How productive is workplace health and safety?*

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Abstract

This paper investigates the causal impact of workplace health and safety practices on firm performance, using Danish longitudinal matched employer-employee data merged with unique cross-sectional representative firm survey data on work environment conditions. We estimate standard production functions, augmented with workplace environment indicators, addressing both time-invariant and time-varying potentially relevant unobservables in the production process. We find positive and large productivity effects of improved physical dimensions of the health and safety environment (specifically, "internal climate" and "monotonous repetitive work").

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I Introduction

The workplace environment has been central to labor policy debates in industrialized countries. For example, a 2001 European Commission report on employment lamented the status of working conditions in Europe, emphasizing direct and indirect large costs of occupation-related health risks and accidents, in the order of 2.6%- 4% of the EU member states' GNPs[1]. The estimated costs of job-related accidents and illnesses for the USA are equally large, cca. 3% of GNP, e.g., Leigh et al (1996).

Despite the policy interest motivated by such macro-level figures, there has been little concern with the micro-level picture, such as the employers' (dis)incentives for improving their workplace environment. For instance, there is almost no empirical research to date linking workplace environment quality to corporate performance. Our paper helps in filling this knowledge gap, by contributing to the evidence on the connection between a firm's work health and safety environment and its production organization. Expenditures by firms to enhance workplace conditions should be seen as investments in the economic sense, i.e. costs borne today in order to reap benefits in terms of higher profits tomorrow. Such investment decisions are therefore expected to be strategic; it is not *a priori* obvious which of several specific dimensions of the workplace environment should be targeted, and in what way altering them impacts firm productivity. One can envisage several channels through which good health and safety conditions at the workplace could be improving firm performance. For instance, employees would likely be more satisfied – and hence more productive, and less likely to separate from the firm; alternatively, a healthier work environment could lead to less absenteeism due to job-related illness and disease, which might again translate in better firm performance[2]. The empirical quest is to shed light on possible theoretical mechanisms, by investigating the *causal* productivity effects of changes in specific work environment health and safety indicators, and by quantifying their relative importance.

[1] Quoting from the report, "*Accidents at the workplace and occupational diseases remain a challenge to the EU economies, with direct and indirect costs due to work-related health risks and accidents at work estimated to amount to between 2.6% and 3.8% of GNP in the EU*".

[2] There is ample evidence that employee attitudes influenced by workplace organization can have significant effects on economic outcomes, e.g., Bartel et al (2003). Earlier research has also shown that individual bad health can result from exposure to poor work conditions, e.g., Fletcher et al. (2011) or Cottini and Lucifora (2013), and that this might affect both worker productivity and absenteeism rates, e.g. Ose (2005).

Among the few more directly related studies, an early paper connecting health and safety to productivity is by Gray (1987). He estimates the effect of governmental health and safety regulation on total factor productivity at industry level, and finds large negative productivity effects on regulated industries. That paper acknowledges that such an aggregate-level analysis has many caveats and that disaggregated microdata is highly desirable. A couple of other studies estimate the effect of pollution abatement expenditures on firm productivity, using establishment-level data. Gray and Shadbegian (1995) find that implementing abatement measures leads to significantly lower productivity levels; Porter and van der Linde (1995) obtain that environment regulations may induce firms to use alternative operational processes, ultimately enhancing productivity. Berman and Bui (2001) attribute such conflicting results to heterogeneity bias and measurement error in abatement costs, and conclude at their turn that pollution abatement can increase firm productivity. To the best of our knowledge, there have not been, however, any studies so far explicitly analyzing the impact of health and safety workplace practice on firm productivity in country-wide representative datasets, at firm (or establishment) level. Indirectly addressing our concerns are case studies such as Katz et al (1983), who analyze the relationship among economic performance and quality of working life programs among plants within General Motors, or Gittel et al (2004), who investigate the link between quality of labor relations, wages and firm performance in the airline industry. More generally, there is also a large literature focusing on the impact of industrial resource management systems on corporate performance, e.g., promoting advantages of using high involvement or high commitment human resource practices, see, e.g., Osterman (1994), Gittleman et al (1998). Empirical links between the use of such practices and overall firm-level performance have been documented at country or cross-industry level, e.g., Osterman (2000), Cappelli and Newmark (2001), Caroli and Van Reenen (2001), or for specific industries, e.g., Batt (1999), Ichiniowski et al (1997), Ichiniowski and Shaw (1998). Finally, worker data has also been used to study the relationship between new practices and worker safety and health, e.g., Brenner et al (2004), Askenazy and Caroli (2010).

The study by Black and Lynch (2001) is the most related to our paper in terms of methodology; they estimate a production function that incorporates variables reflecting work reorganization and firm specific aggregate employee characteristics, next to standard production inputs. In our paper, we adapt and enhance their method to investigate productivity effects of improvement in specific workplace environment health and safety indicators[3]. We make use of three separate datasets, uniquely merged through firm identifiers: we match detailed workplace health and safety environment quality indicators from a representative cross-sectional survey of establishments, to Danish longitudinal register linked-employer-employee data, and to the firms's business accounts. We estimate Cobb-Douglas production functions, augmented with specific workplace environment indicators, and firm and aggregate-employee characteristics. The longitudinal dimension of the register worker-firm data enables us to estimate these production functions in two stages: in the 1st stage, fixed firm effects (FE) or, respectively, system-generalized method of moments (GMM) panel-data regressions of output on classic production inputs, plus firm and aggregate-employees characteristics; in the 2nd stage, ordinary least squares (OLS) of the resulting mean residuals on the cross-sectional work environment indicators. This enables us to handle known biases due to unobserved time-invariant firm heterogeneity and simultaneity of classical inputs in the production function. In addition, a major advantage conveyed by our data is the observation of a large set of firm and employee characteristics over time. This allows us to account also for potentially relevant time-variant unobservables such as managerial input, by instrumenting for changes and lagged levels of the proportion of firm managers. Our main finding is that a few concrete, physical workplace health and safety environment dimensions– specifically having solved problems relating to "monotonous repetitive work" and "internal climate"– strongly and positively impact firm productivity. This conclusion is robust across our main empirical specifications and for alternative ways of constructing the workplace environment indicators from the initial categorical variables in the survey. The Danish work environment context and the data are described in Section II. Section III contains the core analysis on the causal impact of the workplace environment on firm productivity. Section IV discusses caveats and concludes.

[3]Zwick (2004) also adopts the empirical setup in Black and Lynch (2001) to study the productivity impact of shop-floor employee involvement, while Bockermann and Illmakunnas (2012) use a similar method for investigating job satisfaction effects on productivity.

II Danish work environment and data used

Danish workplace environment

Denmark tops OECD charts on job satisfaction of employees with their workplace conditions, and awareness and active interest among Danish workers concerning health and safety at the work environment is very high[4]. Denmark has also got a generous social safety net (and publicly funded, universal health care) and is arguably quite vulnerable to externalization of any costs of occupational-related risks or injuries from the employer to the society[5]. For instance, Dorman (2000) states that "*[i]ronically, countries with highly developed public welfare programs are more vulnerable to cost externalization, since these programs either pool risks (dissipating the risk to the individual enterprise) or transfer a portion of the burden to taxpayers. An example would be publicly funded health care systems, which absorb much of the cost of occupational accidents and diseases*". Finally, a huge deal of policy attention has been given to enhancing workplace conditions in Denmark. As an example, explicit targeting of improvement in both psycho-social and physical workplace conditions has been for long on the agenda of the Danish Ministry of Labor and the Danish Working Environment Authority. The public and policy awareness in workplace environment render Denmark almost ideal for the type of empirical analysis in this paper. For example, informational asymmetries on the part of employers and employees can be assumed largely absent in this context.

Data description

We use three distinct datasets, which we match based on the firm (i.e., business unit) identifier. The matching procedure and resulting data selection and structuring are described in

[4]For job satisfaction with workplace conditions, see the corresponding chart from an online statistics source on job quality of the "Canadian Policy Research Networks": www.jobquality.ca/indicators/international/satisfaction_main.shtml (no longer accessible on 1 July 2015, but archived here: http://archive-ca.com/page/349098/2012-10-01/http://www.jobquality.ca/fr/indicators/international/satisfaction_main.shtml). For cross-country awareness, see the summary of findings on the "European Survey of Enterprises on New and Emerging Risks", by the European Agency for Safety and Work; accessible at https://osha.europa.eu/en/publications/reports/en_esener1-summary.pdf (last accessed on 1 July 2015).

[5]We are not aware of attempts to decompose the burden of the job-related injury and disease costs on various societal agents for other countries than the USA, where Leigh et al (1996) estimate that, out of the approx. 3% of the GDP translated in such costs, 11% falls on the employer, 9% on the consumer and 80% on the worker.

detail in the Online Appendices (see Buhai et al (2015)), A.1 to A.3. Descriptive statistics of the variables used in the final, merged working dataset are presented below in Table 1. The first data source we use is the "Company Surveillance Data" (referred to as "VOV", its Danish acronym, throughout the rest of this paper), a 2001 survey on detailed workplace health and safety conditions, in a representative private sector sample of Danish establishments. The data cover information on subjective, both general and specific, workplace environment conditions, and on various practices undertaken within the work environment context. These answers are provided by an employee health and safety representative in each establishment[6] and have been collected by the *National Research Center for the Working Environment.* A similar workplace conditions survey, collected by the same research center, but representative at the individual rather than establishment level, has been used by Cottini et al (2011).

We create a first set of binary indicators for specific work environment problems as taking value 1 if a firm indicates that the "*majority*" of problems are solved, and value 0 if "*few*" or "*none*" problems are solved, where the three categories represent the full set of choices the respondents have to the survey question "*To what extent problems related to: heavy lifting/ monotonous repetitive work/ chemical loads/ noise causing deafness/ problems in connection with young people´s work/ mental stress/ internal climate/ risk of accident or accident, are solved?*"[7]. In Online Appendix A.5 we show that all results are virtually identical if we use a version with continuous, rather than dichotomized, work environment indicators[8].These

[6] As detailed in Online Appendix A.1, we have two independent measures for each work environment indicator, given that both a health and safety representative *from the side of the employees*, and one *from the employers*, completed the survey. Analogous to Bloom and van Reenen (2006), the two measures have a high correlation, suggesting little bias in individual answers. The reported analysis uses the answers of the employees' representatives, but results do not change qualitatively if we use the other measure.

[7] Note that we do not know *when* such problems have beeen solved. Remark also that, given this question's design, respondents who *did not experience problems* would fill in "*majority of problems are solved*". First, this is not necessarily a concern for our analysis since "problem solved" is equivalent for our purpose to "made sure to avoid problem"– i.e., a cost was incurred to *avoid that specific problem from happening.* Otherwise said, an additional category entitled "did not experience that problem" would not necessarily help, since it would, wrongly, gather also firms who incurred costs to avoid that problem from the start. Second, this might not be *a practical concern* in our context anyway, given there is substantial variance in the respondents' answers for all specific work environment indicators, which is true even for firms within industries atypical from the perspective of the incidence of particular workplace environment problems.

[8] The practice in the literature is to dichotomize categorical variables in survey contexts like ours; there are few exceptions, e.g., Muñoz de Bustillo et al (2011), Eurofond (2012), or Leschke and Watt (2014). In Online Appendix A.5 we provide full descriptive and estimation results for an alternative analysis where, following these studies, we transform our multi-categorical work environment variables in continuous indicators normalized on [0,1], assuming equal weights for each category.

health and safety dimensions fully cover the "vision areas" of work environment quality envisaged by the Danish Work Environment Authority and they are all well known to the survey respondents. The question has been designed by the National Research Center for the Working Environment in accordance with these vision areas, such that each categorical variables codifying answers corresponds directly to a specific work environment area of interest[9]. A second set of variables we also use describe various other practices undertaken at the firm related to the work environment, such as: "*Does the company have a written work environment policy? yes/ no/ don´t know*"; "*Has the company/ workplace held courses, project days, seminars or similar events for its employees where the work environment has to a greater or lesser extent been included as a subject? yes/ number of events in the last year/ no/ don´t know*"; "*Have you drawn up action plans to solve the work environment problems? yes/ no/don´t know*" and respectively "*Have you prioritised the work environment problems that are to be solved? yes/ no/ don´t know*". For each of these variables we construct binary indicators taking value 1 if the answer is "*yes*" and 0 otherwise.

Although VOV is collected at the establishment level, we can link it to the firm business accounts only via the firm identifier, which means that we need to limit our empirical analysis to firms with a single establishment[10]. In our Online Appendices, see Tables A.2 and A.3, we show that the industry and geographic distribution of the firms with a single plant remains very similar to that in the initial dataset, alleviating possible external validity concerns. Table 1 below contains summary statistics on our working sample of firms, with summary statistics for the variables from VOV in the upper horizontal panel.

[9]Among the mentioned indicators that might not be immediately familiar to all readers, "*mental stress*" refers to psycho-social type of risks such as excessive time pressue, lack of influence in decisions, perceived violent/uncooperative environment; "*internal climate*" subsumes conditions related to workplace temperature fluctuations, lack of ventilation, humidity, etc; "*problems in connection with young people's work*" refers to work environment risks faced by the young employees. As stated earlier, all indicators are well known in work environment evaluation contexts, and in this case the Danish original names have been translated by professionals from the *National Research Center for the Working Environment* to their widely-used English equivalents; for instance "*monotonous repetitive work*" is the international correspondent of the Danish "*ensidigt gentaget arbejde*" (EPA): http://www.leksikon.org/art.php?n=692 (last accessed at July 1st, 2015). See also a short summary in English of a 2002 Danish Work Environment Authority Report mentioning, i.a., the seven "vision areas"(last accessed 1 July 2015): http://www.eurofound.europa.eu/observatories/eurwork/articles/fewer-work-accidents-but-increasing-proportion-of-repetitive-strain-injuries.

[10]Using single-plant firms is not unusual; on the contrary, this is the established practice when estimating production functions using data originating from both firm (typically, all business account data) and establishment level, see, for instance, Carlsson and Skans (2012).

Table 1: Descriptive statistics VOV, IDA and REGNSKAB, for year 2001

variable	definition	mean	s.d.	N
	VOV			
general work environment	work environment is 5=very good, 4=good, 3=not bad, 2=bad, 1=very bad	3.86	.68	449
heavy lift	1 if problems related to heavy lifting are solved, 0 otherwise	.76	.43	448
monotonous repetitive work	1 if problems related to monotonous repetitive work are solved, 0 otherwise	.78	.41	442
chemical loads	1 if problems related to chemical loads are solved, 0 otherwise	.88	.33	441
noise	1 if problems related to noise causing deafness are solved, 0 otherwise	.77	.42	444
problems with young workers	1 if problems related to young people's work are solved, 0 otherwise	.94	.24	436
mental stress	1 if problems related to psychological conditions/mental stress are solved, 0 otherwise	.78	.41	439
internal climate	1 if problems related to internal climate are solved, 0 otherwise	.71	.45	441
accidents	1 if problems related to accidents or danger of accidents are solved, 0 otherwise	.80	.40	441
courses	1 if courses with general work environment content have been held at the firm, 0 otherwise	.24	.43	426
written policy	1 if the firm has a Written Work Environment Policy, 0 otherwise	.32	.46	363
action plans on work env.	1 if action plans have been drawn up to solve the work environment problems, 0 otherwise	.57	.49	437
prioritise work environment	1 if work environment problems have been prioritised to be solved, 0 otherwise	.68	.47	441
	IDA			
proportion female	women as a proportion of all employees	.25	.26	572
proportion unskilled	unskilled as a proportion of all employees	.10	.19	572
proportion turnover	employees with tenure less than two years as a proportion of all employees	.21	.22	572
proportion managers	managers as a proportion of all employees	.078	.15	572
average education	average years of education among all employees	12.22	1.58	572
firm size	number of employees in the firm	49.37	96.09	572
age of firm	age of the firm	12.05	9.38	572
average wage	mean wage in the firm	171.48	35.7	565
	REGNSKAB			
capital		15780.5	42698.6	465
sales		72639.3	190177	465
materials		54673.6	170577.6	465

The second dataset is the "Integrated Database for Labor Market Research" ("IDA" henceforth), constructed by *Statistics Denmark* from data registers used for the production of official EU and Danish aggregate statistics. This dataset has been described in detail in earlier publications, e.g., Buhai et al (2014). IDA allows for matching of workers at establishments (local entities) and of establishments to firms (legal entities). It tracks every work establishment, and every Danish resident between 15 and 74 years old. IDA is collected as of 1980 and includes detailed individual demographics such as gender, age, level of education, labor market state, experience, earnings, etc. The labor market status of each person is recorded in November each year. On the firm side, we have information on plant and firm employment size, region of firm, location, industry, and we can construct a lower bound for the firm age. We further use the IDA individual information for constructing employee aggregates at the firm level, such as proportion of certain employee groups (i.e. proportion of females, unskilled workers, managers), mean and variance of years of education, and mean and variance of wages.

Finally, we make use of a third data source, on the firms' financial accounts. The "statistics of business accounts" (REGNSKAB henceforth), see, e.g, Bagger et al (2014a) for a detailed description, is compiled by Statistics Denmark and it covers construction and retail trade from 1994; manufacturing from 1995, wholesale trade from 1998, and the remaining part of the service industries from 1999. These registers have data on items of the annual accounts of business enterprises, notably items of the profit and loss account, the balance sheet and the statement of fixed assets. Here, we are specifically interested in the reported values for sales, capital stock and intermediate inputs (materials). There are several ways through which the REGNSKAB data are gathered, and not all have the same reliability. We use only directly surveyed firms, and firms where information has been obtained from tax forms, implying some data loss when merging to other datasets. Online Appendix A.3 gives a full overview of the data loss due to the merger steps. For means and standard deviations of the variables of interest in the merged working dataset see the lower panel in the summary statistics Table 1.

In Online Appendix A.4 we perform a purely descriptive analysis of the between-firm work environment differentials, in order to have an idea of the observed firm and employee aggregate characteristics that correlate with different reported work health and safety environments. The conclusions are that the proportion of managers at the firm, followed by offering worker training courses related to the work environment, are the only attributes that strongly correlate with most specific measures of a good workplace environment. To less extent, the proportion of females within the firm, and prioritizing work environment practice in the firm also seem to explain across-firm differences in some of the work environment dimensions. Our descriptives might suggest a beneficial effect of both managerial involvement (proportion of managers) and employee awareness in workplace environment quality improvement[11].

Having described the data, we stress that the *objective* variables of interest in the two (independent) register datasets, IDA and REGNSKAB, are completely different in terms of collection method, timing and source, than the *subjective* workplace indicators contained in the VOV survey data. This represents a data bonus vis-à-vis much of the literature hitherto, which used subjective measures on both dependent and independent variables, typically gathered at the same time, from the same questionnaire respondents.

III Impact of work environment on firm productivity

The core of this study consists in investigating the causal role of the workplace's health and safety environment in enhancing total factor productivity. We estimate standard Cobb-Douglas production functions, augmented with the firm specific workplace environment indicators used as dependent variables in the binary outcome regressions from the previous section, and with firm and aggregate-employee characteristics. Although the VOV dataset is cross-sectional, we are able to make use of the longitudinal information from the IDA and REGNSKAB datasets. Our analysis extends the two-step empirical strategy by Black and Lynch (2001) in several ways. We start by presenting in detail our empirical models,

[11] These two factors could well be complementary within a firm, e.g., Kato and Morishima (2002): they provide evidence on the association between top-level management and shop-floor employee participation in workplace organization decisions.

reserving an in-depth discussion of our estimation results for the second part of this section[12].

Empirical specifications

The baseline specification is to use only the 2001 cross-sectional sample with all merged variables, i.e. estimating the following OLS regression:

$$\ln(Y/L)_i = c + \alpha \ln(K/L)_i + \beta \ln(M/L) + \delta X_i + \gamma' Z_i + \varepsilon_i \tag{1}$$

with c a constant term, Y/L sales per employee, K/L capital per employee, M/L intermediate inputs (materials) per employee, vector X containing the firm and firm specific aggregate-employees characteristics, and vector Z containing our establishment-specific workplace indicators and practices. We use the capital and material inputs per employee, as we have verified that the constant returns to scale restriction is not at odds with the data.[13] We use the stock value of capital K and intermediate materials M, reported in REGNSKAB[14]. The results of the estimation above are reported in column (1) of Table 2. The estimation controls, in addition to the reported covariates, for region, industry, and age category of the firms. No work environment indicator is found to be statistically significant in this preliminary, single-stage cross-sectional OLS analysis[15].

Since our cross-sectional estimates from (1) may be subject to endogeneity due to unobserved heterogeneity in the firm characteristics, captured above by the error term ε_i, we further exploit the fact that in IDA and REGNSKAB we observe several firm employee-aggregate characteristics over time, to address potential unobserved *time-invariant* hetero-

[12] As noted earlier, all our analysis is robust to changing the way the work environment indicators are constructed. Online Appendix A.5 shows that all our results presented in this section are virtually identical if continuous indicators are used instead of the dichotomized ones. See also footnote 8.

[13] Allowing L as separate input in the production function does not change any of our qualitative implications. Since we do not have information on "production" and "non-production" workers, we also do not make further distinctions among the labor inputs.

[14] K is computed by adding the intangible and tangible fixed assets; using the book value of fixed assets or computing the capital stock using the perpetual inventory approach gives identical results; this is consistent with findings in previous papers using this data, e.g., Bagger et al (2014a); M is calculated as sales minus value added, using the official value added formula applied by Statistics Denmark in the production of official statistics; for a detailed description in English of this value added computation formula, see Bagger et al (2014b), page 6.

[15] Since the "general work environment indicator" is not found statistically significant in any of our estimations, we omit it below, reporting estimates for specific workplace indicators only.

geneous effects. We do so by estimating a first stage firm fixed effect (FE) specification for the production function. We then use the *residual from the first stage, averaged over time* (i.e. the time-invariant component of the residual), as dependent variable, in a second stage OLS regression on the 2001 cross-section of work environment indicators[16]. The empirical specification in this case is given by

$$\widetilde{\ln(Y/L)}_{it} = a\widetilde{\ln(K/L)}_{it} + b\widetilde{\ln(M/L)}_{it} + c\widetilde{X}_{it} + \widetilde{\nu}_{it} \text{ (step 1)} \tag{2}$$

$$R_i = d + e'Z_i + \xi_i \text{ (step 2)}$$

where R_i is the (time) average of $R_{it} \equiv \widetilde{\ln(Y/L)}_{it} - \widehat{a}\widetilde{\ln(K/L)}_{it} - \widehat{b}\ln\widetilde{(M/L)}_{it} - \widehat{c}\widetilde{X}_{it}$

The upper tilde denotes deviations from the means over time. ν_{it} and ξ_i are white noise disturbance terms, and d is a constant term. Vector X contains firm and aggregate-employee features observed over time, including region, industry, and firm age. In addition, we also include in X interactions between the cross-sectional years and industry dummies, in order to capture eventual industry-specific productivity shocks. Z is defined as in (1) above.

We differ in our empirical modeling here from Black and Lynch (2001) in that we also observe time-varying firm and firm-specific aggregate employee characteristics– and not only standard production inputs– and thus can use that variation in the 1st stage regression. The values for sales, capital and materials are deflated using the net price index provided by Statistics Denmark, with 2000 as base year. We report results using years $\overline{1998, 2001}$, but results do not change at all if we use an even longer time span[17]. The results are presented in column (2) of Table 2. Since we use an estimated dependent variable, R_i, in the step 2 OLS regression of (2), we report White heteroskedastic-robust standard errors.

Although the specification from (2) above would take care of any time-invariant firm

[16] In the 1st stage we have the option of using all available observations (including observations for establishments with missing values on certain work environment indicators in 2001) or just observations from the establishments used in the second stage. Results are virtually identical under either alternative; we report 1st stage results for the larger sample.

[17] The earliest cross-section available in REGNSKAB is 1994, but manufacturing is not covered till 1995, and other sectors not covered till 1998. Hence, there are far fewer observations for firms present both in the 2001 VOV cross-section and in the early REGNSKAB cross-sections.

effects correlated with the choice of inputs in the first stage, the typical simultaneity problem in choosing the production inputs or the potential measurement error in the explanatory variables (capital and materials) has not yet been dealt with. The pitfall in production function estimation, known since Marschak and Andrews (1944), is the endogeneity of input choices in the production function, given their likely correlation to unobserved productivity shocks, e.g., Griliches and Mairesse (1998). We exploit the fact that we can observe most of the variables (except the VOV ones) over time, to apply a system-GMM estimation à la Arellano and Bover (1995) and Blundell and Bond (1998, 2000) in the 1st stage, and to subsequently use the *time-averaged first stage residuals as dependent variable in a 2nd stage*, as an OLS on vector Z, containing work environment health and safety indicators. This is the same 1st stage estimation from expression (2), but *in levels* (notation-wise, eliminate the upper tildes), by using appropriately lagged values of both levels and changes in capital, material, and labor, as instruments for levels of capital, material and labor respectively. Furthermore, as enhancement relative to Black and Lynch (2001), given that the *proportion of managers* is strongly correlated in the data with improved work environment quality for most indicators, we also instrument with lagged levels and changes of this variable. Hence, we are able to proxy for a (type of) time-varying managerial input, which might otherwise remain endogenously correlated with the work environment indicators in the final stage of the estimation procedure. As in the case of the 2nd step estimates of column (2), we compute White heteroskedastic-consistent standard errors for step-2 estimates. Prior to the estimation, we check that the conditions for applying the system-GMM are in place: the validity of our instruments and, respectively, the assumption of no serial correlation in the levels of the error term ν_{it}. The estimates are reported in the third column of Table 2, using again time lags down to 1998 in the first step; as earlier in the case of the FE estimation, we check that results do not change if we expand or narrow the time interval in the first step estimation. According to the Sargan-Hansen test for overidentifying restrictions, we cannot reject the validity of our instruments at conventional statistical levels. We also cannot reject the null hypothesis of no serial correlation in ν_{it}. Since the reported LM tests are performed for differenced residuals $\Delta\nu_{it}$, see Arellano and Bond (1991), we are interested in confirming the absence of the second order serial correlation, whereas the negative first-order serial correlation obtained is consistent with our specification, see also Dearden et al (2006).

Table 2: Augmented production functions

	OLS 2001	2-stage FE+OLS	2-stage GMM+OLS
	(1)	(2)	(3)
		1^{st} stage	
K/L	.034*	.048***	.060**
	(.017)	(.011)	(.027)
M/L	.671***	.751***	.745***
	(.026)	(.022)	(.061)
proportion female	.002	-.053	-.053
	(.106)	(.053)	(.053)
proportion unskilled	-.262**	-.022	-.013
	(.111)	(.033)	(.036)
proportion turnover	-.138	-.082***	-.096***
	(.130)	(.021)	(.035)
proportion managers	.329	.017	.127
	(.217)	(.075)	(.187)
average education	.002	-.006	.003
	(.016)	(.006)	(.008)
Nobs 1^{st}stage		1627	1627
Sargan			χ^2(15)=19.40 (p-value=0.20)
LM 1^{st} order serial corr			z=-3.65 (p-value=0.00)
LM 2^{nd} order serial corr			z=-0.30 (p-value=0.77)
		2^{nd} stage	
courses	.044	.043	.040
	(.035)	(.034)	(.034)
written policy	.021	.018	.011
	(.031)	(.030)	(.029)
action plans on work env.	.004	-.0006	.022
	(.047)	(.048)	(.046)
prioritise work environment	-.030	-.028	-.029
	(.046)	(.047)	(.046)
heavy lift	-.021	-.035	-.041
	(.044)	(.044)	(.044)
monotonous repetitive work	.070	.094**	.092**
	(.045)	(.042)	(.042)
chemical loads	.074	.058	.059
	(.073)	(.063)	(.063)
noise	-.008	.010	.006
	(.035)	(.031)	(.030)
problems with young workers	-.022	-.043	-.043
	(.047)	(.041)	(.040)
mental stress	-.025	-.013	-.012
	(.036)	(.037)	(.035)
internal climate	.041	.074**	.080**
	(.037)	(.031)	(.031)
accidents	.011	-.008	-.015
	(.036)	(.031)	(.030)
R^2	0.920	0.225	0.242
Nobs	215	215	215

Significance levels: *** 1%,**5%, *10%; White heteroskedastic-consistent standard errors in parentheses. Estimations also include a constant term, regional, industry, and firm age category indicators. For the 1st stage FE and GMM regressions in columns (2) and (3), we also control for the interaction between years and industry indicators. The reported GMM here instruments appropriately for K, M, L, and the proportion of managers (there are no qualitative differences with the case where proportion of managers is not instrumented for). Sargan is a χ^2 test of overindentifying restrictions; LM is a Lagrange Multiplier test of 1^{st} and respectively 2^{nd} order serial correlation in Δv_{it}, distributed N[1,0] under the null; p-values for the significance test of the null hypotheses are reported in parentheses, after the test coefficients

Discussion and interpretation of the estimation results

Intuitively, the causal effect of interest in our main estimation strategies from columns (2) and (3) is identified from the cross-sectional variation in the *time-averaged production function residual purged of time-invariant and some time-varying possibly confounding effects* in the 1st estimation steps (FE or respectively system-GMM), which is explained by our work environment indicators in the 2nd estimation steps (OLS). While, in theory, we inherit some of the potential remaining biases from Black and Lynch (2001), we are able to do considerably more to alleviate them, as explained above. The results reported in the estimates Table 2 are largely consistent with the findings in Black and Lynch (2001), or Zwick (2004). For instance, our point estimate for K/L increases from the first column (simple OLS) to the third column (OLS+ system GMM) [18]. There are some differences between the estimation results reported in column (1) and the ones in column (2) and (3): both "proportion of unskilled" and "proportion of managers" lose their statistical significance from the OLS estimation once we account for unobserved time-invariant firm heterogeneity, or some types of time-varying unobserved heterogeneity in the FE and GMM estimations. This suggests that both these aggregate-employee characteristics are to some extent time-invariant within-firms and thus that most of their sample variance is between-firms[19]. In fact, as earlier found, only the "proportion of turnover employees" is statistically significant, and of expected sign, among all aggregate-employee characteristics, in our two main specifications[20]; also, in line with Black and Lynch (2001), most results concerning the effect of aggregate-employee characteristics are qualitatively and quantitatively robust under FE and system-GMM. Remark finally that whether or not we instrument the proportion of managers GMM-style - the estimates in Table 2, column (3) are reported for the case where the proportion of managers is instrumented-

[18] Our point estimate for K/L is on the low end of what is found in the literature; there are however studies that have found even lower capital intensities in augmented production frameworks, using similar system-GMM techniques, e.g., Zwick (2004).

[19] Unlike the proportion for unskilled, the estimated coefficient magnitude for the proportion of managers is much larger under column (3) than under column (2), though the estimated variance is also very large, rendering the effect still statistically insignificant. The large estimated magnitudes are because we also instrument proportion of managers in the system-GMM specification, as earlier explained.

[20] We have employed a host of other empirical specifications including several other firm specific aggregate-employee characteristics, e.g., first and second moments of the distribution of education, experience, tenure, or age within the whole firm or within particular subgroups (managers, skilled workers), etc. None matters for productivity.

does not matter; hence, managerial input (at least as proxied by the proportion of managers over time, as here) does not appear to directly impact firm productivity, even though it is strongly associated, in a statistical sense, to improved work environment in several specific dimensions. So how productive is workplace health and safety environment, our main question of interest? In both our FE and system-GMM specifications, the only work environment indicators found statistically significant are having solved *internal climate* problems and respectively having solved problems concerning *monotonous repetitive work*, both with large marginal productivity contributions relative to any other "non-standard" inputs in the production function [21]. Since there is no literature precedent in terms of productivity effects of work environment dimensions, we relate our estimates to the productivity of standard production inputs; Table 2 suggests that these effects are of comparable magnitude to the marginal productivity of capital per employee– hence, by no means negligible.

IV Concluding remarks

Ours is the first economics study investigating the causal impact of workplace environment health and safety quality on firm total factor productivity. We use firm, worker, and workplace environment data from three distinct Danish sources, merged on firm identifiers. We estimate Cobb-Douglas production functions augmented with specific workplace health and safety indicators, and with appropriate firm and aggregate-employee characteristics. As least squares estimates of such production functions are known to be potentially biased due to endogeneity and simultaneity of production inputs and output, we implement appropriate estimation methods to tackle these econometric problems in our context. These consist in applying fixed firm effects and respectively GMM system estimation in a first production function estimation stage on longitudinal data, and OLS of first stage residuals on the cross-sectional specific work environment indicators, in a second stage. Our findings are robust across these specifications: the workplace environment factors that contribute to enhancing

[21] These two work environment indicators are estimated with similar coefficient magnitudes also in the single stage OLS from column (1), but are not statistically significant at conventional statistical significance levels ("monotonous repetitive work" is significant also in the OLS when we use continuous rather than binary indicators, see Online Appendix A.5). Indicators such as chemical loads have also relatively high estimated magnitudes, but their variance is consistently estimated as very high.

firm productivity are having solved problems related to "internal climate" and respectively, to "monotonous repetitive work", both with large positive marginal contributions to firm productivity. From our set of work environment indicators, nothing else matters for firm performance. The fact that improvement in two directly experienced physical health and safety dimensions at the workplace has such an important effect on firm productivity might suggest that the nature of the causal mechanism channel has to do with making workers directly more productive– potentially via increased ability to accomplish tasks, motivation, and satisfaction.

Firms not implementing certain work environment health and safety quality improvements must have different expected costs associated with enacting such changes compared to firms that do, costs that are not observed in the data. Some time-varying unobserved heterogeneity correlated both with firm profitability and work environment quality could therefore, in theory, still bias our final estimates. However, in practice it is challenging to point out sources for further omitted variable bias. We adapt the careful methodology by Black and Lynch (2001), in addition exploiting, in the first stages of our estimation alternatives, the fact that we observe a large host of employer and employee characteristics over time. In particular, in our system GMM estimation procedure, we are able to control for the potential endogeneity of the firm specific aggregate-employee feature having the largest explanatory power in the between-firm work environment quality differential, i.e., the proportion of managers at the firm. This is somewhat akin to proxying for unobserved, time-varying, general managerial ability/inputs at the firm level. Our results are robust across our main specifications.

Given the nature of our data sources and their merger, we need to limit the working sample to the firms with a single establishment. Although this implies some caution about validity of the results extrapolated to the initial sample, in Denmark the mono-plant firms are to a large extent representative both region- and industry-wise. Moreover, studies estimating production functions using firm business data and establishment-level (aggregate) characteristics typically use only the subsample of single establishment firms. Another potential caveat concerns validity of our results outside the Danish context: as documented in the paper, both awareness about and reported satisfaction with workplace conditions in Denmark are very high. In other words, variation in work environment quality might be relatively low compared to other countries. Comparative empirical studies on representative firm/ establishment samples in other countries would be informative on this issue. A final possible limitation comes in the form of the relatively low sample size of our final working dataset, which is an unavoidable consequence of data loss during the matching procedure. However, note that we found no estimates that are only borderline statistically (in)significant, at conventional statistical significance levels: what matters, matters a lot. The caveats on external validity notwithstanding, our study can be interpreted as showing, for the first time at disaggregate, firm/ establishment level, that improving specific, physical, health and safety workplace quality indicators might considerably enhance firm productivity.

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