aligned} Y_{jt} = \alpha_i + \rho_j + \beta Specialization_{jt} + \tau Down_{kt} + \\ + \sigma(Specialization_{jt} * Down_{kt}) + \upsilon X_{jt} + \varepsilon_{jt} \end{aligned} \tag{4}$$

where subscripts $j = 1, ..., n$ represent firms, k is the industry and t is year (1995-2010). Y_{jt} is the midpoint change in productivity, firm average wages and the net change of employment, hires and separations [22]. $Down_t$ is the dummy variable indicating slumps[23] at time t ($Down_{kt} = 1$ if $BC_{k(t)} < BC_{k(t-1)}$ and 0 otherwise).

The variable of interest is σ, which represents the differential effect of being specialized during downturns. The control variables X_{jt} are lagged size (when the dependent variable is productivity) or size (when the dependent variables are labor outcomes) and year. The specification also controls for the interactions between the downturn indicator variable and the other covariates (e.g. firm characteristics), to account for differential levels of outcome changes by firm size and year. Firm fixed effects ρ_j allow absorbing the unobserved heterogeneity across firms. Standard errors are clustered at the firm level.

(http://ec.europa.eu/eurostat/web/national-accounts).

[21]This is due to the Dismissals Protection Act, which applies to employees employed in the business unit for at least six months, working under an employment contract. Additional rules apply to collective dismissals and certain groups of employees (members of the works council, disabled people, pregnant women, etc.).

[22]Instead of the natural logarithm, I use the midpoint change, given these three variables can be zero.

[23]As a check of robustness of the results, I work with the same specification but use a measure of the business cycle incremental change, based on the industry gross value added: $BC_{i(t-1)} = VA_{i(t)} - VA_{i(t-1)}/VA_{i(t-1)}$. The results are presented in Appendix 2

4.2 Results

As a starting point, we take an overview of firm characteristics. Firms of low (below mean) and high (above mean) levels of specialization in this sample look different in many aspects. Table 1 documents how more specialized firms pay higher average wages and have higher wage dispersion. Their business volume and size are in mean, also greater.

Consistent with the development of firm-specific human capital, specialized firm's employees are in mean, older and exhibit a higher tenure. These features give preliminary signs that specialized firms may be keen on preserving employees, during adverse shocks.

The empirical strategy focuses on negative demand shocks. Figure 1 depicts three major downturns in annual GDP growth rate. The most important slump happens in 2008. Figure 2 reveals that these shocks are not homogeneous across industries: different industries face plunges in value added growth rates at different time and even at different extent. This study exploits this heterogeneity as a source of variation.

To control for differences between firms — that go beyond specialization, the specifications include firm fixed effect. Table 2 documents the effects of these shocks regarding productivity, separations, net changes of employment and wages.

Column 1 shows that specialized firms are hit in terms of labor productivity. The coefficient of the interaction term between *Downturn* and *Specialization* is negative and highly statistically significant, suggesting specialized firms procyclical behaviour in terms of productivity. An explanation is that specialized firms could appear less productive, because they hoard employees during slumps due to sunk costs and low levels of substitutability. Instead of laying off, these firms retain workers even above the minimum level required to produce a given output.

Columns 2 to 4 show that the coefficients of the interaction term in the absolute and relative change separations and the net employment, the coefficients of the interaction term are close to zero and not statistically significant at any conventional level. This is not the case for generalists firms, where there is a positive and statistically significant association between separations and downturns

(column 3).

Interestingly, specialized firms countercyclically rise average wages during slowdowns (i.e. the coefficient of the interaction between *Downturn* and *Specialization* is positive and statistically significant), as shown in column 5. The logic is that specialized employers may use wages to labor hoard their employees and avoid them moving to sectors, which may be facing more prosperous times and could offer more attractive wages.

The results suggest that specialized firms may be less resilient to adverse shocks: they have a harder time to adjust, as reflected in their productivity[24]. Instead, their employees are preserved and are offered higher wages. Taken together, specialized firms seem to bear the brunt during downturns.

5 Labor Specialization After Labor Supply Shocks

5.1 Empirical Strategy

To explore other frictions related to the matching process, this study looks at exogenous idiosyncratic labor supply shocks. The empirical strategy evaluates the effects of the unexpected death of an employee, on firms that work at different levels of specialization.

Deaths happen in different years and the subscript j keeps track of which firm the death is assigned to. Potentially, specialized firms could be more concerned about finding another good job match (i.e. typically their search process is more involving in time and effort) given the degree of specificity of the required skills.

Firstly, the study concentrates on the replacement of a deceased employee. The basic specification is:

$$\begin{aligned} TTR_{jt} = \alpha + \beta Specialization_j + \omega Tnr_{jt} + \\ \phi(Specialization_j * Tnr_{jt}) + \upsilon X_{jt} + \varepsilon_{jt} \end{aligned} \tag{5}$$

[24]The findings look similar considering slowdowns in the whole economy. In this case, the downturn variable is computed as described above, but using the aggregated GDP (constant prices, national base year).

where TTR_{jt} is the time needed to replace the deceased and Tnr_{jt} is tenure as an additional regressor of interest. The focus is on the differential effect that this unexpected event has on specialized firms — or the causal effect of interest which is ϕ or the differential effect the deceased's tenure has on the span needed to replace a deceased employee — on top of being a specialized firm. X_{jt} represents a set of firm controls (size, industry, region, year).

This kind of firm-specific shock should not affect the labor market. Nevertheless, the replacement of the missing employee may be conditioned by the labor market availability. The second specification introduces the variable $Agglom_l$ that accounts for a greater pool of employees in the occupation of the deceased — within the local labor market. This is especially relevant because it allows disentangling whether specialized firms peremptorily replace a missing employee, when they have the opportunity to do it.

$$\begin{aligned} TTR_{jt} = \alpha + \beta Specialization_j + \omega Tnr_{jt} + \\ \phi(Specialization_j * Tnr_{jt}) + \psi(Specialization_j * Agglom_l) + \\ \gamma(Tnr_{jt} * Specialization_j * Agglom_l) + \upsilon X_{jt} + \varepsilon_{jt} \end{aligned} \tag{6}$$

To investigate the effects of the absence of the job matching, the empirical strategy evaluates the effects of the unexpected death of an employee on productivity and wages. The sample includes firms that experience the death of an employee and firms that do not suffer this shock at different points in time. The following difference-in-differences specification is implemented:

$$\begin{aligned} Y_{jt} = \alpha + \rho_j + \beta Specialization_j + \sum_{t=-3}^{5} \kappa_t DRDth_{jt} + \\ \sum_{t=-3}^{5} \delta_t (DRDth_{jt} * Specialization_j) + \upsilon X_{jt} + \varepsilon_{jt} \end{aligned} \tag{7}$$

where the dependent variable Y_{jt} are labor productivity and average wages[25] paid by firm j.

[25]These are wages paid to the deceased's coworkers after the death on an employee

The difference in firm's patterns predates the death and δ could be spurious. To capture differences in trends in the absence of a death effect, the study introduces firm fixed effect parameters ρ_j and includes covariates to control for other sources of omitted firm-specific trends at the firm level X_{jt} and at the individual level X_{it}, as described above. X_{jt} and X_{it} also include leads and lags, interactions of covariates and the death, as well as leads and lags of those interactions. In this case, the evidence of a death effect comes from the sharp deviation from otherwise smooth trends (i.e. even if those trends are not common).

5.2 Results

Table 3 shows that in this sample, firms that suffer the death of an employee tend to be different in several aspects to those that do not experience a death. The former firms are larger (i.e. larger firms have a higher probability to experience a death), their workforce is longer tenured (on average) and exhibit a higher level of net employment change.

Delving into the former firms, figure 3 compares the deceased and his coworker's characteristics. It illustrates that around the 80 percent of the dead employees have achieved at the most secondary education — with vocational qualification, and were working within non managerial or professional occupations[26], compared to around a 70 percent of the surviving deceased's coworkers. Figure 4 complements this characterization, showing that the vast majority of the deceased exhibits low propensity to change job or occupation[27]: they did it only once, at the time they died. These findings seem appealing and could indicate that the deceased in the sample would have developed some dexterity in their roles, at the time they died.

An important feature, is that the surviving employees may not be able to substitute the deceased in his role within specialized firms — given complementarities

[26]Most of the deceased employees were not covering managerial or supervising tasks (i.e. they were not decision makers). This suggests, that a decrease in labor productivity is probably due to the employee's absence from his role — rather than, for instance, due to changes in firm's strategy issued by the deceased's replacement.

[27]In this sample, neither lateral moves nor promotions appear relevant.

and low levels of communication between employees. As a result, we could expect that specialized firms should expedite the deceased's replacement[28]. Interestingly, the evidence suggests the opposite: there is no instantaneous job matching for specialized firms, as they spend more time to replace a deceased worker than their counterparts generalist firms, controlling for size, industry, region and year (i.e. in Table 5 columns 1 and 2, the specialization coefficients are positive and highly significant). Nevertheless, the time spent is substantially less (by around a third), while replacing a high-tenured employee: the differential effect on top of specialization is negative and highly significant (-0.697 and -0.661). Intuitively, there is more haste in finding a substitute of an employee who has matured experience within the firm, as shown in columns 3 and 4. Complementary the study looks at the effects a thicker or more agglomerated local labor market can have on the replacement of the deceased. The evidence from this sample is not quite conclusive, as the estimates are not statistically significant at any conventional level (column 5 and 6) . Columns 7 and 8 leverage the previous results and provide evidence combining the deceased's tenure and lthe abor market agglomeration. The coefficients of the triple interaction $Tnr_{jt} * Specialization_j * Agglom_l$ indicate that specialized firms spend less time replacing a high-tenured deceased employee, conditioned on the labor market agglomeration. This seems reasonable and supports the premise that specialized firms aim to replace a missing experienced employee shortly, if the labor market allows it.

The results from the econometric strategy suggested in equation (6) are presented in Figure 5 and Table 5. Columns 1, 2, 5 and 6 (Table 5) complement the previous results and present evidence regarding labor productivity. All regressions include firm fixed effect and a set of controls, as described above. The findings suggest that firms are not immediately hit by the death of an employee in terms of labor productivity (i.e. the effect in the first year is negligible and not statistically significant), but the effect arises in the second year after the death — for the sample of all firms, or in the third year after the death — for the subsample of small firms.

[28]Furthermore, if specialized firms behave as monopsonists, they could be already falling short of what would be hired in a perfectly competitive labor market, therefore $n-1$ employees could make the production process infeasible.

Considering the sample of all firms, the interaction term between the second and third year dummies and specialization are negative and around -0.06. The effect is substantially stronger (in absolute values) for the subsample of small firms: around -0.20 and -0.30 but at lower significance level. In both samples, the differential effect of being specialized eventually (from the fourth year in the aftermath of the death) becomes not statistically significant at any conventional level. There can be different explanations for becoming less productive, the simplest one suggests that, specialized firms rely on firm specific human capital and gets particularly hit by the loss of an employee.

Figure 5 shows the dynamics of the differential effect of specialization, on deceased's surviving coworker average wages. It documents that specialized firms decrease average wages — in the aftermath of the unexpected death of an employee, and confirms the sharp deviation from previous trends (i.e. the coefficients of the interaction between $Specialization$ and $DRDth_{jt}$ are statistically indistinguishable from zero). This effect is stronger even though less precise, for small specialized firms — as shown in the lower panel, presumably due to small employer's higher monopsony power. Columns 3, 4, 7 and 8 (Table 4) expand on the results presented in Figure 5, confirming that the coefficients of the interaction terms remain statistically significant for the first three years after the unexpected death of an employee. The main interpretation relates to the specialized firm's production function and the derived complementarities: specialized firms are hit and therefore lower the remaining employee's wages. An complementary explanation is that the deceased's coworkers accept the unfavorable conditions due to their dependence on the specialized employer (derived from the specificity of their human capital).

6 Conclusion

This paper empirically evaluated some frictions derived from labor specialization. The hypothesis was that a good match is particularly important for firms, which work under high levels of the division of labor and rely on firm specific human capital. The study suggested channels such as complementarities among employees

and low levels of substitutability, could underpin this hypothesis.

The first story looked at downturns. Specialized firms' strong dependence on employees, propelled them to preserve employees, even during slumps. The reasons revolved around developing employment relationships consolidated by specific skills, and pointed at frictions in the labor market. These decisions echoed in specialized firms' labor productivity: they appeared less productive than generalist firms during downturns. As a testimonial of labor hoarding, these firms ended increasing their employee's wages.

The second story, focused on exogenous labor supply shocks. The results suggested search frictions related to the replacement of a missing employee: consistent with the specificity of human capital, specialized firms took more time — compared to generalist firms. Instead, the replacement of high-tenured employees was faster, as far as the labor market allowed it. Additionally, specialized firms became less productive than their counterpart generalist firms, in the aftermath of the unexpected death of an employee. Regarding firm average wages, the evidence cast doubt on how much monopoly power employees possessed over their employers, given specialized employers decreased a deceased's coworkers' wage at a higher level than generalist employers. The effect was even higher within small firms, where specialized employers probably exercised more monopsonistic power.

Specialized employers appeared to rely on their employees more than generalist firms, fostering slow job reallocation. Given the employee-employer mutual dependence, a bilateral monopoly was plausibly in place, within specialized firms. The evidence suggested that these firm's bargaining power was limited (adverse demand shock), albeit providing a signal of some employer's monopsonistic power (adverse labor supply shock). All in all, specialized firms emerged as not quite resilient to adverse shocks.

References

Acemoglu, D. and J. S. Pischke. 1998. Why Do Firms Train: Theory and Evidence. *Quarterly Journal of Economics*, 113: 79-119.

Aghion, Philippe, Nicholas Bloom, Brian Lucking, Rafaella Sadun and John Van Reenen. 2017. Turbulence, Firm Decentralization and Growth in Bad Times. National Bureau of Economic Research, Working Paper 23354.

Ashenfelter, O.C., Henry Farber and Michael R. Ransom. 2010. Labor Market Monopsony. *Journal of Labor Economics*, 28: 203-210.

Autor, David and Michael J. Handel. 2013. Putting Tasks to the Test: Human Capital, Job Tasks, and Wages. *Journal of Labor Economics*, 31: S59-S96.

Azoulay, Pierre, Joshua S. Graff Zivin and Jialan Wang. 2010. Supestar Extinction. *The Quarterly Journal of Economics*, 125: 549-589.

Baumgardner, James R. 1988. The Division of Labor, Local Markets, and Worker Organization. *Journal of Political Economy*, 96: 509-527.

Becker, Gary S. 1962. Investment in Human Capital: A Theoretical Analysis. *Journal of Political Economy* 70: 9-49.

Becker, Gary S. and Kevin M. Murphy 1994. The Division of Labor, Coordination Costs, and Knowledge in Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education. *(Chicago: University of Chicago Press).*

Becker, Sascha and Hans K. Hvide. 2013. Do Entrepreneurs Matter? CESifo Working Paper Series 4088, CESifo Group Munich.

Bennedsen, M., K. M. Nielsen, F. Perez-Gonzales and D. Wolfenzon, 2007. Inside the Family Firm. the Role of Families in Succession Decisions and Performance. *Quarterly Journal of Economics*, 122: 647-691

Bernanke, Ben S. 1986. Employment, Hours, and Earnings in the Depression: An Analysis of Eight Manufacturing Industries. *The American Economic Review*, 76: 82-109.

Bernanke, Ben S. and Martin L. Parkinson. 1991. Procyclical Labor Productivity and Competing Theories of the Business Cycle: Some Evidence from Interwar U.S. Manufacturing Industries. *Journal of Political Economy*, 99: 439-459.

Burnside, Craig, Martin Eichenbaum and Sergio Rebelo. 1993. Labor Hoarding and the Business Cycle. *Journal of Political Economy*, 101: 245-273.

Caliendo, Lorenzo, Ferdinando Monte and Esteban Rossi-Hansberg. 2015. The Anatomy of French Production Hierarchies. *Journal of Political Economy*, 123: 809-852.

Dessein, Wouter and Tano Santos. 2006. Adaptive Organizations. *Journal of Political Economy*, 114: 956-995.

Dumais, Guy, Glenn Ellison and Edward L. Glaeser. 2002. Geographic Concentration as a Dynamic Process. *The Review of Economics and Statistics*, 84: 193-204.

Ellison, Glenn and Edward L. Glaeser. 1997. Geographic Concentration in U.S. Manufacturing Industries: A Dartboard Approach. *Journal of Political Economy*, 105: 889-927.

Fadlon, Itzik and Torben H. Nielsen. 2017. Family Labor Supply Responses to Severe Health Shocks. UC San Diego Working Paper.

Fair, Ray. 1985. Excess Labor and the Business Cycle. *The American Economic Review*, 75: 239-245.

Fay, Jon A. and James Medoff. 1985. Labor and Output Over the Business Cycle: Some Direct Evidence. *The American Economic Review*, 75: 638-655.

Fischer, Gabriele, Florian, Janik, Dana, Müller and Alexandra Schmucker. 2009. The IAB Establishment Panel Things Users Should Know. In: Schmollers Jahrbuch. Zeitschrift für Wirtschafts- und Sozialwissenschaften, Jg. 129, H. 1, S. 133-148.

Gathmann, Christina and Uta Schönberg. 2010. How General Is Human Capital? A Task-Based Approach. *Journal of Labor Economics*, 28: 1-49.

Glaeser, Edward L. 2007. Entrepreneurship and the City. *National Bureau of Economic Research* WP 13351.

Gibbons, Robert and Waldman Michael. 2004. Task-Specific Human Capital. *The American Economic Review*, 94: 203-207.

Hall, Robert E. 1988. The Relation between Price and Marginal Cost in U.S. Industry. *Journal of Political Economy*, 96: 921-947.

Heining, Jörg, Wolfram Klosterhuber and Stefan Seth. 2014. An Overview on the Linked Employer Employee Data of the Institute for Employment Research (IAB). In: Schmollers Jahrbuch. Zeitschrift fr Wirtschafts- und Sozialwissenschaften, Jg. 134, H. 1, S. 141-148.

Isen, Adam. 2013. Dying to Know: Are Workers Paid Their Marginal Product?. Working Paper.

Jäger, Simon. 2016. How Substitutable Are Workers? Evidence from Worker Deaths. MIT Working Paper.

Jaravel, Xavier, Neviana Petkova and Alex Bell. 2018. Team-Specific Capital and Innovation. *American Economic Review*, 108: 1034-1073.

Jones, Benjamin. 2005. The Burden of Knowledge and the 'Death of the Renaissance Man': Is Innovation Getting Harder? *Review of Economic Studies*, 76: 283-317.

Jones, Benjamin. 2014. The Knowledge Trap: Human Capital and Development Reconsidered. *Journal of Political Economy*, 96: 921-947.

Jones, Benjamin and Benjamin A. Olken. 2005. Do Leaders Matter? National Leadership and Growth since World War II. *Quarterly Journal of Economics*, 120: 835-864.

Klosterhuber, Wolfram, Jörg Heining and Stefan Seth. 2013. FDZ-Datenreport, 08/2013 (en). Linked-Employer-Employee-Data from the IAB: LIAB longitudinal model 1993-2010 (LIAB LM 9310).

Kremer, Michael. 1993. The O-Ring Theory of Economic Development. *The Quarterly Journal of Economics*, 108: 551-575.

Lazear, Edward P. 2005. Entrepreneurship. *Journal of Labor Economics*, 23: 649-680.

Lazear, Edward P. 2009. Firm-Specific Human Capital: A Skill-Weights Approach. *Journal of Political Economy*, 117: 914-940.

Manning, Alan. 2003. A Generalised Model of Monopsony. *The Economic Journal*, 116: 84-100.

Michaillat, Pascal. 2012. Do Matching Frictions Explain Unemployment? Not in Bad Times. *American Economic Review*, 102: 1721-1750.

Molina-Domene, Maria. 2018. Specialization Matters in the Firm Size Wage Gap. CEP Discussion Paper.

Mortensen, Dale and Christopher Pissarides. 1994. Job Creation and Job Destruction in the Theory of Unemployment. *Review of Economic Studies*, 61: 397-415.

Oettl, Alexander, 2012. Reconceptualizing Stars: Scientist Helpfulness and Peer Performance. *Management Science*, 58: 1122-1140.

Oi, Walter. 1983. The Fixed Employment Costs of Specialized Labor, in The Measurement of Labor Cost, ed. by Jack Triplett. Chicago: University of Chicago Press.

Pissarides, Christopher. 2011. Equilibrium in the Labor Market with Search Frictions. *American Economic Review*, 101: 1092-1105.

Rosen, Sherwin. 1978. Substitution and Division of Labour. *Economica*, 45: 235-250.

Roy, Andrew D. 1951. Some Thoughts on the Distribution of Earnings. *Oxford Economic Papers*, 3: 135-146.

Staiger, Douglas O., Joanne Spetz and Ciaran S. Phibbs. 2010. Is There Monopsony in the Labor Market? Evidence from a Natural Experiment. *Journal of Labor Economics*, 28: 211-236.

Sullivan Daniel. 1989. Monoposony Power in the Market for Nurses. *Journal of Law and Economics*, 32: S135-S178.

Wasmer Etienne. 2006. General versus Specific Skills in Labor Markets with Search Frictions and Firing Costs. *American Economic Review*, 96: 811-831.

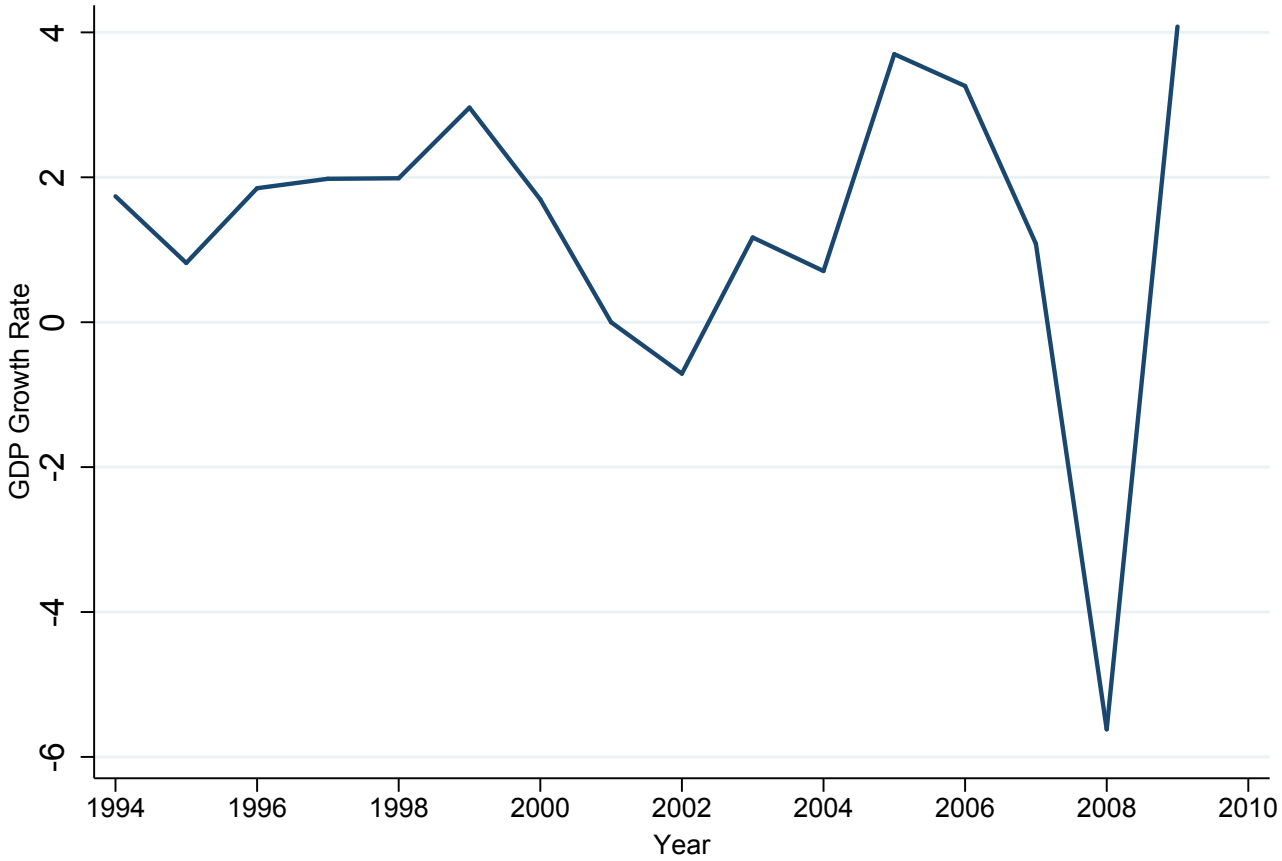
Tables and Figures

Table 1: Firm Characteristics by Different Levels of Specialization

	Low specialization			High specialization		
	Mean	St.Dev.	N Firms	Mean	St.Dev.	N Firms
Avg Ln Wage	3.90	0.69	29,774	4.07	0.52	54,728
Within firm wage dispersion	0.45	0.45	29,774	0.48	0.31	54,728
Business volume	11,700	159,000	27,863	33.900	625,000	50,338
Average number of employees	234.07	544.25	29,774	432.63	1,518.50	54,728
Net Change of Employment	-0.64	1.67	29,774	-4.55	46.50	54,728
Average Employee Age	38.29	7.79	29,774	40.94	5.66	54,728
Average Employee Tenure	1,791.62	1,389.71	29,774	2,573.66	1,575.68	54,728

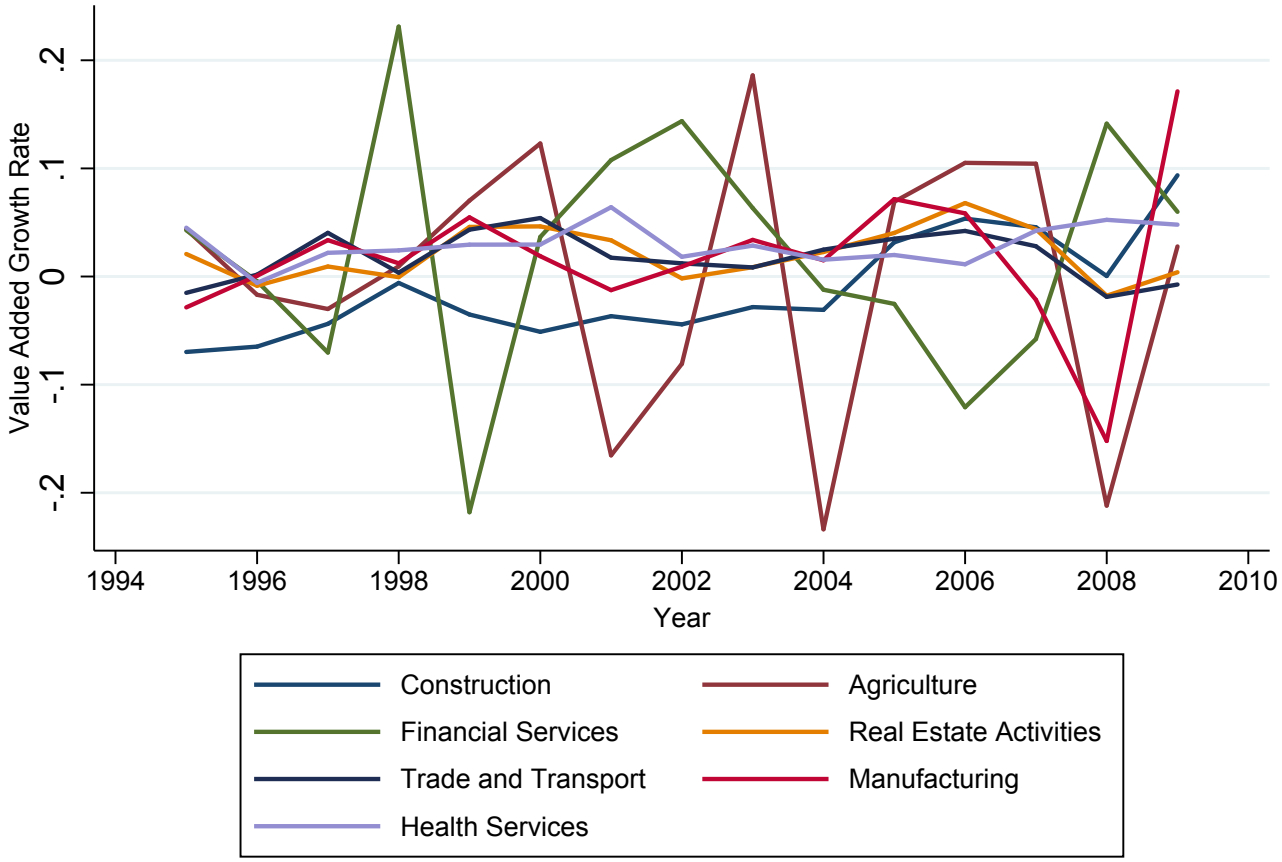
Note: Low specialization equals 1 if firm's EG is less than mean EG. High specialization equals 1 if firm's EG is more or equal than mean EG. Firm wage dispersion is the standard deviation of wages by firm and by year. Business volume is expressed in 10,000 euro. Average measures are computed by firm and by year. Tenure is computed in days.

Figure 1: German Gross Domestic Product - Growth Rate (1994-2009)



Source: Eurostat

Figure 2: German Industry Value Added - Growth Rate (1995-2010)



Source: Eurostat

Table 2: Regressions with a Demand Shock. Data from LIAB9310+Eurostat

	(1) Productivity	(2) Separ	(3) Separ	(4) Net Employ.	(5) Avg Wages
Downturn	0.028	-0.070	0.214**	-0.193	-0.024**
	(0.066)	(0.103)	(0.120)	(0.186)	(0.011)
Downturn x Special	-0.065*	0.003	0.013	0.079	0.017**
	(0.037)	(0.062)	(0.143)	(0.134)	(0.007))
Observations	32,103	48,456	48,456	48,456	61,947

Note: All dependent variables are midpoint changes. Col (1): change in productivity is the firm value added divided number of employees; col (2): annual change in hires; col (3): annual change in separations relative to employment; col (4): annual change in employment; col (5) annual change in the average of gross daily wages, paid by the establishment. The specialization proxy EG is the average level of specialization across years. Regressions in col (1) to (4) control for firm lagged size, year and interactions of covariates and the downturn dummy. Regression in col (5) control for firm size, year and interactions of covariates and the dummy. Grouped data regressions, weighted by firm. Fixed-effect estimates at the firm level. Standard errors clustered at the industry level, in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure 3: Summary Statistics of Deceased and Surviving Coworkers (in percentages)

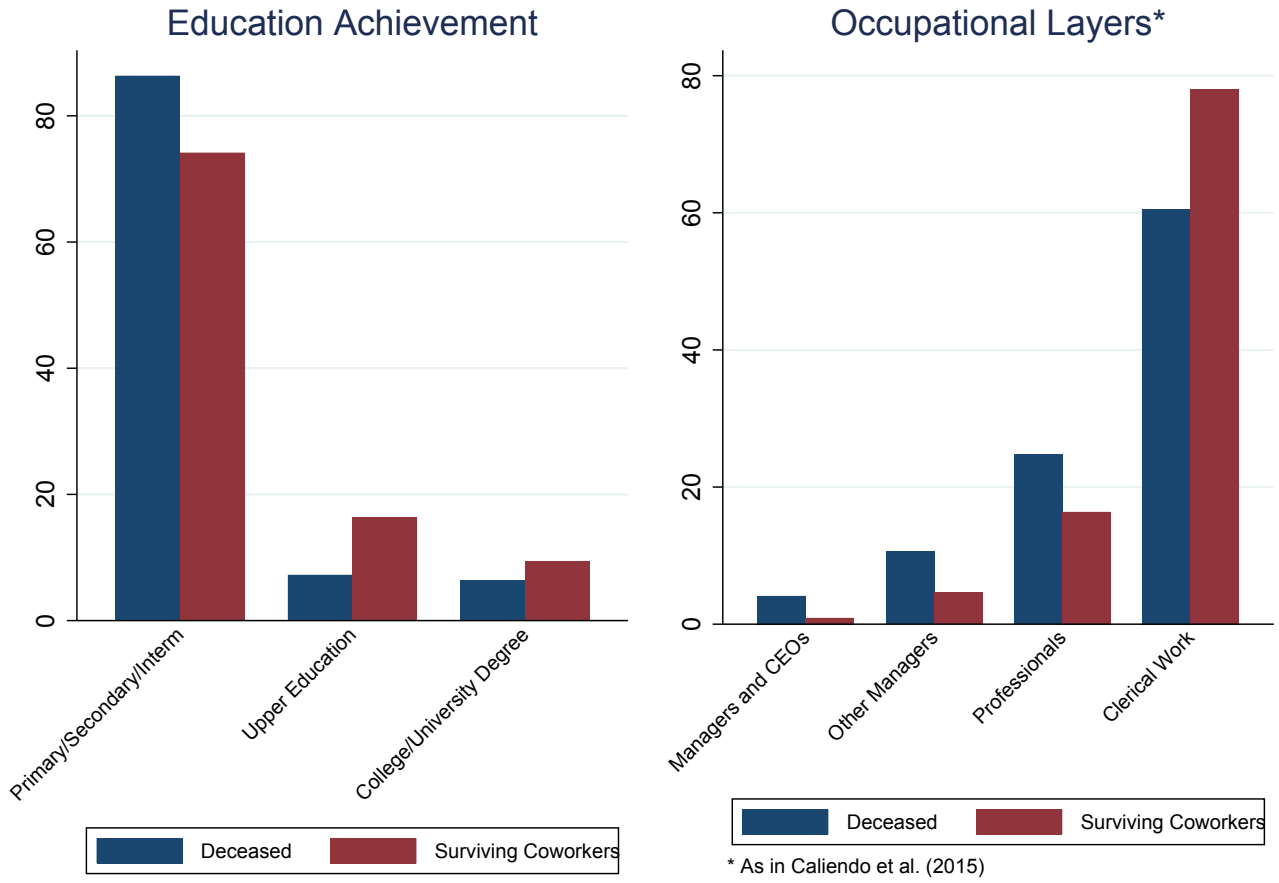


Figure 4: Summary Statistics of the Deceased and Surviving Coworkers (in percentages)

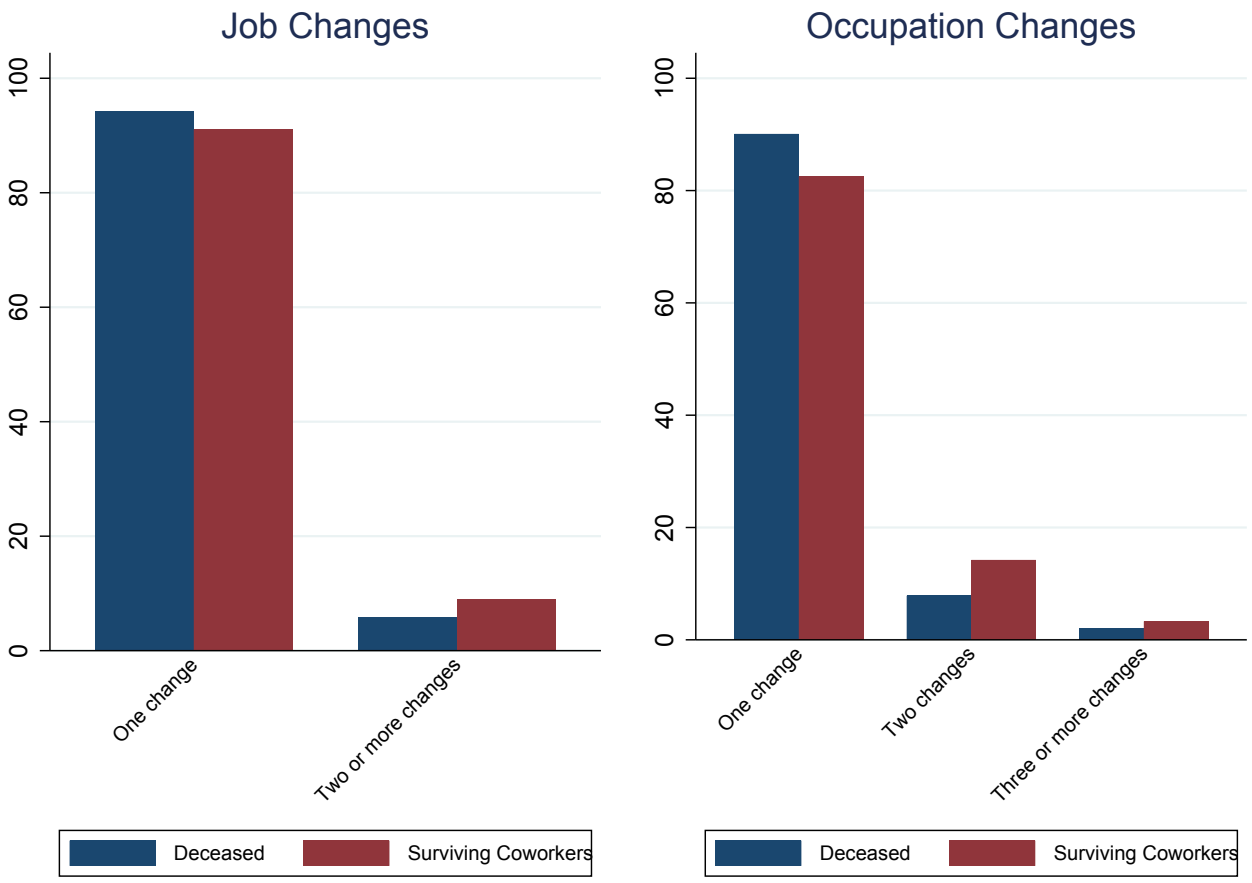
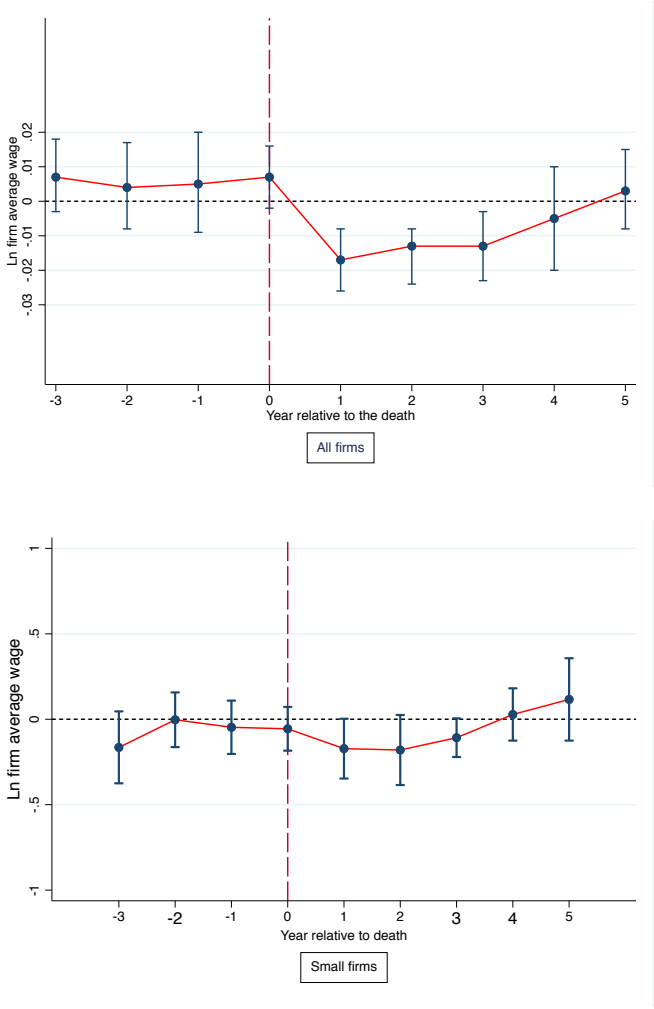


Table 3: Firm Characteristics for Firms With and Without a Death

Panel A: all firms	Without a Death			With a Death		
	Mean	Sd.Dev.	N Firms	Mean	Sd.Dev.	N Observations
Av Ln Wage	3.99	0.59	81,645	4.28	0.47	2,857
Avg Business Volume	24,400	506,000	75,612	72,800	628,000	2,589
Avg Size	339.10	1223.51	81,645	1,036.30	2,067.68	2,857
Annual Net Employm Change	-2.45	27.81	81,645	-23.86	137.84	2,857
Average Employee Tenure	2,253.78	1,529.59	81,645	3,564.94	1,814.66	2,857
Average Employee Age	39.91	6.67	81,645	42.76	3.84	2,857
Panel B: small firms						
	Mean	Sd.Dev.	N Firms	Mean	Sd.Dev.	N Observations
Av Ln Wage	3.61	0.66	16,999	3.70	0.74	46
Avg Business Volume	126.91	1,880.00	15,811	260.53	759.17	35
Avg Size	5.36	2.49	16,999	5.93	2.59	46
Annual Net Employm Change	-0.90	16.01	16,999	-27.5	127.33	46
Average Employee Tenure	2,462.35	1,648.91	16,999	2,629.63	1,793.01	46
Average Employee Age	41.68	7.72	16,999	45.23	6.20	46

Note: firms with a death are firms that experience the unexpected death of at least one employee. The sample excludes firms that experience the death of more than one employee within a calendar year. The number of observations refers to firms. Business volume in ten thousands and average tenure in days. The annual net change of employees is given by annual hires minus annual separations.

Figure 5: Differential Effect on Deceased's Coworkers Wage for Specialized Firms



Note: Regression coefficients and associated 95 percent confidence intervals of the differential effect of being a specialized firm (i.e. the interaction between the dummies DRDth and the specialization variable EG). Average wages grouped data regressions, weighted by firm. Fixed effect estimates at the firm level. Standard errors are clustered at the firm level.

Table 4: Deceased Replacement Regressions

	(1) TTR	(2) TTR	(3) TTR	(4) TTR	(5) TTR	(6) TTR	(7) TTR	(8) TTR
EG	1.934***	1.944***	1.969***	1.994***	1.957***	1.969***	1.984***	1.995***
	(0.408)	(0.410)	(0.438)	(0.431)	(0.413)	(0.413)	(0.430)	(0.432)
LnTenure			-1.129***	-1.070**			-1.154**	-1.133**
			(0.421)	(0.423)			(0.506)	(0.509)
EG X LnTenure			-0.697***	-0.661***			-0.631**	-0.613**
			(0.255)	(0.255)			(0.259)	(0.259)
LaborMktAgglom					-47.964	-51.923	69.924	72.678
					(36.822)	(36.498)	(59.870)	(60.071)
EG X LaborMktAgglom					-33.885	-36.333	60.915	64.110
					(22.799)	(22.475)	(46.505)	(46.621)
EG X LnTenure X LaborMktAgglom							-20.142*	-21.915*
							(11.146)	(11.060)
Surviving Employees Charact	No	Yes	No	Yes	No	Yes	No	Yes
No. of Observations	12,925	12,925	12,925	12,925	12,925	12,925	12,925	12,925

Note: TTR is the is the natural logarithm of the number of days requested to hire a new employee after facing the unexpected death of an employee. Grouped data regressions, weighted by firm.. They control for size, industry, region and year. Standard errors in parentheses are clustered at the firm level. Levels of significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 5: The effect of the death of an employee on labor productivity and average wage - Regression DD estimates

	All firms				Small firms (less than 10 employees)			
	(1) Ln Prod	(2) Ln Prod	(3) Ln AvgWage	(4) Ln AvgWage	(5) Ln Prod	(6) Ln Prod	(7) Ln AvgWage	(8) Ln AvgWage
YearOneDRDth X Special	0.000	0.002	-0.017***	-0.008*	-0.016	-0.005	-0.172*	0.166*
	(0.027)	(0.025)	(0.005)	(0.004)	(0.083)	(0.083)	(0.089)	(0.085)
YearTwoDRDth X Special	-0.070***	-0.063***	-0.016***	-0.009**	-0.129	-0.133	-0.180*	0.182*
	(0.026)	(0.025)	(0.004)	(0.004)	(0.107)	(0.110)	(0.105)	(0.104)
YearThreeDRDth X Special	-0.064*	-0.057*	-0.013**	-0.007	-0.348*	-0.370*	-0.108*	-0.114**
	(0.035)	(0.033)	(0.005)	(0.005)	(0.199)	(0.206)	(0.058)	(0.057)
YearFourDRDth X Special	0.006	0.009	-0.005	0.001	0.026	0.024	0.028	0.027
	(0.025)	(0.024)	(0.008)	(0.008)	(0.166)	(0.157)	(0.078)	(0.078)
YearFiveDRDth X Special	0.030	0.033*	0.003	0.008	0.074	0.086	0.116	0.114
	(0.019)	(0.020)	(0.006)	(0.005)	(0.104)	(0.105)	(0.122)	(0.124)
Leads and lags of Covar	No	Yes	No	Yes	No	Yes	No	Yes
No. of Observations	4,393,439	4,393,439	7,395,888	7,395,888	60,727	60,727	83,585	83,585

Note: Ln Prod is the natural logarithm of the value added divided by the number of employees working in a firm. AvgWage is the natural logarithm of the average gross daily wages (in euros) paid by a firm within a year. All regressions control for size (except productivity regressions that control for lagged size), level of education, age, age squared, occupational status, gender, industry, region and interactions of covariates and the TRDth dummies. Grouped data regressions, weighted by firm. Fixed effect estimates at the firm level. Standard errors in parentheses are clustered at the firm level. Levels of significance: *** p<0.01, ** p<0.05, * p<0.1.

Appendix: The Specialization Proxy

A dynamic version of the **Ellison and Glaeser Index** (1997) (Dumais et al., 2002) with LIAB LM9310 and LIAB LM9310 + IAB Panel data.
This index is corrected by the Herfindahl-style measure to account for the fact that the concentration of occupations should be larger in small firms. It compares the degree of concentration of occupations within an establishment to the concentration of occupation of other establishments within the same economic activity. The EG index is given by:

$$EG_{jt} = \frac{G_{jt}/(1 - \sum_s S_{st}^2) - H_{it}}{1 - H_{it}} \tag{8}$$

where:
N_{kjst} is the number of workers in occupation k working in establishment j, sector s, at time t.
N_{jst} is the total number of workers in establishment j, sector s, at time t.
$k = 1, ., K$ are the occupations described in Measure 1.
i=1,.,n indicate the different establishments.
$s = 1, ., m$ represent 3-digit industry according to the WS73 or Classification of Economic Activities for the Statistics of the Federal Employment Services (1973). Before 2003 the variable contains the original values and from 2003 this information is continued or recoded (if necessary). It includes primary economic activities, manufacturing, construction and services.
$t = 1, ., T$ are the different split episodes, which are non-overlapping periods.
S_{jst} is the establishment occupation share computed as N_{kjst}/N_{jst}.
S_{st} is the average of S_{jst} within each industry.
$G_{jt} = \sum_s (S_{jt} - S_{jt})^2$ is the sum of squared deviations of establishment occupation share S_{jst} from a measure S_{st} of the share of occupations within a specific industry.
$H_{it} = \sum_k b_{jt}^2)/(\sum_k (b_{jt})^2$ is a Herfindahl-style measure where b_{jt} is the number of occupations within an establishment at different split episodes.

CENTRE FOR ECONOMIC PERFORMANCE
Recent Discussion Papers

1579	Arturs Kalnins Stephen F. Lin Catherine Thomas	In-House and Arm's Length: Productivity Heterogeneity and Variation in Organizational Form
1578	Emanuel Ornelas Marcos Ritel	The Not-So-Generalized Effects of the Generalized System of Preferences
1577	Matthew Ridlay Camille Terrier	Fiscal and Education Spillovers from Charter School Expansion
1576	John Van Reenen	Increasing Differences Between Firms: Market Power and the Macro-Economy
1575	Margarida Madaleno Max Nathan Henry Overman Sevrin Waights	Incubators, Accelerators and Regional Economic Development
1574	Esteban M. Aucejo Patrick Coate Jane Cooley Fruehwirth, Sean Kelly Zachary Mozenter	Teacher Effectiveness and Classroom Composition
1573	Stephan Heblich Stephen J. Redding Daniel M. Sturm	The Making of the Modern Metropolis: Evidence from London
1572	Johannes Beohm Ezra Oberfield	Misallocation in the Market for Inputs: Enforcement and the Organization of Production
1571	Hans R. A. Koster Edward W. Pinchbeck	How do Households Value the Future? Evidence from Property Taxes

1570	Holger Breinlich Elsa Leromain Dennis Novy Thomas Sampson Ahmed Usman	The Economic Effects of Brexit – Evidence From the Stock Market
1569	J. Vernon Henderson Sebastian Kriticos Dzhamilya Nigmatulina	Measuring Urban Economic Density
1568	Philippe Bracke Silvana Tenreyro	History Dependence in the Housing Market
1567	Ester Faia Sebastien Laffitte Gianmarco Ottaviano	Foreign Expansion, Competition and Bank Risk
1566	Brian Bell Rui Costa Stephen Machin	Why Does Education Reduce Crime?
1565	Richard Murphy Felix Weinhardt Gill Wyness	Who Teaches the Teachers? A RCT of Peer-to-Peer Observation and Feedback in 181 Schools
1564	Paola Conconi Giovanni Facchini Max F. Steinhardt Maurizio Zanardi	The Political Economy of Trade and Migration: Evidence from the U.S. Congress
1563	Stephen Gibbons Stephan Heblich Ted Pinchbeck	The Spatial Impacts of a Massive Rail Disinvestment Program: The Beeching Axe

The Centre for Economic Performance Publications Unit
Tel: +44 (0)20 7955 7673 Email info@cep.lse.ac.uk
Website: http://cep.lse.ac.uk Twitter: @CEP_LSE