Received: 22 June 2020 | Accepted: 23 January 2021

DOI: 10.1111/ecot.12273

ORIGINAL ARTICLE

ECONOMICS OF TRANSITION AND INSTITUTIONAL CHANGE

WILEY

Investments in worker health and production: Evidence from Vietnam

Massimo Filippini[1,2] | **Suchita Srinivasan**[1]

[1]Center of Economic Research (CER-ETH), ETH Zürich, Zürich, Switzerland

[2]Università della Svizzera italiana, Lugano, Switzerland

Correspondence
Suchita Srinivasan, Center of Economic Research (CER-ETH), ETH Zürich, Zürichbergstrasse 18, 8032 Zürich, Switzerland.
Email: suchitas@ethz.ch

Abstract

In manufacturing industries, occupational health and safety measures ensure better working conditions for employees, which may influence their productivity. We study the impact of investments undertaken by small and medium enterprises in Vietnam in mitigating indoor pollution (including air quality improvements, heat and noise protection as well as lighting) on firm-level gross output and value added. We find that the amount invested by the firm in health has a significant positive effect on both outcomes. Given historically poor working conditions in Vietnam, policy implications relate to incentivizing and enabling firms to undertake such investments, on both moral and economic grounds.

KEYWORDS

gross output, indoor pollution, investments in health, small and medium enterprises, value added, Vietnam

JEL CLASSIFICATIONS

D22; D25; J24; Q53

1 | INTRODUCTION

Human capital investments have important repercussions on the quality of labour, and thus on firm-level performance. The economic literature has for long regarded education and training of workers to be an important means of augmenting human capital; however, good health has also been recognized as a critical determinant of production and productivity (Currie & Madrian, 1999). Moreover, improving the health of the workforce has intrinsic benefits, and also reduces the burden on the healthcare system. The onus of improving public health outcomes lies on both policymakers and firms: while governments can implement regulations and standards, ensure that sanitation and nutrition-related guidelines are met and promote health-related education, the private sector has the primary responsibility to ensure a healthy work environment for employees.

An important example of how they can do this is by adopting occupational health and safety (OHS) measures for workers. Investment in health of workers is a critical determinant of not just their well-being, but it has also been found through case studies to have an impact on the productivity, as well as profitability of firms (WHO, 2010). These measures are a means to mitigate the risks of chronic illnesses and disabilities engendered by difficult working conditions, as well as of accidents and chemical exposures that may inflict workers (Currie & Madrian, 1999; Pouliakas & Theodossiou, 2013). They are thus likely to lead to a healthy workforce that is more productive, and can work more and better (Well, 2007).

According to estimates from the International Labour Organization, about 2.3 million women and men around the world succumb to work-related accidents or diseases every year; and there are around 340 million occupational accidents and 160 million victims of work-related illnesses annually worldwide (International Labour Organization, 2019). In developed countries, policies such as regulations, information disclosure and financial incentives like compulsory accident insurance have tried to attenuate these occupational incidents, and ensure that firms provide basic standards of health and safety for their workforce, although the literature has been ambiguous on whether these measures have been effective (Pouliakas & Theodossiou, 2013; Viscusi, 1979; Weil, 1996). In developing countries, where a higher proportion of the workforce is engaged in manual labour, and regulatory enforcement is often weak, OHS investments are often either not undertaken, or not to the extent that may be necessary (Lucchini & London, 2014).

Our objective in this study is to shed light on the role of investments made to mitigate indoor pollution (and thus improve worker health), on gross output as well as on value added of manufacturing firms by adopting a structural production function estimation approach, using data on a sample of small and medium enterprises (SMEs) in Vietnam. With this study, we aim to contribute to the literature on the importance of health in determining firm-level economic outcomes, by using an alternative approach with respect to the previous studies that mainly adopted reduced-form approaches. Gross output and value added are important economic outcomes to consider, for several reasons. Firstly, they are both barometers of several important economic indicators such as firm-level competitiveness, economic growth and living standards in an economy. They have also been found to be important determinants of export competitiveness, and the relationship between these factors has been found to hold in both directions (Bernard & Bradford Jensen, 1999; Bernard et al. 2007). This is of particular relevance with respect to firms in countries that are relatively more export-oriented (such as Vietnam, for example).[1]

Vietnam is an interesting and relevant case study: SMEs comprise almost 98% of all enterprises in the economy, and employ about 80% of the country's workforce (Dezan Shira & Associates, 2017). Moreover, as a rapidly developing economy, the industrial sector in Vietnam has expanded significantly, especially after its accession to the World Trade Organization. Vietnam is now one of Asia's largest exporters, and this 'ramping up' of its manufacturing sector has posed increased pressure on both working conditions and the environmental sustainability of Vietnam's development. For a long period, Vietnam had a reputation for being a 'sweatshop' for many large multinationals, with several reports in popular media outlets commenting on poor working conditions of labourers in the country (Greenhouse, 1997; Guilbert, 2018). While regulations have been passed on worker health and safety

[1]Vietnam's share of exports of goods and services as percentage of gross domestic product (GDP) was 101.59%, whereas its share of imports was 98.79% in 2016 (World Integrated Trade Solution, 2016).

over the years, there is a lack of evidence on whether they have been effective in improving working conditions. This lends to the importance of a study on whether investments in worker health may lead to improvements in firm-level economic outcomes such as gross output and value added in low- and middle-income countries (LMICs) such as Vietnam, where (a) employers are likely to find it costly to undertake such investments and (b) where workers have historically suffered due to deleterious working conditions.

In this paper, we adopt a simple structural approach based on production function estimation to better understand whether a specific form of a 'good' workplace practice (investment in equipment to curb indoor pollution) has an impact on gross output and value added. While a broad consensus emerges from studies based on production function estimation on the importance and effectiveness of other workplace practices such as investment in information technology (IT), or of management practices, in determining firm-level outcomes such as value added or labour productivity (Black & Lynch, 2002; Bloom & Van Reenen, 2007; Lee et al. 2013), these studies have less to say on the specific types of firm-level interventions which we consider in our paper. To this end, a stream of literature has adopted a reduced-form approach to study the effect of ambient pollution (or its mitigation) on worker productivity, mostly relying on natural experiments or quasi-experimental settings (Carson et al. 2011; Chang et al. 2019; Hanna & Oliva, 2015; He et al. 2019; Lichter et al. 2017; Walker, 2011; Zivin & Neidell, 2012).

Through our study, we contribute to the literature on the impact of improving indoor environmental quality on production outcomes by estimating production functions, as an alternative to the reduced-form approaches used to study this question so far in the literature. To the best of our knowledge, our study is one of the first to adopt this methodology to evaluate the effects of investment in health on output and value added, not just in a developing country, but also among developed countries. We treat investment in worker health as an example of a vital management practice, given that improved health outcomes due to improved indoor environmental quality are likely to lead to fewer sick days, fewer risks of illness and disabilities, and workers who can work harder and longer (Currie & Madrian, 1999; Well, 2007). Other inputs may also be used more efficiently due to better health of workers, for instance, physical capital per worker (Well, 2007). In our opinion, these may be some of the channels through which investment in worker health may affect gross output, as well as value added.

There are distinct advantages and disadvantages to using the production function estimation approach over the others that have been adopted in the literature. The main advantages are the clear link of the methodology to economic theory, its simplicity and the ease of interpretation of the results. The production function approach allows one to control for endogeneity in input choice across firms, and it yields parameter estimates that have specific interpretations. A disadvantage of the methodology is that it imposes functional form and behavioural assumptions on the data-generating process. However, we are of the opinion that in this setting, the advantages outweigh the disadvantages, as the approach allows us to determine the elasticity of gross output and value added with respect to investments in worker health.

The focus of this paper is on a sample comprising predominantly SMEs in Vietnam. We use panel data from the UNU-WIDER Vietnam SME firm-level database (United Nations University UNU-WIDER, 2011) that collects information on about 2,500 firms, mostly SMEs, from 2011 to 2015 biennially. The specific types of measures that we are studying include investments to improve indoor air quality in manufacturing enterprises (such as the establishment of efficient ventilation systems), in heat protection, in lighting, as well as in protection against noise pollution (through investment in noise protection gear for instance).[2] We evaluate the effects of investment in equipment to improve worker health, possibly through reduced indoor pollution, on gross output and value added over a broad spectrum of industries. In our study, we are able to interpret the impact of these investments in terms of marginal effects. This has important policy implications, especially in developing countries where investments in worker health by firms are often few, and of negligible amounts.

From an econometric point of view, we employ two approaches adopted frequently in the literature on production function estimation, the Levinsohn–Petrin (LP from now onwards) approach (Levinsohn & Petrin, 2003), and the Ackerberg–Caves–Frazer (ACF) approach (Ackerberg et al., 2015), although we emphasize the ACF model, given the advantages it offers us in this context. Moreover, we focus our analysis on those firms that have undertaken positive amounts of investment in health in at least one of the years of our data sample, that is on the intensive margin, and thus base our findings on a sample of firms with a common production function for which health is a viable input.

We find that health investments have a significant and positive impact on both gross output and on value added among SMEs in Vietnam. We find that increasing investment in health per year by 1% leads to an increase in value added by about 0.08%. This suggests that workers may be experiencing better health outcomes due to these investments, which enables them to work more (plausibly due to lower risks of illness, accident or disability). This result is robust across specifications.

The positive effect of investments in health on gross output and value added is sustained, even on accounting for investments in fire safety, providing further support for the fact that such investments may be enabling workers to work better and more, by reducing the risk of accidents or disability. Our main result is also confirmed when we account for past enforcement efforts, such as inspections. Additionally, the marginal effect of health capital on production is not mitigated on accounting for other preventative or remedial measures to ensure worker health and safety (such as social insurance contributions, or compensation for accidents or work-related illness). Finally, we do not observe effects of the same magnitude for investments in equipment to control external pollution (such as water, soil and waste), suggesting that investments in health capital are likely to improve working conditions (by reducing indoor pollution), and thus augment gross output/value added.

Vietnamese policymakers have in recent times implemented policies to ensure that firms curtail industrial pollution: the chief legal instrument remains the Law on Environmental Protection (originally passed in 1993, with amendments in 2005 and 2015) that mandates certain firms to conduct environmental impact assessments, and obtain certification, as well as authorizes various government bodies to undertake monitoring and enforcement efforts. The Ministry of Natural Resources and Environment (MONRE) has drafted a National Action Plan on Air Quality Management (2020–2025), which includes a 20% reduction target for pollutants emitted by cement, chemicals, fertilizer and petroleum production facilities (International Trade Administration, 2019). The Vietnam Cleaner Production Centre was established in 1998 with the notion of providing assistance to firms looking to undertake investments in energy-efficient and environmentally friendly technologies.

However, there are currently no mandates or policy instruments to ensure that firms control indoor pollution at plants. The results of this study may be fruitful, as we show investments in health have a positive effect on economic outcomes. SMEs in Vietnam face many challenges that are not uncommon in developing country settings: capital constraints, lack of information, corruption, weak enforcement of laws and regulations, as well as a dearth of pro-business policies imply that small businesses may need additional incentives from the government to undertake such investments. Shedding light on the

[2]While we have information on these four types of investments, we choose to club them together into one measure of investment in health, as we feel that they are very closely related to one another.

value these investments can bring to firms, we think, is an important first step towards encouraging owners and managers to be more proactive in undertaking investments.

The structure of the paper is as follows: Section 2 provides a brief review of the literature. Section 3 provides details on the data and methodology used for the analysis. Section 4 includes the main results of the paper as well as of robustness checks, while Section 5 concludes and includes policy implications.

2 | PREVIOUS LITERATURE

There is a vast literature, both policy-oriented and economic, that has evaluated the effects of the role of health in determining economic outcomes. The International Labour Organization (2014) provides a summary of some qualitative (and a few quantitative) policy-oriented studies that have looked at the effect of social protection for workers in SMEs on economic outcomes, across countries.[3]

In the economics literature, both macroeconomic and microeconomic approaches have been used to assess the role of health. For instance, Bloom et al. (2004) find that health (measured in terms of life expectancy) has a considerable effect on output using a cross-country estimation methodology, while controlling for other factors that may determine aggregate human capital, such as education and work experience. Cole and Neumayer (2006) find that poor health (measured by prevalence of malaria, water-borne diseases and malnutrition) has a significant negative impact on total factor productivity (TFP), using cross-country data.

The microeconomic approaches, on the other hand, have thus far largely focused on individual or household-level estimates of the effect of measures of health on hours worked and on wages. Strauss and Thomas (1998) conduct a comprehensive review of the literature providing microeconomic evidence for households and workers on the effects of health (measured by height, weight and nutritional status, for instance) on productivity and wages in developing countries, using both reduced-form, as well as experimental or quasi-experimental approaches.

In this study, we focus on investments made by firms in worker health, and how that affects economic performance at the firm level. As mentioned in the previous section, two strands of the literature are a suitable fit to what we are exploring through this study. The first is the one on production function estimation, which has been augmented in some studies to assess the impact of not just traditional inputs such as capital, labour and raw materials, but also of management or workplace practices, investments in infrastructure such as IT, and pro-worker activities (such as allowing workers to work from home, or work part-time) on worker productivity as well as on value added. The second looks at the effect of outdoor air pollution on labour productivity/production.

Black and Lynch (2002) was one of the first studies to evaluate the impact of workplace practices on economic outcomes such as labour productivity, by estimating a production function; using a generalized method of moments (GMM)-based approach, and panel data on firms in the United States, they found that there was a positive effect of the intensity of the implementation of good workplace practices on labour productivity. Bloom and Van Reenen (2007) showed that good management practices (such as performance reviews, rewards for good performance, setting clear targets, etc.) had a strong

[3]For instance, Rocco et al. (2011) found that having a chronic condition or disability reduced the likelihood of employment for workers in SMEs by 7% in Egypt. Davis et al. (2005) report that workers without access to paid sick leave in the United States were more likely to report missing work or being unable to focus on work, when they visited their doctors. Cheng et al. (2010) found that attention to health and safety practices, compliance with health and safety regulations, and workers' education have played a key role in reducing accident rates in the construction industry in Taiwan.

and positive effect on worker productivity across a broad spectrum of countries. Bloom et al. (2010) also used production function approaches to evaluate the effects of better management practices on energy intensity of firms, and they found that better managed firms not only had higher gross output, but they also released fewer emissions. Lee et al. (2013) provided evidence from California on the positive (and significant) effects of IT-specific labour and IT capital on hospital-level value added.

Methodologically, our study is similar to these papers, in that we also estimate firm-level production functions. We use information on investments in worker health and safety to construct our measure of 'health capital', following work by Grossman (1972) in which health is considered as a durable capital good in the production function. Moreover, in line with the findings of these papers, we provide robust evidence to value these investments positively, in that we consistently find that higher levels of health capital have had a positive impact on gross output, as well as on value added. By using data spanning several industries, we show that our results have external validity in the Vietnamese context.

This literature, to the best of our knowledge, has not adequately focused on the impact of efforts to improve worker health on firm-level outcomes. While a few studies in the health and development literature have evaluated the effects of indoor air pollution mitigation on household-level outcomes (by studying whether there are any improvements in indoor air quality, respiratory health as well as education outcomes due to investments in technologies such as improved cook-stoves, for example; Hanna et al., 2016), there is scant evidence on whether workers may also reap the benefits of efforts in the workplace to improve their health.

In the second stream of literature that we alluded to in the previous section, several papers have looked at the effect of outdoor air pollution on worker productivity/production outcomes, and have focused on developing countries, where the concentration of pollutants is often more pronounced (Dominici et al., 2014). Most of these studies employ either a natural experiment-based or a quasi-experimental approach to evaluate this question. Many utilize daily-level data on pollution and output or productivity. For instance, He et al. (2019) used data on daily shifts in worker output at two manufacturing sites in China to find that SO_2 and $PM_{2.5}$ concentrations did not have a significant effect on worker output.

On the other hand, Hanna and Oliva (2015) studied the short-term impact of the closure of a refinery in Mexico City on hours worked, and they found that due to reduced levels of SO_2 in the refinery's vicinity, there was an increase in the hours worked by labourers residing in nearby neighbourhoods. Zivin and Neidell (2012) found that even marginally lower levels of ozone could lead to significant improvements in worker productivity among agricultural workers in California, suggesting that environmental improvements may be an effective means of achieving positive economic outcomes. Likewise, Lichter et al. (2017) found that higher levels of air pollution had a significant negative effect on the number of passes made in a match by football players, and that these negative effects already began to appear at moderate levels of pollution. Another study that analysed the effect of improving working conditions is that by Adhvaryu et al. (2018). They found that investing in LED lighting in garment factories in Bangalore, India raised the productivity of workers, especially on hot days, as their use decreased the temperature on factory floors (and thus reduced indoor heat pollution). The results of these studies suggest that worker productivity as well as output could potentially be influenced by the negative effects of pollution, which has important repercussions for the course of policy.

From an econometric point of view, we adopt the LP and ACF structural approaches to estimate our production functions. Several studies have utilized these methodologies, often in combination with others, to estimate production functions. Topalova and Khandelwal (2011), for instance, use the LP approach to model the effects of trade liberalization (and reduction of tariffs) on competitiveness of Indian firms (measured by TFP), and find that lower tariffs resulted in an increase in productivity of firms. Fleisher et al. (2011) estimate an ACF-based production function to evaluate the returns to education for Chinese workers. They find that the returns to education, as measured by the marginal product of labour, are much higher than the reported wages/earnings of workers. De Loecker and Warzynski (2012) utilize the ACF production function framework to estimate firm-level markups, and find that exporting firms charge higher markups using Slovenian manufacturing data.[4]

Finally, studies from other disciplines have also found a positive effect of improved air quality on work productivity (measured by text-typing, addition and proof-reading in Wargocki et al. 2000, for instance), and have evaluated the link between office air quality and productivity in developed country settings (Fisk, 2000; Wyon, 2004). However, these are not economic studies, and they focus specifically on the 'sick building syndrome' and its effects on office workers in a different context to what we are studying in this paper.

3 | DATA AND EMPIRICAL APPROACH

3.1 | Model specification and econometric approach

The methodology adopted in this paper closely resembles that of some other studies mentioned in the previous section, which have utilized one of the structural approaches to estimate production functions.

In line with some of these studies, we use data on firms belonging to a broad spectrum of industries for the analysis, rather than focusing on any one particular industry (Black & Lynch, 2002; De Loecker & Warzynski, 2012; Pavcnik, 2002). While we have data on firms belonging to about 20 different industries, we do not have sufficient observations for any single industry, and thus we choose to pool data over all industries in our sample for the regression analysis. This also enables us to use a broader, more representative sample of firms.

We estimate production functions using both gross revenue as well as value added as dependent variables, and by utilizing a standard Cobb–Douglas functional form. The general econometric specification that we estimate given our panel data setting can be expressed as:

$$\ln Y_{i,t} = \alpha_0 + \alpha_1 \ln H_{i,t} + \alpha_2 \ln K_{i,t} + \alpha_3 \ln M_{i,t} + \alpha_4 \ln L_{i,t} + \rho_{j,t} + \lambda_{k,t} + \nu_t + \mu_{i,t}. \quad (1)$$

We define the output and input variables as described below. $Y_{i,t}$, our dependent variable, denotes either the gross output of firm i in year t, or its value added in year t. Gross output is measured as the sum of the products of the total quantities sold of the top three products produced by firm i and their respective sales prices in year t. Value added is measured as the total revenue from sales minus the costs of intermediate goods, raw materials as well as other indirect costs for firm i in year t. Our main independent variable of interest (and one of the inputs) in Equation 1 is the value of health capital (or total investments undertaken by the firm in worker health), $H_{i,t}$. Following work by Grossman (1972), we consider health to be a durable capital good in the production function, and our measure comprises the total investments made by firm i in protection against poor air quality, noise protection, heat protection and lighting in year t, and is measured in VND (or Vietnamese Dong).

The other inputs are the log of capital $K_{i,t}$, of raw materials $M_{i,t}$, and of labour $L_{i,t}$. The variable for capital $K_{i,t}$ is defined as the market value (in VND) of total equipment and machinery owned by the

[4]Several studies in the literature have utilized these approaches, often in combination with others such as the Olley–Pakes approach (Olley and Pakes, 1996), including Lee et al. (2013), Jang and Du (2019), Pavcnik (2002) and Griffith et al. (2006).

firm at the end of the previous year. $M_{i,t}$ is defined as the market value (in VND) of the raw materials and input inventory assets of the firm at the end of the previous year. $L_{i,t}$ denotes the total labour force of the firm in year t. The variables for the inputs, as well as the dependent variables, have been deflated using 2010 constant prices (World Bank, 2017).

$\rho_{j,t}$ is an industry-year fixed effect for a firm belonging to industry j in year t, $\lambda_{k,t}$ is a province-year fixed effect for firms located in province k in year t, and ν_t denotes a time trend. $\mu_{i,t}$ denotes the idiosyncratic error term. In estimating the Cobb–Douglas production function and in using monetary values for both output and the inputs, we are assuming perfect competition in both product and factor markets. Given that our sample largely comprises micro or small enterprises, we believe that this assumption is likely to be tenable. This model can either be estimated assuming constant, increasing or decreasing returns to scale. We test for the constant returns to scale assumption in our estimations, and find that the restrictions implied by this assumption are rejected for our data.

There are several empirical approaches available to an econometrician interested in production function estimation using panel data, such as the standard ordinary least squares (OLS), fixed effects, first-differencing and instrumental variable (IV)-based methods, as well as other approaches that account for endogeneity issues related to input choice (the structural approaches). The standard estimators such as the OLS are well known to yield inconsistent estimates in these settings, given the endogeneity in input choice, which may arise due to correlated unobservables (unobserved determinants of production that may be correlated with observed input choice by the firms), simultaneity bias (namely that the inputs, output and investments are chosen simultaneously) or even measurement error (especially in the measure of inputs in the production process, such as capital and raw materials). The fixed effects and first-differencing estimators, while useful in addressing time-invariant unobserved heterogeneity across firms, have also been found to be insufficient in addressing endogeneity-related biases because they both assume the strict exogeneity of inputs, conditional on time-invariant firm heterogeneity. This effectively rules out changes to input demand in response to past or current productivity shocks.

In order to deal with these econometric challenges, the modern empirical literature on the estimation of production functions has proposed several approaches. These can be divided into two sets of methodologies: the first one adopts the dynamic panel data approach (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998), whereas the second uses observed input choices as a means of accounting for unobserved productivity shocks (Ackerberg et al. 2015; Levinsohn & Petrin, 2003; Olley & Pakes, 1996). Each set of methodologies has distinct advantages and disadvantages.

The first set of methodologies use a GMM-based estimator. In one form, this involves using lagged values of inputs and output in levels as instruments for the lagged difference in inputs (Arellano & Bond, 1991), known as the difference GMM model. In another form, these instruments are augmented by using the lagged differences in firm-level inputs as instruments for the values of these variables in levels (Blundell & Bond, 1998). These lagged values of the input variables, as well as differences in input values, are assumed to be independent of the error term (Arellano & Bover, 1995; Blundell & Bond, 1998).

The second set of models mentioned above assume that the error term, denoted by $\mu_{i,t}$ in model (1) above, can be expressed as follows:

$$\mu_{i,t} = \omega_{i,t} + \eta_{i,t}, \quad (2)$$

where $\omega_{i,t}$ is now an unobserved productivity term which evolves according to an autoregressive process, that may be correlated with the observed inputs, and $\eta_{i,t}$ is the residual. In this context, the three most common modelling strategies are those proposed by Olley and Pakes (1996) (OP), Levinsohn and Petrin

(2003) (LP) and Ackerberg et al. (2015) (ACF), and they make different assumptions on the evolution of $\omega_{i,t}$ in Equation 2, as well as on the timing of input selection (Lee et al. 2013). These models use two-step control function-based estimators, employing proxy variables to control for productivity shocks. In order to achieve identification, these approaches rely on variation in input use that is assumed to be orthogonal to $\omega_{i,t}$. The OP methodology uses investment as a proxy variable for the productivity shock $\omega_{i,t}$. LP argue that firm or plant-level data on investment often have many zeroes, as they are not made every year and may be lumpy in nature. They overcome this challenge by using intermediate inputs (such as raw materials, electricity or fuels) as proxy variables.

The assumptions that both these models make are: (a) that the material input (investment in the case of the OP model) is strictly monotonic in terms of productivity; (b) that productivity is the only unobservable in the production process, and that it evolves following a first-order Markov process; and (c) that capital is a quasi-fixed/state input and that it is determined prior to current productivity shocks, whereas labour is chosen knowing the productivity shock $\omega_{i,t}$, and it is treated as a flexible or free input. The LP methodology additionally treats materials as a flexible input.

The OP and LP methodologies assume that firms are instantaneously able to adjust inputs at no cost, when subject to productivity shocks. The LP model, in particular, assumes that labour and intermediate inputs are allocated simultaneously at a given time period *t*. ACF, on the other hand, suggest that if a flexible input, for example labour, is also a deterministic function of the unobservable productivity and quasi-fixed inputs, then it is likely that its coefficient is non-parametrically unidentifiable (the so-called 'functional dependence' problem that leads to collinearity in input choices; Ackerberg et al., 2015). ACF address this concern by identifying all the input coefficients together in the second stage using additional moment conditions. They assume that both labour and capital are chosen prior to observing the period *t* productivity shock.

In this paper, we choose to estimate a production function for both gross revenue as well as for value added, using the LP methodology (given that data on investments made are available for only 51% of the observations in our dataset, which would reduce the sample size for the OP model). Furthermore, given the functional dependence problem with the LP estimation, in our main estimation we apply the ACF transformation to the LP model, while using value added as a dependent variable. We do not apply the ACF transformation when using gross output as a dependent variable, as recommended by ACF. Ackerberg et al. (2015) suggest that it is not advisable to use this model when the production function to be estimated is not Leontief in terms of intermediate inputs such as raw materials, as it may lead to non-identification unless further restrictions are imposed on the model. We treat both the log of capital and log of health capital as state variables in our estimation, log of labour as a free variable and log of materials as a proxy variable in these estimations.

We choose to estimate the LP and ACF models over the dynamic panel data-based approaches for several reasons. Firstly, the assumptions of the dynamic panel approach are a bit restrictive, in that they impose a linear autoregressive structure on the evolution of the unobserved productivity term, while the ACF and LP approaches allow that it follows an arbitrary first-order Markov process. Moreover, the ACF and LP methodologies adopt a non-parametric approach to estimation in the first stage. Finally, the dynamic panel approaches (such as the system GMM) are also likely to suffer from weak instrument problems (Bun & Windmeijer, 2010). Nonetheless, estimates obtained from the dynamic panel approach are likely to be more robust in the presence of measurement error. Moreover, the ACF and LP models are not suitable for taking into account the unobserved heterogeneity in TFP across firms (Lee et al., 2019). However, these methods do allow us to correct for input endogeneity with respect to a time-varying unobservable, namely the productivity shock.

Another issue that we need to address in our estimation framework is that a significant share of firms does not seem to invest in health capital at all during our period of analysis (this is true for about

47.18% of the observations in our dataset). This may imply that these firms cannot be characterized as having the same production technology as the ones that are investing in health capital. For this reason, we choose to concentrate our analysis only on those firms that made positive investments in health capital in at least one of the years during 2011–2015, that is we are interested in the intensive margin of these investments in this study, and not on the extensive margin. Our data show that firms that invest in health capital are relatively large firms, and thus likely to be different from those that do not invest in health.[5]

Summarizing, in order to estimate the production functions, we use two econometric approaches (the LP and the ACF) and use two different dependent variables (log of gross output as well as log of value added). The model estimated using the ACF transformation with log of value added as dependent variable is the baseline model of our paper. While the main models are sparse in terms of control variables in line with the production function methodology, we also estimate a version of our baseline model including some firm and respondent-level controls as a robustness check.

3.2 | Data

For this study, we use data from the UNU-WIDER Vietnam SME firm-level database (United Nations University UNU-WIDER, 2011). The database tracks a sample of 2,500 predominantly small and medium-sized firms in nine provinces of Vietnam biennially over the period 2011–2015, creating an unbalanced panel. The dataset collects information on the economic accounts, as well as data on various enterprise-level, as well as some employee-level characteristics, by means of surveys. The enterprises surveyed are distributed across approximately 20 sectors such as food processing, fabricated metal products and manufacturing of wood products. Firms are classified according to the current World Bank definition, with micro-enterprises having up to 10 employees, small-scale enterprises up to 50 employees, medium-sized enterprises up to 300 employees and large enterprises having more than 300 employees.[6] The database also includes variables related to firm performance, enterprise history, employment, business environment and owner/manager background characteristics. The geographical coverage of our study is nine provinces of Vietnam, from different regions, the north (Hanoi, Phu Tho and Hai Phong), south (Ho Chi Minh City, Long An and Khanh Hoa) and central (Nghe An, Quang Nam and Lam Dong), including some of the most important manufacturing centres of the country (such as Ha Noi, Hai Phong, Quang Nam, Ho Chi Minh City and Long An). The survey was representative at the province level in the first year that the survey was conducted, namely in 2005 (Sharma & Tarp, 2018).

In order to accurately measure the level of health capital employed by firms in the production process, we would need to have detailed information on investments in health capital performed by the firm over a long time period. Using this information, we could compute the total health capital, and also consider its depreciation over time. Unfortunately, this information is not available in our data. Therefore, we have approximated the level of health capital with yearly investments in worker health. Of course, we are aware that this may be an incomplete representation of health capital, and therefore we should keep this in mind during the interpretation of results.

[5]The main results of our analysis, provided in Table 3, are also confirmed on estimating the models using the entire sample of firms, including those firms that have made zero investments in health capital. However, we believe that due to the difference in size as well as other important firm-level characteristics of these firms, it is better to focus our study on firms that have invested in health capital.

[6]99.8% of the 7,701 observations in our data sample have fewer than 300 employees. The results of the analysis that follows are robust to restricting the sample to fewer than 300 employees.

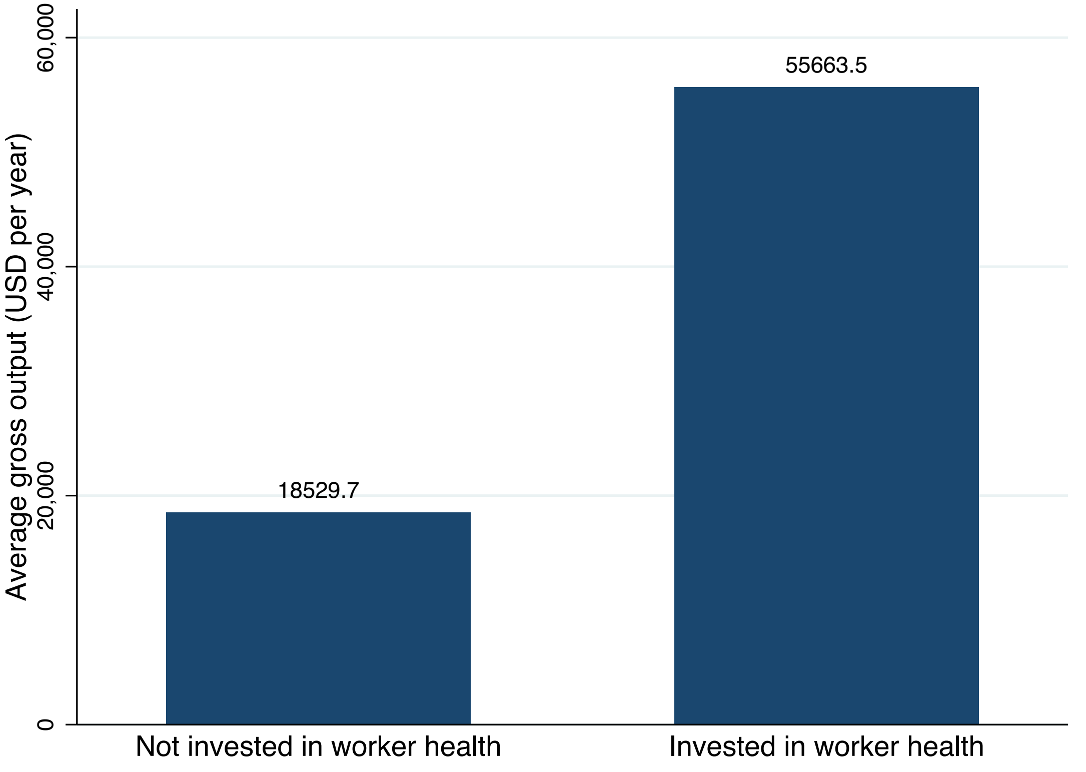

FIGURE 1 Gross output (in USD) and investments in worker health [Colour figure can be viewed at wileyonlinelibrary.com]

We use information on the total amount of investment made by the firms in four types of equipment that could potentially improve working conditions to construct our measure of the value of health capital. Furthermore, to take into account the fact that a small share of firms (about 14% of the observations) did not make positive investments in every year of the period of the data, and that investment levels are likely to fluctuate from year to year in general, we compute the average investment made by the firm over the time period 2011–2015, and use it as our measure of the value of health capital.

The database collects information on investments undertaken by the firm in equipment to protect worker health, the value of this investment made by the firm as well as the year when the investment was undertaken. In this paper, we focus on four kinds of investments that we feel are likely to have an impact on worker health, namely air quality (in improving ventilation, or removing particles and dust), equipment that prevents excessive heat (such as fans, air conditioners and cooling systems), improved lighting (such as window systems and light bulbs) as well as noise reduction equipment (such as investments in protective gear).[7] We have information on investments made by firms since 1981; however, most of the investments made in what we call 'health capital' are closer to the sample period of 2011–2015.

[7]While the UNU-WIDER database questionnaire asks whether firms treat environmental factors, and conditional on saying yes, whether they invest in treating these factors, we are of the opinion that selection is unlikely to be a significant concern in our case, because most firms that treat a factor also undertake investments (the proportion varies from 81% for noise reduction investments to 93% for heat-prevention investments).

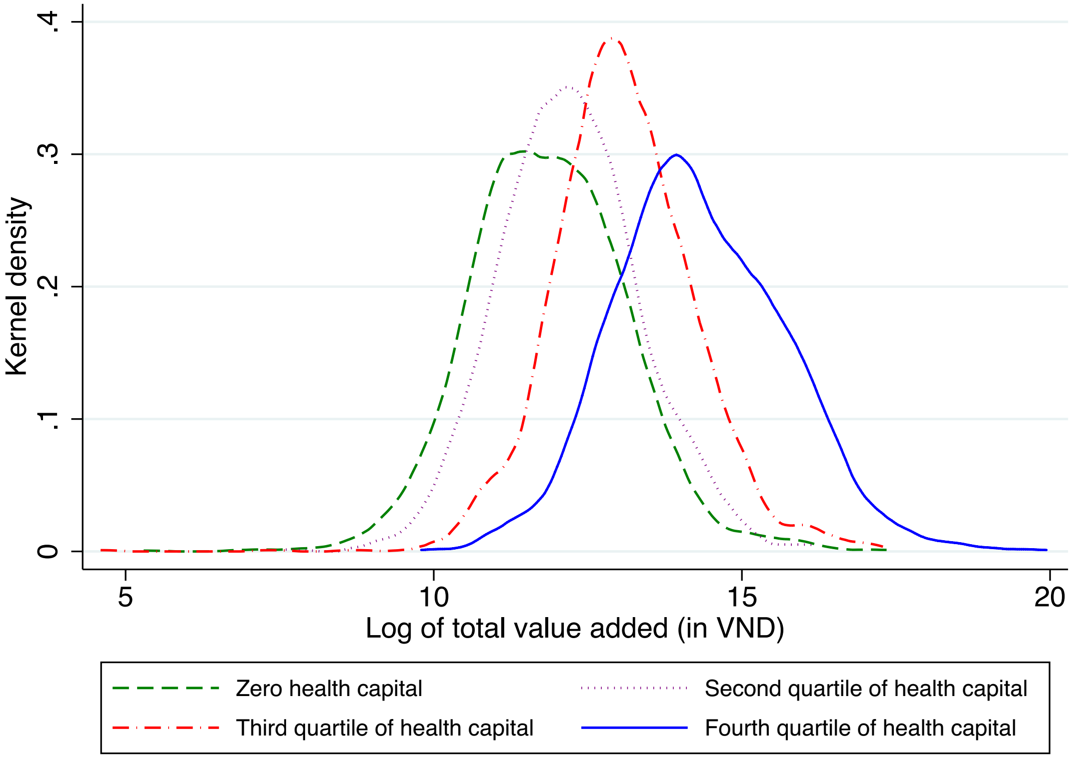

FIGURE 2 Kernel density plot of value added [Colour figure can be viewed at wileyonlinelibrary.com]

As mentioned in the previous subsection, in our analysis, we only focus on those firms that have undertaken positive amounts of investment in worker health in at least 1 year of the data sample, and do not include firms that have never invested in health capital. In Figure 1, we express the relationship between the decision to invest in worker health and the average gross output of firms in a bar plot. We find that the decision to invest in worker health is correlated with firms having significantly higher levels of gross output. The average gross output for firms that do not invest in worker health is about 18,530 USD per year, whereas it is estimated to be about 55,664 USD per year for firms that have invested in worker health. Given this, it is apparent that these are inherently different kinds of firms, and thus we choose to only focus on the intensive margin in this study, and to look at firms that have invested a positive amount in health capital.

Complementarily, Figure 2 provides the kernel density plots of the logarithm of value added across quartiles for investment in health. The first quartile corresponds to firms having zero health capital, that is those that have made zero investments in health in the duration of our data sample. From this graph, it seems reasonable to conclude that higher levels of investment in worker health are positively associated with a shift in the distribution of economic outcomes such as value added among firms in Vietnam. This confirms that there may be fundamental differences between firms that invest in worker health and those that choose to not do so. Firms that invest at low (but positive levels) in worker health have similar economic performance to those that do not invest at all, as can be seen by the closeness of the kernel density plots for firms with zero health capital, and those at the second quartile. This is also noticeable in Figure A1 in the appendix, in which we include kernel density plots of gross output across different investment levels. While these insights are descriptive, and do not imply causality of investment decisions on either gross output or on value added, they are certainly suggestive of the

TABLE 1 Summary statistics on investments in worker health by category

Type of investment	Median amount of investment (in VND)	Median amount in USD	Median year of investment
Air quality	9.22 million	399	2010
Protection against noise	5.37 million	232	2009
Protection against heat	9.81 million	425	2010
Lighting	4.39 million	190	2010

Notes: The investment amounts are measured at constant (2010) prices. The sample size is 3,215 observations, comprising the regression sample of the main results in column (3) of Table 3. The median investment amounts in USD are calculated using an exchange rate of 1 VND = 0.000043 USD.

Source: UNU-WIDER Vietnam Database.

role of these investments in improving labour outcomes (particularly among SMEs in the Vietnamese context). Moreover, they also suggest the possibility that these investments may have limited effects on economic outcomes, if undertaken at low levels.

Table 1 presents some summary statistics on the types of investments that we are focusing on in this study for the regression sample (averaged over all 3 years of the data, 2011, 2013 and 2015). The regression sample comprises all observations for those firms that have made positive investments in health capital, with manufacturing as the main sector, and that do not change their location over time. After accounting for these restrictions, as well as for missing values for some variables, the regression sample in our main estimation (column (3) of Table 3) comprises 3,215 observations out of a total of 7,701 observations included in the dataset. From Table 1, we find that the median year of investment by firms was slightly before the period of our data sample across these categories. Moreover, we find that the average amount of investment made in a year is the highest in the case of equipment protecting against heat (about 9.81 million VND, or about 425 USD at current exchange rates[8]), as well as in investments in air quality improvements (about 399 USD).

As previously mentioned, we combine information on these four types of investments by firms to generate the variable for total value of health capital because we are interested in capturing the effect of aggregate health investment on gross output and value added, using the structural production function approach. Moreover, while we also have information on investments in fire protection, we do not include this in our main specification. While investment in fire protection equipment is also relevant for firms in developing countries, we are focusing our attention on investments protecting workers from indoor pollution in this study. However, we do incorporate this information in one specification as an extension of our main results, provided in column (1) of Table 4.

We observe that there is heterogeneity in the amount invested in health, both by industry as well as by province. Table A1 in the Appendix includes information on the average amount (in VND) invested in health per year by industry for the regression sample. We find that the firms in the paper industry invested the highest amount in health, at about 47.8 million VND (or about 2,055 USD) per firm per year, while firms belonging to the refined petroleum industry invested the least at about 2.12 million VND (or 91 USD) per firm per year (even though we also have one observation for a firm belonging to the tobacco industry with a value of health capital of 1.47 million VND). The paper industry also comprises 'larger' firms in our dataset, with the average size of labour force being about 48 workers per firm (this is only exceeded for firms in the apparel industry, that have about 49 workers per firm). The two largest

[8]We use an exchange rate of 1 VND = 0.000043 USD.

TABLE 2 Summary statistics of important variables

Variable	Mean	*SD*	Minimum	Maximum
Gross output	41,532.62	840,612.4	0.007	35.3 million
Total value added	106.36	520.92	0.004	19,675.81
Value of equipment/ machinery	38,438.24	147,432.6	6.10	3.54 million
Value of raw materials and input inventories	22,301.72	180,693.3	3.05	7.45 million
Number of workers	21.89	51.63	1	1,700
Value of health capital	769.70	5,934	0.60	221,880
Whether respondent is the owner	0.66	0.47	0	1
Whether respondent is a male	0.60	0.49	0	1
Whether respondent is college educated	0.39	0.49	0	1
Age of firm	14.61	9.50	2	61
Age of respondent	45.60	10.98	19	85
Whether firm is a household enterprise	0.53	0.50	0	1

Notes: The amount-related variables are deflated to constant (2010) prices, and are expressed in terms of US dollars. The sample size is 3,215 observations, comprising the regression sample of the main results in column (3) of Table 3. Data on gross output are only available for 3,202 of these observations in the regression sample.

Source: UNU-WIDER Vietnam Database.

industry groups in terms of sample size in our regression sample are the food and beverage industry, as well as the fabricated metal industry, which comprise 25% and 18% of the sample respectively.

Province-level differences in the amount of investments can also be expected, as shown in Table A2 (in the Appendix) for the regression sample. There is significant heterogeneity in the values of these investments across provinces: the largest investments in health are made by firms in Ho Chi Minh City (about 30.6 million VND or 1,315 USD per firm per year) as well as in Quang Nam (about 21.9 million VND or 897 USD per firm per year). Hai Phong and Hanoi belong to the relatively industrialized northern region of Vietnam. Quang Nam is a centrally located province, which is also one of the leading export hubs of the country, and Ho Chi Minh City is a part of the most active industrial zone in Vietnam, and we see that these provinces have relatively larger levels of investments. The largest firms in our sample belong to the Khanh Hoa province, where the average size of the labour force is about 30 workers per firm.

Table 2 presents summary statistics on the modelling variables, including the dependent variables, as well as on some important firm and respondent-level characteristics. The amount-related variables are expressed in terms of USD. We find that the average gross output is equal to about 41,533 USD per firm per year, while the average value added is about 106 USD per year (suggesting that the costs of intermediate goods, as well as of other raw materials may be high for this sample of firms).[9] The

[9]The UNU-WIDER dataset collects information on the total value added for the years 2011 and 2013; however, it does not provide this information for firms in the year 2015. In our data sample, we thus substitute value added for firms in the year 2015 with their corresponding values for 2014, on which we do have information. The main results of our paper, provided in Table 3, are robust to dropping these observations and limiting the analysis to the years 2011 and 2013, and can be provided on request.

TABLE 3 Production function estimation results

Dependent variable	Gross output	Value added	Value added
Estimation	LP	LP	ACF
Column	(1)	(2)	(3)
Log of value of health capital	0.056**	0.081***	0.080***
	(0.003)	(0.011)	(0.008)
Log of value of capital	0.152***	0.176***	0.160***
	(0.014)	(0.033)	(0.017)
Log of value of raw materials and input inventories	0.133***		
	(0.026)		
Log of total labour force	0.605***	0.719***	0.803***
	(0.022)	(0.018)	(0.008)
Observations	3,483	3,215	3,215
Wald test on constant returns to scale: chi-squared	1,200,000	870,000	13,000,000
p-value	0	0	0

Notes: All specifications include industry-year fixed effects, province-year fixed effects and a general time trend. Regression sample comprises firms with manufacturing as the main production sector that do not change their location over the duration of the sample, and that invested a positive amount in health capital.

*, **, and ***respectively denote significance at the 10%, 5% and 1% levels. The coefficients of the constant are not reported.

average value of health capital is about 770 USD per year (at constant 2010 prices), among the sample of firms that make positive investments in health capital. As one can expect, the average value of investments in health capital is less than the value of capital (about 38,438 USD per year) or raw materials (about 22,302 USD per year). The size of the labour force varies from one worker to about 1,700 workers, with an average of about 22 workers per firm.

Regarding the respondents of the survey, we learn that about 60% of them are male, while 66% of them are the owners of the firm (34% are managers). The average age of the respondent is about 46 years, whereas about 39% of them are college educated. The average age of the firm is about 15 years, whereas almost 53% of the sample comprises household enterprises (the rest are sole/private proprietorships, limited liability companies, cooperatives and partnerships).

4 | RESULTS

4.1 | Main results

Table 3 presents the main results of the paper. In column (1) of Table 3, we present the results of the estimation using log of gross revenue as a dependent variable, while columns (2) and (3) include the results using log of value added as the dependent variable. The methodology adopted for deriving the results presented in columns (1) and (2) is the LP-based estimator, whereas in column (3) we present the results of using the ACF transformation for the LP model, which is our preferred estimation. All explanatory variables in Table 3 have been log transformed, and each of these estimations includes a time trend, as well as industry-year and province-year fixed effects. Moreover, we estimate these

TABLE 4 Additional results and extensions

Specification	Fire and health	Other preventative and remedial measures	External pollution	Enforcement as control
Column	**(1)**	**(2)**	**(3)**	**(4)**
Log of value of health capital		0.072*** (0.007)	0.077*** (0.0007)	0.089*** (0.009)
Log of value of capital	0.159*** (0.012)	0.148*** (0.010)	0.175*** (0.0002)	0.155*** (0.012)
Log of total labour force	0.803*** (0.002)	0.758*** (0.002)	0.801*** (0.0009)	0.806*** (0.003)
Log of value of health capital and fire protection equipment	0.076*** (0.007)			
Compensated workers for accidents or professional illness		0.147*** (0.008)		
Paid social insurance contribution for workers		0.161*** (0.001)		
Log of value of equipment to control external pollution			0.003** (0.001)	
Whether firm was inspected (in the previous period)				−0.012*** (0.004)
Observations	3,215	3,215	3,215	2,899

Notes: All specifications include industry-year fixed effects, province-year fixed effects and a general time trend. Models are estimated using the specification of column (3) of Table 3. Regression sample comprises firms with manufacturing as the main production sector that do not change their location over the duration of the sample, and that invested a positive amount in health capital.

*, **, and ***respectively denote significance at the 10%, 5% and 1% levels. The coefficients of the constant are not reported.

models only for the subset of firms that have undertaken positive levels of investment in health over 2011–2015, as mentioned in the previous section.

The parameter estimates of column (1) suggest that higher levels of all inputs, including health capital as we have measured it in our study, have had a positive impact on the gross revenue of small and medium Vietnamese firms (while accounting for endogeneity due to input choice). These results suggest that a 1% increase in the value of health capital has led to a 0.056% increase in gross revenue (given the log-log specification of our production function, the coefficients on the inputs in this table can be interpreted as elasticities).

On using the log of value added as a dependent variable in columns (2) and (3), we find that a 1% increase in the value of health capital has resulted in an approximate increase of about 0.08% in the value added of these small and medium businesses. Given the possible issues with using the ACF transformation on the LP model with gross output as a dependent variable (Ackerberg et al., 2015), we only implement it in the value added regression. Furthermore, given the benefits the transformation

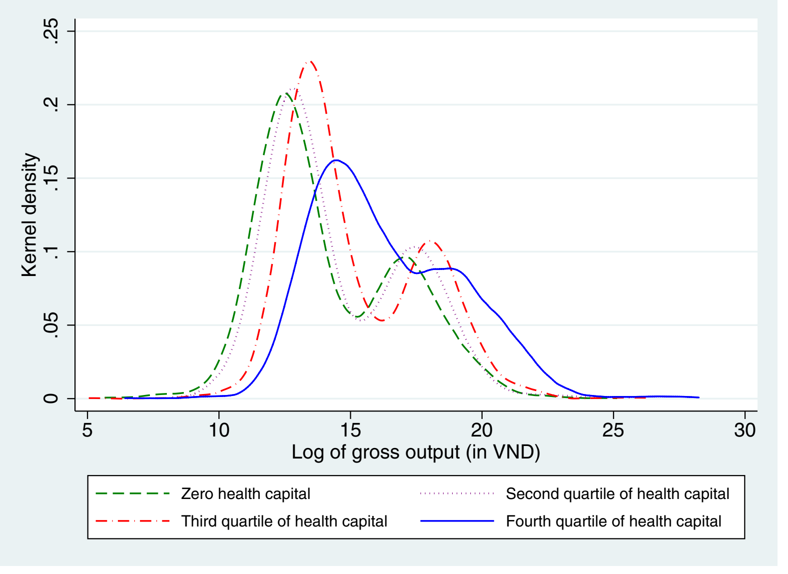

FIGURE A1 Kernel density plot of gross output [Colour figure can be viewed at wileyonlinelibrary.com]

offers in terms of addressing the well-known functional dependence challenge in using the LP estimation, we interpret the specification in column (3) to be the main estimation of this paper.

The other input variables are also significant at the 1% level, and have the expected positive coefficients. The elasticity of both gross output, as well as of value added, is highest with respect to labour (the coefficients vary from 0.61 in column (1) to 0.80 in column (3)), which can be expected, given the labour-intensive nature of many of these industries. In line with intuition, a higher value of capital stock, as measured by the log of value of equipment and machinery, also has a positive effect on both the gross output as well as on value added, with lower marginal products than those for labour (the elasticities vary from about 0.15 to 0.18). In the LP model estimated in column (1), we are also able to estimate a coefficient on the variable capturing the log of raw materials, and we find that a 1% increase in the value of raw materials or input inventories leads to a 0.13% increase in the gross output. We are able to reject the null hypothesis on constant returns to scale being valid in each of these estimations using a Wald test. Moreover, as the ACF-corrected estimation in column (3) of Table 3 is an exactly identified model, there are no overidentifying restrictions to be tested.

In all three estimations, we account for time-variant industry-specific as well as province-specific shocks due to the inclusion of industry-year fixed effects, as well as province-year fixed effects. Additionally, the incorporation of a time trend to capture common time-varying shocks ensures that we are likely to control for macroeconomic phenomena and policies that may influence all firms in our sample.

While we are able to obtain marginal effects for the value of health capital in the production process, as derived in Table 3, we choose to not interpret these effects in monetary terms in our study. This is because, as mentioned in the previous section, we are using data on investments made in health to generate our measure of health capital, and thus it is not straightforward to interpret these coefficients in monetary terms as one could do for other inputs such as capital or raw materials. However, our results do suggest that investments in health are important, and likely to contribute to increases in value added as well as gross output for firms. Given that the marginal effects of the value of health capital are relatively smaller than those for other inputs, it is possible that current levels of investment in health may be low, holding all other inputs and the rate of technological change fixed (as also observed in Figures 2 and A1).

In Table A3 in the Appendix, we present the results of some estimations to check the robustness of our main results presented in column (3) of Table 3. As mentioned in the Data and Empirical Approach section, in creating the value of health capital variable, we computed the average value of investments done by the firm over the 3 years. We did not account for depreciation in constructing this variable, as it is virtually impossible to obtain information on depreciation rates for the specific types of investments in indoor pollution prevention equipment in Vietnam that we are considering in this study. In the results of column (1) of Table A3, we assume a proxy annual depreciation rate of 5%, to test the sensitivity of our results to having made this assumption. We draw this estimate from the Penn World Table 9.1, and it equals the average depreciation rate of capital in Vietnam in 2011 (University of Groningen, 2011). We find that on applying this depreciation rate, the coefficient on the value of health capital variable is still significant, and positive, even though its magnitude is smaller than in column (3) of Table 3.[10]

The results of column (2) of Table A2 confirm whether our main result changes on including some firm and respondent-specific control variables. We find that the value of the health capital variable continues to have a significant and positive effect on value added. The results of column (2) also suggest that higher levels of value added are associated with firms having owners or managers who are younger, as well as college educated. On the other hand, older firms are likely to have higher levels of value added, while household enterprises are likely to have lower levels of value added, on average, compared to other types of businesses (namely sole proprietorships, partnerships, cooperatives, limited liability firms as well as joint stock companies), as is in line with intuition. We do not find any significant difference between male and female owners/managers in terms of value added.

In columns (3) and (4), we test for the robustness of our results across different subgroups of industries. The two largest industry groups in our data are the food and beverage industry, and the fabricated metal industry (together, they comprise about 43% of our regression sample). The results of our analysis in column (3) of Table 3, where we pool data over all industries, may be driven by these two industries. In column (3) of Table A3, we re-estimate the model of column (3) of Table 3 for the subsample of firms belonging to these two industries, and in column (4), we estimate the model for firms in all other industries. Our main results are robust for both subsamples of firms, suggesting that they are not driven by the dominance of particular industries in our sample.

4.2 | Extensions

In Table 4, we present some additional results on extensions of our main estimation. For these estimations, we use our preferred model specification, which was the LP model with the ACF correction (column (3) of Table 3), as well as log of value added as a dependent variable.

In column (1), we present the results of the estimation including investments in fire prevention as a component in our main explanatory variable, along with those in air quality, heat, lighting and noise. We find that our main results are confirmed with a marginally smaller coefficient than in column (3) of Table 3. Thus, investments in fire prevention and safety may also play a role in enhancing value added in SMEs; however, we choose not to include them in our main estimations, as indoor pollution is the focus of our study.

[10]The results, as can be expected, are sensitive to the choice of this depreciation parameter, with the magnitude of the coefficient varying as we vary it; however, the significance and sign of the coefficient remain intact across estimations.

The model presented in column (2) tests whether the marginal effect of the value of health capital weakens on introducing other variables related to worker health and safety in the model, such as dummy variables for whether the firm pays the social insurance contribution of workers, and whether the firm directly compensates workers for accidents or illness. Investing in the health of workers can be considered as a preventative measure by firms to ensure that working conditions for workers improve over time. Another preventative policy measure is insurance. In Vietnam, social insurance includes coverage for sickness, occupational diseases and accidents, maternity, as well as retirement and death. Social insurance coverage is mandatory for formal workers in the private sector in Vietnam, whereby employers are required to pay a portion of the contribution, and it can be considered as a buffer to help workers deal with illness or disability in case of accidents. Other measures may be of a more remedial nature. Firms may, for instance, choose to monetarily compensate firms for the risk of accidents and illness (either by paying a wage premium, or by compensating them as and when needed). In the results of column (2), we treat these two variables as control variables.[11] We find that on controlling for these other possible policy measures, the marginal effect is still significant (and of similar magnitude) as in our baseline results of column (3) of Table 3. Moreover, the coefficients on these measures are also significant, and have positive signs in the estimation. This suggests that other preventative as well as remedial measures or policies to ensure the well-being of workers may also have an effect on the value added at the firm level.

In column (3) of Table 4, we present the results of a form of ‘placebo test’ of our main results. Our hypothesis was that investing in equipment to reduce air pollution improves working conditions for employees, which may make them more productive (by reducing the number of sick days and work-related disabilities, for example). In our dataset, we also have information on investments made by firms in equipment to control external pollution (such as water, waste and soil).[12] Given that these types of investments are more likely to influence the external environment of the plants and factories, rather than directly improve the working conditions for workers, one can argue that they may have a weaker effect on the value added of firms. In column (3), we treat the total value of investments made to control external pollution as a control variable. As with the variable measuring the value of health capital, we take the average of these investments over the 3 years as our measure of the total investment in equipment to control external pollution. The results suggest that the value of investments related to external pollution (which has also been log transformed in this specification) has a relatively weaker effect on the value added of the firm, while the value of health capital variable retains its significance. These results also suggest that the we find only partial or weak evidence in favour of the ‘Porter hypothesis’, according to which firms that pollute can benefit from environmental regulations that may facilitate efficiency, and encourage innovations that improve productivity as well as their competitiveness (Porter, 1991; Porter & van der Linde, 1995; at least in view of investments to mitigate water, soil and waste-related pollution by SMEs in Vietnam).

Lastly, in column (4), we include a dummy variable for whether the firm has been inspected as a control variable to evaluate whether accounting for stricter enforcement or monitoring may alter the magnitude of our main effect. This variable captures whether the firm was inspected in the previous time period (we were able to refer to an older version of the database to collect this information for some firms for the year 2011). Inspections may have been conducted for policy compliance reasons

[11]Although it is likely that these variables may be endogenous, we do not treat them as input variables in our estimation, given that they are not traditional inputs into the production process.

[12]Investments in air quality may also be categorized as equipment preventing external pollution; however, given that they are more likely refer to equipment such as efficient ventilation systems in our context, we consider them as a means to control indoor pollution.

(such as for violations of the labour code, or tax law), technical compliance reasons (such as for violations related to environmental laws or fire safety rules), as well for other reasons (such as after accidents). We find that the coefficient on the health capital variable retains significance at the 1% level, even though it is of slightly larger magnitude than in our main result, whereas the coefficient on the dummy variable is significant, and has a negative sign. Thus, we find that past enforcement is associated with lower levels of current value added. This may imply either that firms that were inspected for labour, tax, health or environmental violations were inherently 'bad' and thus continued exhibiting relatively poor economic performance, or that inspected firms had to undertake steps to address concerns raised during inspections by investing in more intermediate inputs, which then reduced their value added. While we are not able to disentangle this channel, we are still able to confirm the importance of health capital in determining value added, while controlling for enforcement.

5 | POLICY IMPLICATIONS AND CONCLUSION

Our findings suggest that health capital, measured in this study by investment in equipment to protect worker health, is likely to lead to improved firm-level outcomes such as gross output and value added, possibly through improved working conditions for workers. This result is particularly important, given that while some of the industries that we consider have been important for Vietnam's economic development, they have also been responsible for significant environmental deterioration, as well as poor working conditions for labour in the country (Dore, 2008).

The main contribution of this study is that we identify an effect for investment in worker health on both gross output, as well as on value added, using structural production function-based methodologies (the LP and ACF approaches) which allow us to control for the choice of important inputs, and serve as an alternative to the experimental and quasi-experimental approaches thus far adopted to study the effect of pollution on firm-level outcomes. Referring to the results of our main specification (in column (3), Table 3), a 1% increase in the value of health capital is likely to lead to a 0.08% increase in the value added for firms. While this effect may seem low, we are of the opinion that it reflects low current levels of investment, and that sizeable increases in investments in worker health may still be needed to be made by firms to achieve significant increases in value added or gross output (ceteris paribus).

Evaluating such investments is of considerable importance, given that (a) small business owners in LMICs may find such investments to be particularly costly, and thus would expect to obtain good returns to these investments if they undertake them, thereby possibly requiring policy interventions; and (b) workers in these firms need, and could benefit greatly from, such investments.

Our study also finds that the main result is valid, even when we take into account investments made in equipment related for fire safety, or whether the firm has been inspected, suggesting that health and safety measures are both effective in augmenting firm-level value added, and that controlling for enforcement does not preclude the main result. Moreover, the marginal effect of health capital on production is not mitigated on accounting for other preventative or remedial policy measures to ensure worker health and safety (such as compensation for accidents or social insurance contributions). Finally, we observe a much smaller effect of investments in equipment to control external pollution (such as water, soil and waste) on value added, suggesting that investments in health capital are likely to improve working conditions (by reducing indoor pollution), and thus enhance worker and firm outcomes.

It is important to put our results in perspective, both in the context of prevailing conditions in Vietnam, but also in the light of similar studies that may have been conducted in other countries (especially in developing countries). Unfortunately, with respect to the latter, there is a clear dearth of research using enterprise-level data on the relationship between investments to improve worker health and firm performance (Croucher et al. 2013; International Labour Organization, 2014). While there are studies in similar spirit to ours, we are not able to benchmark our results against any of these, due to a difference in context, methodology as well as in the choice of indicators of economic performance.

For instance, Lanoie et al. (2008) found, using data on the manufacturing industry in Quebec, that the lagged share of investment in pollution control equipment to total cost in an industry was associated with increased TFP growth in certain industries. They found that it contributed to about 24% of the observed change in TFP, thus providing some evidence in favour of the Porter hypothesis. However, this analysis was done at a sectoral level, it considered different types of investments to those that we consider in our study and of course the institutional environments in the two countries are also vastly different, making it impossible to directly compare our results.

Secondly, in our study, we are focusing on the intensive margin of the investment decision, and not on the extensive margin. Thus, while our results are relevant to understand the effectiveness of investments in improving firm-level outcomes, they do not shed light on the decision to invest.

It is also important to understand the implication of our results for SMEs in Vietnam that face credit constraints, poor quality of human resources, and often have challenges in market access and in facing competition. While current returns to investments may be low, this may be due to low levels of investment, and thus higher levels of investment may be warranted. This may require policy assistance from the government (in the form of low-interest loans, for example), especially for micro and small enterprises that cannot afford these investments, and have problems with access to capital.

Both researchers and policymakers need a better understanding of the reason for underinvestment in worker health and safety, especially in developing country settings. Factors such as low awareness of legislative requirements, corruption, costs of investment and difficulties in complying with regulation have been found to be significant setbacks among SMEs, even in developed countries (Vickers et al., 2005), and these may be highly relevant in the case of developing countries such as Vietnam as well. Our study does not address this question; however, it is remains an important area for future research.

Our results suggest that OHS may be important, both as a form of human capital investment and as a workplace practice, and that it may be particularly biting for workers in the manufacturing sector in developing countries such as Vietnam. This has clear repercussions for policymakers, given that regulations are often weakly implemented in many such contexts. Moreover, given the rapid industrialization underway in several developing countries, these findings also have a bearing on policies regarding indoor pollution and environmental quality, in general.

ACKNOWLEDGEMENTS

We thank participants at the UNU-WIDER Development Conference 2019 in Bangkok, Thailand, and those at the 25th EAERE Annual Conference, as well as Nicholas Bloom and Gale Boyd for helpful suggestions and comments. We also thank Armin Burgmeier, Neda Trifkovic and Janis Vehmann-Kreula for assisting us in data preparation.

REFERENCES

Ackerberg, D. A., Caves, K., & Frazer, G. (2015). Identification properties of recent production function estimators. *Econometrica*, *83*(6), 2411–2451.

Adhvaryu, A., Kala, N., & Nyshadham, A. (2018). *The light and the heat: Productivity co-benefits of energy-saving technology*. NBER Working Paper No. 24314.

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, *58*(2), 277–297.

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, *68*(1), 29–51.

Bernard, A. B., & Bradford Jensen, J. (1999). Exceptional exporter performance: Cause, effect, or both? *Journal of International Economics*, *47*(1), 1–25.

Bernard, A. B., Jensen, J. B., Redding, S. J., & Schott, P. K. (2007). Firms in international trade. *Journal of Economic Perspectives*, *21*(3), 105–130.

Black, S., & Lynch, L. M. (2002). How to compete: The impact of workplace practices and information technology on productivity. *Review of Economics and Statistics*, *83*(3), 1–47.

Bloom, D. E., Canning, D., & Sevilla, J. (2004). The effect of health on economic growth: A production function approach. *World Development*, *32*(1), 1–13.

Bloom, N., Genakos, C., Martin, R., & Sadun, R. (2010). Modern management: Good for the environment or just hot air? *Economic Journal*, *120*(544), 551–572.

Bloom, N., & Van Reenen, J. (2007). Measuring and explaining management practices across firms and countries. *Quarterly Journal of Economics*, *122*(4), 1351–1408.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115–143.

Bun, M. J., & Windmeijer, F. (2010). The weak instrument problem of the system GMM estimator in dynamic panel data models. *The Econometrics Journal*, *13*(1), 95–126.

Carson, R. T., Koundouri, P., & Nauges, C. (2011). Arsenic mitigation in Bangladesh: A household labor market approach. *American Journal of Agricultural Economics*, *93*(2), 407–414.

Chang, T. Y., Zivin, J. G., Gross, T., & Neidell, M. (2019). The effect of pollution on worker productivity: Evidence from call center workers in China. *American Economic Journal: Applied Economics*, *11*(1), 151–172.

Cheng, C. W., Leu, S. S., Lin, C. C., & Fan, C. (2010). Characteristic analysis of occupational accidents at small construction enterprises. *Safety Science*, *48*(6), 698–707.

Cole, M. A., & Neumayer, E. (2006). The impact of poor health on total factor productivity. *Journal of Development Studies*, *42*(6), 918–938.

Croucher, R., Stumbitz, B., Vickers, I., Quinlan, M., Banfield, W., Brookes, M., Lange, T., Lewis, S., Mcllroy, J., Miles, L., Ozarow, D., & Rizov, M. (2013). *Can better working conditions improve the performance of SMEs? An international literature review*. International Labour Office.

Currie, J., & Madrian, B. C. (1999). Health, health insurance and the labor market. In *Handbook of labor economics* (Vol. 3 part C, pp. 3309–3416). Elsevier.aaa

Davis, K., Collins, S. R., Doty, M. M., Ho, A., & Holmgren, A. (2005). Health and productivity among U.S. Workers. *Commonwealth Fund Issue Brief*, *856*, 1–10.

De Loecker, J., & Warzynski, F. (2012). Markups and firm-level export status. *American Economic Review*, *102*(6), 2437–2471.

Dezan Shira & Associates. (2017). Lower taxes proposed for profitable SMEs in Vietnam. *Vietnam Briefing News*.

Dominici, F., Greenstone, M., & Sunstein, C. R. (2014). Particulate matter matters. *Science*, *344*(6181), 257–259.

Dore, G. (2008). *Review and analysis of the impacts from Vietnamese manufacturing sectors*. World Bank Group.

Fisk, W. J. (2000). Health and productivity gains from better indoor environments and their relationship with building energy efficiency. *Annual Review of Energy and the Environment*, *25*(1), 537–566.

Fleisher, B. M., Hu, Y., Li, H., & Kim, S. (2011). Economic transition, higher education and worker productivity in China. *Journal of Development Economics*, *94*(1), 86–94.

Greenhouse, S. (1997). Nike shoe plant in Vietnam is called unsafe for workers. *New York Times*.

Griffith, R., Harrison, R., & Van Reenen, J. (2006). How special is the special relationship? Using the impact of U.S. R&D spillovers on U.K. firms as a test of technology sourcing. *American Economic Review*, *96*(5), 1859–1875.

Grossman, M. (1972). On the concept of health capital and the demand for health. *The Journal of Political Economy*, *80*(2), 223–255.

Guilbert, K. (2018). *Adidas, Nike urged to ensure fair wages for Asian workers making World Cup kits*. Reuters.

Hanna, R., Duflo, E., & Greenstone, M. (2016). Up in smoke: The influence of household behavior on the long-run impact of improved cooking stoves. *American Economic Journal: Economic Policy*, *8*(1), 80–114.

Hanna, R., & Oliva, P. (2015). The effect of pollution on labor supply: Evidence from a natural experiment in Mexico City. *Journal of Public Economics*, *122*, 68–79.

He, J., Liu, H., & Salvo, A. (2019). Severe air pollution and labor productivity: Evidence from industrial towns in China. *American Economic Journal: Applied Economics*, *11*(1), 173–201.

International Labour Organization. (2014). *Can productivity in SMEs be increased by investing in workers' health?*. International Labour Office, Social Protection Department.

International Labour Organization. (2019). *World statistic: The enormous burden of poor working conditions*. Retrieved from https://www.ilo.org/moscow/areas-of-work/occupational-safety-and-health/WCMS_249278/lang–en/index.htm

International Trade Administration. (2019). *Environmental and pollution control equipment and services*. Vietnam Commercial Guide.

Jang, H., & Du, X. (2019). Evolving techniques in production function identification illustrated in the case of the US dairy. *Applied Economics*, *51*(14), 1463–1477.

Lanoie, P., Patry, M., & Lajeunesse, R. (2008). Environmental regulation and productivity: Testing the porter hypothesis. *Journal of Productivity Analysis*, *30*(2), 121–128.

Lee, J., Mccullough, J. S., & Town, R. J. (2013). The impact of health information technology on hospital productivity. *The RAND Journal of Economics*, *44*(3), 545–568.

Lee, Y., Stoyanov, A., & Zubanov, N. (2019). Olley and Pakes-style production function estimators with firm fixed effects. *Oxford Bulletin of Economics and Statistics*, *81*(1), 79–97.

Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, *70*(2), 317–341.

Lichter, A., Pestel, N., & Sommer, E. (2017). Productivity effects of air pollution: Evidence from professional soccer. *Labour Economics*, *48*, 54–66.

Lucchini, R. G., & London, L. (2014). Global occupational health: Current challenges and the need for urgent action. *Annals of Global Health*, *80*(4), 251–256.

Olley, G. S., & Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, *64*(6), 1263–1297.

Pavcnik, N. (2002). Trade liberalization, exit, and productivity improvements: Evidence from Chilean plants. *The Review of Economic Studies*, *69*(1), 245–276.

Porter, M. E. (1991). Essay: America's green strategy. *Scientific American*, *264*(4), 168.

Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97–118.

Pouliakas, K., & Theodossiou, I. (2013). The economics of health and safety at work: An interdiciplinary review of the theory and policy. *Journal of Economic Surveys*, *27*(1), 167–208.

Rocco, L., Tanabe, K., Suhrcke, M., & Fumagalli, E. (2011). *Chronic diseases and labor market outcomes in Egypt*. World Bank Policy Research Working Paper No. 5575.

Sharma, S., & Tarp, F. (2018). Does managerial personality matter? Evidence from firms in Vietnam. *Journal of Economic Behavior and Organization*, *150*, 432–445.

Strauss, J., & Thomas, D. (1998). Health, nutrition, and economic development. *Journal of Economic Literature*, *36*(2), 766–817.

Topalova, P., & Khandelwal, A. (2011). Trade liberalization and firm productivity: The case of India. *The Review of Economics and Statistics*, *93*(3), 995–1009.

United Nations University UNU-WIDER. (2011). *Viet Nam SME database*. Retrieved from https://www.wider.unu.edu/database/viet-nam-sme-database

University of Groningen. (2011). *Penn World Table – International comparisons of production, income and prices 9.1*. Retrieved from https://febpwt.webhosting.rug.nl/Dmn/AggregateXs/PivotShow

Vickers, I., James, P., Smallbone, D., & Baldock, R. (2005). Understanding small firm responses to regulation: The case of workplace health and safety. *Policy Studies*, *26*(2), 149–169.

Viscusi, W. K. (1979). The impact of occupational safety and health regulation. *The Bell Journal of Economics*, *10*(1), 117–140.

Walker, R. W. (2011). Environmental regulation and labor reallocation: Evidence from the Clean Air Act. *American Economic Review*, *101*(3), 442–447.

Wargocki, P., Wyon, D. P., & Fanger, P. O. (2000). Productivity is affected by the air quality in offices. *Proceedings of Healthy Buildings*, *2000*(1), 635–640.

Weil, D. (1996). If OSHA is so bad, why is compliance so good? *The RAND Journal of Economics*, *27*(3), 618–640. https://doi.org/10.2307/2555847

Well, D. N. (2007). Accounting for the effect of health on economic growth. *Quarterly Journal of Economics*, *122*(3), 1265–1306.

WHO. (2010). *Healthy workplaces: A model for action*. World Health Organization.

World Bank. (2017). *GDP deflator: Linked series*. World Bank Group.

World Integrated Trade Solution. (2016). *Vietnam trade statistics*. Retrieved from https://wits.worldbank.org/CountryProfile/en/VNM

Wyon, D. P. (2004). The effects of indoor air quality on performance and productivity. *Indoor Air, Supplement*, *14*(Suppl. 7), 92–101.

Zivin, J. G., & Neidell, M. (2012). The impact of pollution on worker productivity. *American Economic Review*, *102*(7), 3652–3673.

How to cite this article: Filippini M, Srinivasan S. Investments in worker health and production: Evidence from Vietnam. *Econ Transit Institut Change*. 2022;30:211–235. https://doi.org/10.1111/ecot.12273

APPENDIX

TABLE A1 Average health capital and labour force by industry

Industry	Observations	Average value of health capital (VND)	Average value of health capital (USD)	Average size of labour force
Food and beverages	792	24.1 million	1,038.30	13.33
Tobacco	1	1.47 million	63.37	8
Textiles	129	8.97 million	385.77	31.67
Apparel	204	24.1 million	1,034.64	49.22
Leather	62	17.3 million	745.17	27.89
Wood	305	7.18 million	308.55	16.99
Paper	96	47.8 million	2055.14	48.16
Publishing and printing	124	9.42 million	404.99	10
Refined petroleum	8	2.12 million	91.22	16.63
Chemical products	85	46.7 million	2006.00	27.13
Rubber	229	22.1 million	949.75	33
Non-metallic mineral products	141	12.7 million	547.86	37.04
Basic metals	50	16.2 million	1,710.90	18.16
Fabricated metal products	578	12.2 million	696.85	13.23
Electronic machinery and appliances	105	33.7 million	1,450.46	31.79
Motor vehicles	21	8.63 million	371.25	32.38
Other transport equipment	12	18.5 million	794.31	32.83
Furniture and other equipment	262	7.26 million	312.31	17.16
Recycling	11	10.4 million	446.71	12.27

Notes: The investment amounts are measured at constant (2010) prices, and represent the total amount invested in health (in air quality improvements, heat and noise prevention, and in lighting) per year. An exchange rate of 1 VND = 0.000043 USD is used for computing the health capital values in USD. The sample size is 3,215 observations, comprising the regression sample of the main results in column (3) of Table 2.

TABLE A2 Average health capital per worker and investment rate by province

Province	Observations	Average value of health capital (VND)	Average value of health capital (USD)	Average size of labour force
Hanoi	460	14.2 million	609.89	24.05
Phu Tho	126	16.9 million	726.71	11.43
Ha Tay	419	4.34 million	186.47	18.83
Hai Phong	407	17.4 million	746.48	23.90
Nghe An	405	7.6 million	327.00	15.77
Quang Nam	176	21.9 million	897.39	10.85
Khanh Hoa	70	13.7 million	588.41	30.3
Lam Dong	26	8.56 million	368.05	20.88
Ho Chi Minh City	1,015	30.6 million	1,314.71	27.23
Long An	111	8.95 million	384.97	14.91

Notes: The investment amounts are measured at constant (2010) prices, and represent the total amount invested in health (in air quality improvements, heat and noise prevention, and in lighting) per year. An exchange rate of 1 VND = 0.000043 USD is used for computing the health capital values in USD. The sample size is 3,215 observations, comprising the regression sample of the main results in column (3) of Table 2.

TABLE A3 Robustness checks

Model	Depreciation	Respondent and firm controls	Two main industries	Rest of the industries
Column	(1)	(2)	(3)	(4)
Log of value of health capital		0.070***	0.080***	0.074***
		(0.0004)	(0.011)	(0.007)
Log of value of capital	0.164***	0.159***	0.147***	0.174***
	(0.004)	(0.0005)	(0.009)	(0.006)
Log of total labour force	0.831***	0.751***	0.813***	0.800***
	(0.001)	(0.0004)	(0.003)	(0.007)
Log of value of depreciated health capital	0.043***			
	(0.009)			
Whether male		0.004		
		(0.002)		
Whether college educated		0.125***		
		(0.0004)		
Whether firm is a household enterprise		−0.223***		
		(0.0003)		
Age of firm		0.008***		
		(0.0003)		
Age of respondent		−0.002***		
		(0.0006)		
Observations	2,768	3,213	1,370	1,845

Notes: All specifications include industry-year fixed effects, province-year fixed effects and a general time trend. Regression sample comprises firms with manufacturing as the main production sector that do not change their location over the duration of the sample, and that invested a positive amount in health capital.

*, **, and ***respectively denote significance at the 10%, 5% and 1% levels. The coefficients of the constant are not reported.