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# Working Paper Worker Training and Quality Competition

GLO Discussion Paper, No. 137

**Provided in Cooperation with:** Global Labor Organization (GLO)

*Suggested Citation:* Bilanakosa, Christos; Heywood, John S.; Sessions, John; Theodoropoulos, Nikolaos (2017) : Worker Training and Quality Competition, GLO Discussion Paper, No. 137, Global Labor Organization (GLO), Maastricht

This Version is available at: https://hdl.handle.net/10419/170708

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# **Worker Training and Quality Competition**

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**Abstract:** We uniquely examine the relationship between firm-sponsored training and product quality competition. Using an oligopolistic model of both price and quality competition, we show that an increase in the sensitivity of demand to product quality will strengthen firms' incentives to train their workforce. Cross section, panel and instrumental variable estimations confirm that British establishments provide more intensive training when their competitive position is more sensitive to product quality. A variety of robustness checks and changes in variable definitions leave this confirmation in place.

**JEL:** L13, L15, M53. **Keywords:** Training, Product Quality, Demand Sensitivity, Competition

**Acknowledgements:** We acknowledge the Department of Trade and Industry, the Economic and Social Research Council, the Advisory, Conciliation and Arbitration Service and the Policy Studies Institute as the originators of the Workplace Employee Relations Survey data, and the Data Archive at the University of Essex as the distributor of the data. None of these organizations bears any responsibility for our analysis and interpretations of the data. We thank participants at the Fourth World Conference SOLE/EALE Meetings (Montreal 2015) and the Centre for Vocational and Educational Research (CVER) Annual Conference (London School of Economics 2017) for useful comments and suggestions. We are also indebted to John Forth for invaluable data advice and to Jack Lucchetti for sharing his instrumental variable interval regression code in Gretl. The normal disclaimer applies.

# 1. Introduction

Introductory economics makes clear that a firm's demand for labor is derived from the demand for its product. An increase in the latter raises the marginal revenue product of labor and so increases the firm's demand for labor. Yet, in many markets, consumers care not only about price but also about product quality. For instance, Baldwin and Harrigan (2010) argue that if consumers care enough about product quality, then goods with the highest observed prices will be the most competitive because their quality-adjusted price is lower. In a follow up paper Baldwin and Ito (2011) find that fully 50 to 60 percent of exports from four large European exporters (Germany, France, Britain, Italy) should be classified as high quality goods. Given the evident demand for quality, we show that it generates a derived demand for improved labor quality and so induces firms to provide more worker training.

The extent to which firms compete by lowering price or increasing quality depends on customer preferences and the nature of the good [Shaked and Sutton (1982), Shapiro (1983), Allen (1984), Banker et al. (1998), Chioveanu (2012)]. Yet, when sales are highly sensitive to quality, firms will demand high quality inputs including labor. This seems likely to require substantial firm-provided training to improve labor quality. Greater training (as opposed to more education) seems especially likely as each firm has unique processes, products and customers that suggest a tight connection between firm-sponsored training and product quality.

Increased worker training as a response to needed product quality fits with the struggles firms actually face. The 2012 Foxconn strike in China revolved, in part, around whether or not workers were provided the training requisite for the exacting quality standards imposed by Apple [China Labor Watch (2012)].<sup>1</sup> Similarly, Nike works explicitly with

<sup>&</sup>lt;sup>1</sup> As of 2015, Apple Inc. was the world's largest company by market capitalization and was also identified by Fortune in 2016 as the "world's most admired company" based, in part, on the quality of its products.

contractors in its supply chain to ensure that they 'provide workers the skills and abilities needed to manage production' and 'to produce at the very highest quality' [Nike (2014)]. More generally, researchers have examined "customer satisfaction" as a measure of quality and argue that it is related to training as part of a successful management strategy [Rogg et al. (2001)]. Thus, in markets where firms regard their customers as sensitive to quality, training appears critical.

In what follows we present a simple model of oligopolistic competition in which the demand faced by each firm is sensitive to both prices and relative product quality. We assume that appropriate firm-provided training can enhance workers' skills and thus increase product quality through, for example, improved workmanship and service. We characterize the optimal choices of price and training intensity and show that an increase in the sensitivity of demand to relative quality increases the profit-maximizing level of training investment.

Our empirical analysis uses British establishment data to test the association between employer-provided training intensity and the importance of competing on product quality. In cross section, panel and plausible instrumental variable estimations we show that the more important is product quality for competitive success, the greater is training intensity. Our data allow us to identify training that is specifically associated with quality control and provides several alternative variable definitions that allow for robustness tests. It also lets us perform a counterfactual analysis that looks at price competition. The pattern across all these tests suggests a genuine link between quality and training. Thus, we argue that investments in employee training can improve product quality and firms that compete vigorously on quality find such investments particularly profitable.

The paper is organized as follows: Section 2 reviews related literature to motivate our contribution. Section 3 sets out a theoretical framework implying that increased training may

result from increased sensitivity of demand to relative product quality. Section 4 discusses our data and empirical methodology. Section 5 presents our empirical results and explores their robustness across different types of training and alternative variable definitions. Section 6 collects final comments and suggests additional research.

# 2. Motivation and Related Literature

Our hypothesized link between greater competition on product quality and investments in worker training has not been a major focus of past literature. Yet, there do exist substantial literature branches on the nature of competition over quality as well as on the determinants of worker training. In what follows, we first give a flavor of those branches with an emphasis on the potential role of increased competition in generating both product quality and worker training. We then focus on the much more limited field of research arguing for a transfer of quality from inputs to outputs as it frames our hypothesis on training.

Consumers frequently value the quality of products and firms respond. This *vertical differentiation*, in which consumers agree that some products are 'better' than others [Gabszewicz and Thisse (1979)], differs from *horizontal differentiation* in which consumers disagree when ranking ostensibly 'similar' products [Lancaster (1990)]. The prevailing, but not unanimous, view is that more competitive markets spur firms to improve product quality. In particular, firms increase quality if greater competition increases the elasticity of demand with respect to quality sufficiently more than the elasticity of demand with respect to price. However, even when consumers are more responsive to quality, a substantial fall in price can lead to lower quality. In the longer run, competition has an ambiguous effect on product quality depending upon whether the emergence of additional supply renders consumers more

or less responsive to differences in quality as compared to differences in price.<sup>2</sup>

The theoretical relationship between product market competition and employer training appears highly dependent upon assumptions. Competition may reduce potential rents from training while at the same time increase the incentive for firms to innovate and thus train workers [Aghion et al. (2005)]. Competition may also affect a union's bargaining power and its ability to negotiate over training [Boheim and Booth (2004)]. Three recent theoretical contributions predict a positive [Bassanini and Brunello (2011)], negative [Gersbach and Schmutzler (2012)] and ambiguous [Lai and Ng (2014)] correlation between product market competition differs among these contributions, the empirical evidence also remains far from settled. Some studies find no relationship between competition and firm-sponsored training [Görlitz and Stiebale (2011), Picchio and Van Ours (2011)], whereas others find a positive correlation [Autor (2001), Lai and Ng (2014), Bassanini et al. (2007), Bassanini and Brunello (2011)] or even a negative one [Bilanakos et al. (2017)].

This description makes clear that any empirical investigation must control for product market competition over prices or quantities. Intensified product market competition might influence both the intensity of competition over quality and the extent of training. Failure to control for such competition could generate serious omitted variable bias. As we will see, the extent of such bias does not appear to be substantial, at least in our data, since estimations with and without such controls appear very similar.

Our investigation into the relationship between product quality and firm-sponsored training can be seen as part of the theoretical view that producing quality products requires a 'quality-transfer' from inputs to output [Bacchiega and Minniti (2015)]. This view is reflected in a long line of work in international trade which assumes that country factor endowments in

 $<sup>^{2}</sup>$  See, for example, the early work by Dorfman and Steiner (1954) and, more recently, Dranove and Satterthwaite (1992). For a review of the ambiguous relationship between competition and the quality of healthcare, see Propper et al. (2008).

labor quality are key determinants of final product quality [see, for example, Keesing (1966), Findlay and Kierzkowski (1983), Leamer (1984), Webster (1993), Oulton (1996), Schott (2004)]. In macroeconomics, Stokey (1991) develops a dynamic model where labor with more human capital produces higher quality goods so as to study the equilibrium growth rate of an economy. In the context of industrial economics, Gabszewicz and Turrini (1999, 2000) show theoretically that firms produce high or low quality goods depending respectively upon whether the available amount of skilled labor is abundant or scarce. They imagine an endogenous supply of qualified labor but assume that workers alone choose whether to invest in human capital or remain unskilled. As far as we are aware, our study is the first to investigate the relationship between endogenous firm-sponsored training, which creates labor quality, and the sensitivity of demand to final product quality.

Our model contributes to the literature examining the link between product quality and firm profitability [see, for example, Allen (1984), Shapiro (1983), Klein and Leffler (1981), Kranton (2003) and Matsa (2011)] as well as to the wider literature focusing on the determinants of employer-provided training [Booth and Snower (1996), Acemoglu and Pischke (1998, 1999), Stevens (1994, 2001), Leuven (2005)]. In particular, several recent works examine how the extent of price or quantity competition influences firms' willingness to train their workforce - see, for example, Gersbach and Schmutzler (2012) and Bilanakos et al. (2017). We enrich this branch of the literature by exploring the independent role of quality competition in determining employers' training incentives.

Empirical studies on the association between labor quality and product quality usually proxy quality by price [Wolinsky (1983), Milgrom and Roberts (1986)]. Thus, they test whether firms producing higher priced products employ higher paid workers [see, for example, Abowd et al. (1996)]. In one such study, Kugler and Verhoogen (2012) provide new insights into the well-known pattern that larger plants pay higher wages. They confirm that larger plants both pay higher wages and charge higher product prices but they also demonstrate that larger plants use higher priced material inputs as well. They interpret this as evidence that larger plants produce higher quality products by employing higher quality inputs. Not examined in any of the studies on prices and wages is the extent to which quality labor is purchased or, instead, created through employer provided training.

In cross-sectional estimates, we find that increased competition on quality is associated with more extensive training (longer average duration). This might be considered only a result of sorting since unmeasured establishment characteristics, such as product specifications or technology, could drive both greater competition on quality and intensified worker training. In response, we use panel data to hold constant establishment fixed effects and still show that greater competition on quality remains associated with greater training intensity. As it might still be thought that competition on quality remains endogenous, we implement an instrumental variable strategy showing that both the cross-section and panel estimates remain robust. We also examine training specifically associated with quality control and confirm the general pattern. We attempt to validate our measure of competition on quality and explore alternatives. Throughout a series of tests we find a durable, consistent and sizeable positive relationship between the importance of competition on quality and the intensity of firm-sponsored worker training. As but a single example of these robustness tests, we perform a counterfactual analysis where we find that when establishment managers claim they compete primarily on price, they report a far smaller intensity of training. Saving greater description for the empirical results, we now turn to our theoretical model.

# **3. Theoretical Model**

#### 3.1 Setup

We consider an oligopolistic industry with two firms (indexed by i=1,2) producing a good that is both horizontally and vertically differentiated. The price and quality of good i are  $p_i$ and  $s_i$  respectively. We extend Dixit (1979) and Singh and Vives (1984) in a way similar to Banker et al. (1998) but assume a linear setting in which the demand faced by firm i depends on prices and relative quality:

$$q_i = \alpha - \beta p_i + \gamma p_j + \lambda (s_i - s_j), \ i, j = 1, 2, i \neq j$$

$$\tag{1}$$

where  $\beta > \gamma > 0$  (i.e. goods are imperfect substitutes) and  $\lambda > 0$  represents the sensitivity of demand for good *i* to an improvement of its quality relative to the quality of good *j*. The marginal production cost for both firms is c > 0. Each firm *i* chooses the level of training,  $I_i$ , to provide its workforce at a cost given by the function  $g(I_i) = \delta I_i^2/2$ , where  $\delta > 0$ . As in Bacchiega and Minniti (2015), the quality of the good offered by firm *i* depends on the skill level of its workforce as determined by the amount of training ( $s_i = I_i$ ). For expositional simplicity, we assume that workers receive a constant wage equal to their reservation wage that is normalized to zero.<sup>3</sup> Therefore, the profit of firm *i* is:

$$\pi_i = (p_i - c)q_i - g(I_i) \tag{2}$$

#### 3.2 Subgame Perfect Equilibrium

The game between the two firms unfolds as follows. In stage 1, both firms simultaneously choose their training levels (thus also determining their brand qualities) and in stage 2 they set prices in a Bertrand-style sub-game. The equilibrium is derived through backward induction. In stage 2, each firm *i* sets  $p_i$  so as to maximize  $\pi_i$  subject to the demand function in (1), implying the reaction functions:

<sup>&</sup>lt;sup>3</sup> The addition of workers' participation constraints or the introduction of an explicit wage bargaining stage does not qualitatively affect the results of the model.

$$p_i(p_j) = \frac{\alpha + \beta c + \gamma p_j + \lambda(s_i - s_j)}{2\beta}$$
(3)

Solving this system yields the second-stage equilibrium prices,  $p_i^B$ , which can then be used to deduce the associated quantities,  $q_i^B$ , and profits,  $\pi_i^B$ :

$$(p_i^B, q_i^B, \pi_i^B) = \left(\frac{a + \beta c}{2\beta - \gamma} + \frac{\lambda(s_i - s_j)}{2\beta + \gamma}, \beta \left(\frac{[\alpha - (\beta - \gamma)c]}{2\beta - \gamma} + \frac{\lambda(s_i - s_j)}{2\beta + \gamma}\right), \frac{(q_i^B)^2}{\beta} - g(I_i)\right) \quad (4)$$

In stage 1, each firm *i* chooses the training level  $I_i$  so as to maximize  $\pi_i^B$  by taking into account that  $s_i = I_i$ . Under the concavity condition  $\delta \ge \delta = 2\beta R^2 / (2\beta + \gamma)^2$ , the reaction functions now are:

$$I_{i}(I_{j};\lambda) = \frac{2\beta\lambda}{\delta(2\beta+\gamma)^{2} - 2\beta\lambda^{2}} \cdot \left[\frac{(2\beta+\gamma)[\alpha - (\beta-\gamma)c]}{2\beta - \gamma} - \lambda I_{j}\right]$$
(5)

where  $\partial I_i / \partial I_j < 0$  implies that firms' training decisions are strategic substitutes [Bulow et al. (1985)]. Solving this system yields the (symmetric) subgame perfect equilibrium levels of training:

$$I_i^* = \frac{2\lambda\beta[\alpha - (\beta - \gamma)c]}{\delta(4\beta^2 - \gamma^2)} \tag{6}$$

The relationship between training and sensitivity of demand to product quality is summarized in the following Proposition.

**Proposition**. Increasing sensitivity of demand to relative product quality increases training:  $\partial I_i^* / \partial \lambda > 0$  for all  $\lambda > 0$ . The intuition behind this result can be better understood by inspecting the Nash equilibrium condition:

$$I_i^*(\lambda) = I_i(I_i^*(\lambda);\lambda) \tag{7}$$

Differentiation of (7) implies:

$$\frac{d\mathbf{I}_{i}^{*}}{d\lambda} = \underbrace{\frac{\partial I_{i}(I_{j};\lambda)}{\partial \lambda}}_{\mathcal{B}\mathcal{E}} + \underbrace{\frac{\partial I_{i}(I_{j};\lambda)}{\partial I_{j}} \cdot \frac{d\mathbf{I}_{j}^{*}}{d\lambda}}_{S\mathcal{E}}$$
(8)

As shown by the last equation, an increase in  $\lambda$  has an overall impact on  $I_i^*$  which can be decomposed into two opposing effects typically present in games with strategic substitutes [Roy and Sabarwal (2010)]. The first term on the right-hand side of (8) represents a positive direct effect (DE) which tends to increase firm *i*'s equilibrium training strategy by increasing its best response to a given strategy chosen by its competitor (firm *j*). The second term is a negative strategic effect (SE) through which an increase in  $\lambda$  also tends to increase the equilibrium strategy of firm *j*, thus having an adverse effect on *i*'s training decision due to strategic substitution. In our symmetric formulation, we have:

$$DE = \frac{2\beta(2\beta + \gamma)[\alpha - (\beta - \gamma)c]}{(2\beta - \gamma)[\delta(2\beta + \gamma)^2 - 2\beta\lambda^2]} > |SE| = \frac{4\beta^2\lambda^2[\alpha - (\beta - \gamma)c]}{\delta(4\beta^2 - \gamma^2)[\delta(2\beta + \gamma)^2 - 2\beta\lambda^2]}$$
(9)

Since the direct effect always dominates the strategic effect, any increase in the dependence of product demand on relative quality strengthens the firms' training incentives, as stated in the Proposition above.

In the following sections, our empirical analysis examines this theoretical prediction. While our theoretical model is stylized, it makes clear the association between training and demand sensitivity to quality. In the on-line Appendix we have generalized the model above to allow cost asymmetry between the two firms. Critically, the positive relationship between training and demand sensitivity to quality still holds within broad parameter ranges giving us further support as we turn to the empirical estimation.

### 4. Data and Empirical Methodology

We draw data from the Workplace Employment Relations Surveys (WERS). These surveys provide large scale, statistically reliable information about a broad range of employment practices across the British economy. We use the 2004 and 2011 cross-sections and a smaller panel survey across those years.

#### 4.1 WERS Data

The 2004 and 2011 cross-sections represent the fifth and sixth instalments of a Governmentfunded survey series of British workplaces. The sample comes from a random draw of the Interdepartmental Business Register, generally considered to be the highest quality UK sampling frame. The surveys are stratified by workplace size and industry with larger workplaces and some industries overrepresented [Kersley et al. (2006)]. As a consequence, we routinely use establishment weights to be representative of the sampling population. We rely primarily on the 'Management Questionnaire' (a face-to-face interview with the most senior manager who has day-to-day responsibility for personnel matters) as it provides information on training and on the extent of quality competition, thus allowing us to construct a panel dataset. This critical question on quality competition was not asked prior to the 2004 survey. We do utilise the 'Employee Questionnaire' for robustness checks and associated variable construction. The survey population includes all British workplaces except private households and those in primary industries.

The response rates for 2004 and 2011 are 64% and 46%, yielding 2295 and 2680 establishments respectively. The decline in response rates reflects prevailing trends in business surveys [see van Wanrooy et al. (2013)]. We limit attention to establishments that

trade externally by providing goods and services to the general public and/or to other organizations. This excludes establishments that trade internally or are administration offices. We also drop observations with missing data on training or product quality competition. The resulting sample sizes are 1554 and 1688 establishments for 2004 and 2011 respectively. The 2011 WERS followed a subset of workplaces that also participated in the 2004 survey. After our sample restrictions, we retain a panel of 439 establishments (878 observations) observed in both 2004 and 2011.

The surveys are attractive as they identify training intensity and the importance of quality competition while also providing a wide range of controls for the nature of the workforce, occupational composition and employer characteristics. The two cross-sections allow us to follow the hypothesized relationship over time and the panel element allows us to remove time invariant unobserved firm heterogeneity.

The core measure of training intensity asks managers if experienced employees in the largest non-managerial occupational group were given time off from their normal daily work duties to undertake training over the past 12 months. If managers answered yes, then they were subsequently asked: '*If any training, on average, how many days of training did experienced employees in the largest non-managerial occupational group undertake over the past 12 months?*' Managers are provided a six-scale option to code their responses. The options are ordinal: 'No time' (1), 'Less than one day' (2), '1 to less than 2 days' (3), '2 to less than 5 days'(4), '5 to less than 10 days'(5), and '10 days or more'(6). All establishments which responded that they did not provide training are identified as 'No time'. Appendix Table A1 provides the distribution of responses and shows the variation of training intensity across establishments, a pattern that is reasonably stable over time. In the 2004 survey around the same percentage of establishments (almost fourteen percent) provided 'No time' and '10 days or more'. Training duration, as opposed to participation, fits more closely with our

theoretical measure of training intensity and is typically recognized as a stronger indicator of skill formation [Green et al. (2013)].

Managers identify the importance of product quality by responding to the following question: 'If in the trading sector and trading externally, to what extent would you say that the demand for your (main) product or service depends upon offering better quality than your competitors?' Managers provide an ordered response from 1. 'Demand does not depend at all on quality' to 5. 'Demand depends heavily on superior quality'. Appendix Table A2 provides the distribution of responses, again showing variation across establishments but a stable pattern between surveys. While five per cent or less of the managers responded that 'Demand does not depend at all on quality', approximately forty three per cent said that 'Demand depends heavily on offering superior quality'. In what follows, we identify these five categories as 'Quality Importance 1' through 'Quality Importance 5'.

This survey question appears closely aligned with the crucial parameter ( $\lambda$ ) of the theoretical model as it measures the dependence of demand on relative brand quality. At best, the responses should proxy the establishment level sensitivity of demand to product quality with larger numbers reflecting greater demand sensitivity. At worst, the responses still provide the managers' perspective on the extent to which quality improvements generate a competitive advantage. Importantly, this managerial perception contains valuable information as it closely reflects the objective characteristics of the establishment with regard to product quality. The surveys indicate (1) whether or not the strategic plan of the establishment includes maintaining and improving product quality; (2) whether detailed records of product quality are kept; and (3) whether product quality measures are routinely targeted. Table 1 shows that as the main quality importance measure increases from 1 to 5, the likelihood of each of these objective characteristics increases monotonically. Managers who perceive quality as important tend to work in establishments with greater activity and expenses

oriented toward high quality.<sup>4</sup> Thus, we argue that exploring the relationship between the intensity of training and the ordered managerial response sheds light on whether or not firms use training to 'transfer quality' from labour inputs to output. We will return in robustness checks to the potential concern that this managerial response may be overly subjective.

#### <<Table 1 about here>>

In examining the relationship between training intensity and the importance of product quality we control for an extensive set of other covariates. We describe this process in the next subsection and note that the descriptive statistics for all the covariates used in the analysis are reported in Table OA1 in the on-line Appendix.

#### 4.2 *Empirical Methodology*

Since the dependent variable is an underlying continuous variable where we only observe an indicator for a particular range, we initially estimate an ordered probit model. The categorical measure of training intensity depends on the importance of product quality and on suitable controls. We begin with cross-sectional estimates for each of the two years. In a baseline estimate we start with a specification containing more nearly exogenous controls but show that the critical results change little by substantially increasing the number and variety of control variables. The first specification includes controls for the workforce and occupational composition of the establishment. We include controls for the percentage of female employees [Green and Zanchi (1997)], the percentage of part time employees, the age structure and the share of the workforce in each of eight occupational groups [Brunello and De Paola (2008)]. We also add seven dummy variables identifying the largest non-managerial occupational group in the establishment as well as industry and region dummies to capture

<sup>&</sup>lt;sup>4</sup> Indeed, probit estimates including a large list of establishment characteristics show that the manager's perception of the importance of quality continues to be a significant correlate with each of the above three product quality activities. These estimates are available upon request.

variation of training across industries and regions. We show that in both cross sections those establishments that face a higher sensitivity of demand to product quality offer more training.

After examining the magnitude of the relationship between training intensity and demand sensitivity to quality, we expand our controls recognizing their possible endogeneity. Vives (2008) makes clear that the nature of competition influences workplace innovation and so may itself influence some of the controls as well as the extent of training. Thus, the stability of our estimates is important as it reduces the probability that endogeneity drives our results.

In adding controls, we take into account that there may be substantial fixed costs in establishing formal training and that large establishments can spread out these costs across many workers [Black et al. (1999)]. Moreover, such formal training programs may take time to develop and may reflect the permanence and scope of the establishment. Thus, we control for the (log) number of employees and for whether the establishment is part of a larger organization (i.e. multi-establishment) or a single independent establishment (omitted category: *sole UK establishment of a foreign organization*). In this estimate we also add the percentage of employees who are trade union members [Boheim and Booth (2004)].<sup>5</sup>

In the third estimate we retain all the controls from the previous estimates and add the number of competitors faced by the establishment, i.e. few (less than 5) or many competitors (omitted category: *none, establishment dominates the market*). This reflects previous empirical work suggesting that a more concentrated product market increases the profitability of training investment [Bilanakos et al. (2017)].

Since the respondent manager is responsible for human resource issues and might not be best placed to assess product quality, we add two dummy variables capturing the gender of

<sup>&</sup>lt;sup>5</sup> There are three continuous variables with a large number of missing observations. These include the percentage of employees in the age groups 18-21 and above 50 as well as the percentage of employees who are trade union members. Instead of dropping important information by deleting these observations list wise, we have replaced missing observations with zeros and added in our specification respective dummy variables for the missing observations.

the manager and if the respondent manager is the owner of the firm [Bloom and Van Reenen (2007a, 2007b)]. The fifth estimate simply reproduces the fourth but uses OLS and treats training as a cardinal count value from 0 to 5. We do this both to get a quick estimate of the associated magnitudes and, more importantly, to set the stage for panel and IV estimates that necessarily rely on linear estimates.

We estimate all specifications for both cross-sections.<sup>6</sup> Using the panel, we estimate analogous fixed-effect ordered probit models [Greene and Henscher (2010)]. The fixed-effect ordered probit model holds constant time invariant characteristics of the establishment but brings with it an incidental parameter problem. We therefore provide a variety of alternative fixed effect estimation techniques that each confirm the pattern of results and are not subject to the incidental parameter problem.

We also recognize that the critical independent variable measuring the sensitivity of demand to quality might be endogenous. In response, we utilize an industrial aggregation technique [Fisman and Svensson (2007), Lai and Ng (2014)] to generate a plausible instrumental variable strategy. The available diagnostics seem reassuring and both the cross-section and the fixed effect results persist in instrumental variable estimates.

#### 5. Empirical Results

#### 5.1 Ordered Probit Analysis

The first column of Table 2 presents the baseline estimate of the determinants of training intensity in 2004. The coefficients on quality importance are positive and monotonically increase, suggesting that establishments engage in more training as quality becomes more

<sup>&</sup>lt;sup>6</sup> In robustness tests we also utilise the employee questionnaire in WERS to construct the average education of the establishment's workforce [i.e. percentage of the workforce with: GCSE (grades D-G), GCSE (grades A-C), 'A'-levels, first degree (BSc, BA), higher degree (MSc, MA, PhD) and other academic qualifications (omitted category: percentage of employees with *no academic qualifications*)]. We merge these establishment level variables in the management using the unique establishment identifier. The reason we do not include these variables in the main sample is that they substantially reduce sample sizes. We lose 405 observations in the 2004 sample and 510 observations in the 2011 sample. When adding these variables to the fourth specification, the estimated coefficients on quality importance retain their magnitude. These results are reported in the on-line Appendix Table OA2.

important. Moreover, the two categories that indicate the greatest importance for quality have the largest coefficients and are significant, implying that training intensity is above that in establishments that place no importance on quality. Column 1 also shows that establishments with higher percentages of part-time employees and employees over 50 years old train less intensively [Booth (1991)]. In contrast, establishments with a higher number of young employees train more intensively.

Column 2 adds firm characteristics as well as the percentage of employees who are trade union members and shows that the magnitude of estimated coefficients for the two higher quality importance categories presented in column 1 remains almost the same. The estimates also indicate that establishments train more intensively if they have more employees and if more of their employees are union members. In contrast, single independent establishments train less.

#### <<Table 2, around here>>

In column 3 we add two indicators capturing the number of competitors faced by the establishment. The estimates show that establishments facing a higher number of competitors train less intensively. This result matches Bilanakos et al. (2017), who find that dominant firms invest in more training, and fits earlier evidence showing a broadly positive relationship between industrial concentration and measures of labour quality [Belman and Heywood (1990)]. Including the new controls does not alter the coefficients on the measures of quality importance.

The final estimate adds indicators of the respondent manager's characteristics. The gender of the manager does not affect training intensity, but establishments where the manager is also the owner offer less training. This fits Bloom and Van Reenen (2007a, 2007b) who argue that owners might be poor managers, especially when firms are inherited [see also Caselli and Gennaioli (2013)]. However, this new relationship does not

fundamentally change the role of product quality competition. If anything, the coefficients of the two higher demand sensitivity categories increase in magnitude while retaining the monotonic relationship with training intensity.

Using these estimates from column 4, we compute the average marginal effects where all covariates are evaluated at their means. These reveal that indicating quality importance 4 decreases the probability of being in the lowest training category by 0.143 while indicating quality importance 5 reduces that probability by 0.189. Similarly, indicating quality importance 4 increases the probability of being the highest training category by 0.136 while indicating quality importance 5 increases that probability 0.169. Column 5 presents OLS estimates and largely confirms the evidence from the ordered probit suggesting that the highest quality category is associated with an increase of 0.31 of a training intensity category relative to the lowest quality category.

In Table 3 we reproduce the series of estimates using the 2011 cross-section. The pattern of significant controls remains very similar. Critically, the role of quality competition very closely mimics that in the 2004 survey. All coefficients across all specifications are positive and increase monotonically in magnitude. Adding the controls again appears to strengthen the relationship. Across all columns the coefficients for the two categories indicating the greatest importance for product quality take the largest values and are all significantly different from zero (recall that no importance for quality is the excluded category). The magnitude of the results appears to have grown as shown by the larger OLS coefficients in 2011 than in 2004 and as confirmed by larger marginal effects for the probit in 2011. A full set of marginal effects are available for both years and all specifications in the on-line Appendix Table OA3.

<<Table 3, around here>>

#### 5.2 Panel Estimates

Table 4 moves to a balanced panel of 439 establishments observed in both 2004 and 2011. Summary statistics in Tables A1 and A2 suggest that these establishments match the distribution of training and the importance of product quality found in the cross-sections. They also broadly match the other characteristics of the establishments reported for the two cross-sections in the on-line Appendix Table OA1.

In the fixed effect estimates, the establishments that change their evaluation on the importance of quality identify the estimation. The number of such changes is sufficiently high over the seven years to get meaningful estimates. Of the 439 establishments in the panel, 268 changed their evaluation on the importance of quality with 133 increasing and 135 decreasing their evaluation.<sup>7</sup>

#### <<Table 4, around here>>

We first present a pooled estimate without establishment fixed effects but on the panel sample. These results are presented in column 1 and reveal the familiar pattern of establishments training more if reporting that demand depends heavily on product quality. As was evident in the two cross sections, the coefficients increase monotonically in magnitude as the sensitivity of demand to quality becomes higher. The point estimates of the two higher quality importance variables are comparable to the two earlier cross-section estimates, suggesting that the establishments in the panel are not an unusually selected sample. As an example, moving from an establishment where product quality has no importance to either of the two highest categories of importance greatly influences the probability of offering training of '10 days or more'. To be sure, the probability increases by 7 percentage points compared to 4 percentage points in the 2004 sample and 5 percentage points in the 2011 sample.

<sup>&</sup>lt;sup>7</sup> This is matched by similar variation in training intensity, with 161 establishments reporting greater intensity and 155 establishments reporting reduced intensity.

As in the two cross sections, we also present results from an OLS model in the pooled sample. The estimates in column 2 show that the magnitudes of the coefficients of the two higher demand sensitivity categories are larger in magnitude than the respective cross-sectional estimates. However, the monotonic relationship with training intensity remains.

Column 3 presents the results from a fixed effects ordered probit model on the same panel. The point estimates are generated by the within establishment variation in quality competition and present the closest analogue to the ordered probits presented for the two cross-sections. The relevance of the incidental parameter problem and the advantages and limitations of the fixed-effect ordered probit are discussed in Greene (2001) and Greene and Henscher (2010). The point estimates suggest that establishments provide more training as they move from a lower to a higher category of quality competition. The point estimates change modestly as a result of the fixed effect estimates (compared to the pooled estimate on the same sample). Yet, to the extent that unmeasured time invariant characteristics influence the cross-section estimates, they do not seem to generate a routine upward bias.

We next alter the functional form of our fixed effect estimate. First, we present results from an OLS fixed effects model. Column 4 shows that the estimated coefficients are higher in magnitude than the cross-section equivalents and retain their monotonic behaviour as well as their statistical significance. We then imagine that the ordered categories measuring the intensity of training represent a count variable from zero to five. While not as accurate as simply recognizing that they represent ordered categories, this strategy allows estimation of a fixed-effect Poisson regression which does not suffer from incidental parameter concern [Hilbe and Greene (2008)]. The results from this exercise are presented in column 5. The estimated coefficients retain their signs and statistical significance.

As described above, the dependent variable measuring training intensity is grouped into intervals as the duration falls into one of six categories. Therefore, a variant of the

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ordered probit is the interval regression model that allows for truncation beyond the maximum number of training days (10 days). Thus, we estimated the cross-section and panel results (with and without establishment fixed effects) using interval regression by constructing an upper and lower threshold of training and setting the truncated number of training days to be 10. The results strongly persist with monotonically increasing coefficients on the quality importance variables and the highest two categories attaining coefficients statistically different from zero. These results are reported in the on-line Appendix Table OA4. Thus, in line with the ordered probit fixed effects, the OLS fixed effects and the Poisson fixed effects specifications, this provides no indication that the cross-sectional finding results from time invariant establishment specific effects.<sup>8</sup>

#### 5.3 *Robustness: Three Extensions*

In this subsection we present three extensions to examine the robustness of the relationship between training and the competitive importance of quality. We start by noting that training can be important for implementing quality control procedures. Thus, if firms compete on quality, establishing such control procedures can be critical in both manufacturing and service [Zeithamal (2000)]. The effective operation of quality control systems involves substantial training both initially and throughout the employment relationship [Lynch and Black (1998)]. We examine whether the role of quality competition remains significant in determining both the targeted training associated with quality control systems and other training not associated with such systems.

The critical question asks those firms that do provide training if this is done for quality control procedures or for reasons other than quality control. These are not mutually exclusive as in both surveys around 39 per cent of establishments provide both types of training. We

<sup>&</sup>lt;sup>8</sup> Recently Baetschmann et al. (2015) have shown that by using a specific data transformation, the fixed effects ordered logit model will not suffer from the incidental parameter problem. We have also estimated this variant and it generates the same pattern yet again (available upon request).

use the training intensity provided from the original question to produce separate estimates by type of training. Thus, in the estimate for quality control training, the nonzero value of training intensity is used only if the firm provides such training.

The estimates for both the 2004 and 2011 cross-sections demonstrate a familiar pattern. The more important product quality is for competing with rivals, the more intensive is worker training. This remains true both for training on quality control systems and for other types of training. While these cross-section estimates are presented in the on-line Appendix Table OA5, we now show the equivalent panel estimates.

#### <<Table 5, about here>>

The estimates show a strong positive relationship for the pooled estimate that broadly matches the cross-sections, indicating that the movers are not an unusually selected sample. The relationship also persists in both fixed effect estimates as shown in columns 3 and 6. The coefficient estimates are larger for the individual types of training than for the general measure in Table 4. Nonetheless, it remains true that the two categories of greatest importance are statistically significant in the fixed effect estimate for quality control training. Thus, this critical type of training becomes more intense when a given establishment faces an increased sensitivity of demand to product quality. Unmeasured but time invariant differences in establishments do not drive the relationship between the competitive importance of quality similar - with monotonically increasing positive coefficients - but here the fixed effect estimates for the categories 2 and 3 also emerge as weakly significant. While the survey structure does not allow us to determine the true intensity for each type of training, this finding remains consistent with both types of training responding to the importance of quality in competition.

The second robustness check returns to the concern that the critical independent variable on quality competition might reflect subjective judgement. Whilst we have demonstrated that the responses correlate with actual quality oriented activities in the firm, one might contest that managers simply inflate the importance of quality competition. Alternatively, managers might view their product as successful regardless of its quality so that those with high quality products report competing on quality is important and those with low quality products report competing on quality is not important. As a way to address these concerns, we exploit another question posed to the managers: "How does your product quality compare to others in your industry?". We include the ordered responses as additional controls in the estimates. We do this under the assumption that the managerial responses to this new question may reflect similar reporting bias as the responses to the original question. If so, including the responses to the new question may help hold constant the bias in the original question.

#### <<Table 6 about here>>

Table 6 shows the ordered probit for both cross-sections as well as for the panel and the panel controlling for fixed effects.<sup>9</sup> The results indicate that all coefficients on the relative product quality variables are positive and increase across categories. This suggests that the higher the reported quality, the higher is training. Yet, only one of the response categories ever reaches statistical significance and thus they do little to change the fundamental result. Training appears to be driven by the importance of quality in competition. This makes sense as a pure monopoly may have either high or low quality but will not feel the spur of competition on quality to increase training. More importantly, it is reassuring that our results do not appear, according to this test, to be largely driven by a reporting bias on the question concerning the competitive importance of quality that is correlated with training.

<sup>&</sup>lt;sup>9</sup>Again, similar results are available for the fixed effect OLS and interval regression estimates.

The third robustness exercise follows a related line of reasoning. If competing on product quality is uniquely important for training, then we should be able to identify a set of firms that compete on other dimensions and find a very different pattern. In particular, WERS asks managers to report the importance of competing on price in an analogous format to our critical quality importance variable. Thus, if stealing demand from rivals depends on low pricing, quality may be irrelevant or even harmful as it raises costs and so makes it more difficult to deal with price competition. According to our argument there should be no or even a negative relationship with training, a costly investment in inputs designed, in part, to improve output quality. We view this exercise as a counterfactual analysis where firms compete on prices rather than on product quality.

#### <<Table 7 about here>>

Table 7 uses exactly the same specification that we have been examining but replaces the ordered importance of quality responses with the ordered importance of price responses. The results are dramatic with each coefficient taking a negative value and with the absolute size of those negative coefficients growing monotonically with the importance of competing on price. In the cross-sections, the pooled sample and the fixed effect estimates, the greater levels of importance have the largest coefficients and are typically statistically significant. This extends to the fixed effect OLS, Poisson and interval regression estimates, all of which are available upon request. Establishments that compete with rivals on price invest less in training. This seems very close to a mirror image of our primary finding that competition on quality generates more training and so helps to confirm that finding. It is not the intensity of competition itself but the competitive importance of quality that drives training. This also helps to support our view that the results on the importance of quality were not generated by a unique reporting bias to that question.

#### 5.4 Endogeneity and IV Estimation

Finally, we recognize that even given the estimations shown, endogeneity could undermine our interpretation. Despite our inclusion of many controls, some establishments may have products or consumer characteristics that make both quality competition and training more likely. Even in the fixed effect estimates there might be unmeasured factors that generate changes both in the extent of quality competition and in the intensity of training. To the extent that this argument is correct, it would require instruments that identify a source of independent variation in the quality competition variable.

While few instrumental variables are perfect, we adopt a strategy based on industrial aggregation [for examples see Fisman and Svensson (2007), Lai and Ng (2014)]. The strategy posits that there are characteristics of the product and its industry that help define the extent of quality competition between firms within that industry. These product and industry characteristics stand as exogenous influences that make it more or less likely that firms within the industry will compete on quality. Simply put, a particular firm is unlikely to find quality important for competition if the other firms in its industry do not. At the same time, it is the individual firm's need to compete on quality, not that of its rivals, that can be anticipated to determine the individual firm's training intensity.

The empirical implementation of this common strategy generates identifying variables that aggregate the quality importance measures. The aggregates (averaged to the proportion in each category) vary by establishment in the industry by excluding the establishment for which they are computed. Thus, the measure is the proportion in the category *for other establishments* in a given establishment's industry.<sup>10</sup>

The estimation uses two stage least squares that treat training as a dependent cardinal count variable from 0 to 5. The first stage consists of four linear probability regressions where the dependent variable each time is the endogenous quality importance variable (zero or one) against all the joint variables and the four aggregated industry proportions (instruments) for the quality importance categories [see Baltagi (2011) p.245]. The second stage returns the four estimated values from the first stage along with the joint variables to the midpoint estimates on training and clusters the standard errors at industry cells.<sup>11</sup>

#### <<Table 8 about here>>

The results are shown in the three panels of Table 8. Panels A and B present the results for the two cross-sections. Columns 1 to 4 report the first stage results. As expected, in each of the first four columns the respective instrument strongly predicts the potentially endogenous variable. Thus, in column 3 of panel A where the dependent variable is quality importance 4, the instrument for quality importance 4 attains a large, positive and significant coefficient. Similarly, in column 4 of panel A where the dependent variable is quality importance 5, the instrument for quality importance 5 again attains a large, positive and statistically significant coefficient. All other instruments take insignificant coefficients. This pattern is reassuring and confidence is further reinforced by the absence of weak instruments [Bound et al. (1995) and Stock et al. (2002)]. An appropriate test for an exactly identified system is given by Stock and Yogo (2005) based on the Cragg and Donald (1993) minimum eigenvalue statistic. In each

<sup>&</sup>lt;sup>10</sup> In order to generate enough observations per industry (especially in the panel) we aggregate establishments into eleven SIC industries: manufacturing, utilities (electricity, gas and water), construction, wholesale and retail, hotels and restaurants, transport and communication, financial services, other business services, education, health and other community services. Descriptive statistics of the industries are reported in Table OA1 in the online Appendix.

<sup>&</sup>lt;sup>11</sup> Estimates retain their statistical significance if we cluster at workplace cells instead.

estimation our estimated statistic exceeds the 10.81 critical value for a model with four endogenous variables and four instruments.<sup>12</sup>

In each cross-section, the second stage shows the familiar monotonically increasing coefficients with the last two significantly different from zero. It is worth comparing the estimated magnitudes with those in the OLS. The cross-sectional estimates in column 5 of Tables 3 and 4 are only modestly larger than the IV estimates in Panels A and B. This suggests the influence of endogeneity may itself be modest. We recognize this conclusion rests not only on the absence of weak instruments but on the independence assumption. The aggregate industry measure IV must be orthogonal to training intensity (conditional on the included controls) and so introduce independent variation in the establishment measure. While this assumption is not directly testable, we can informally include the aggregate industry measures in the OLS estimates in column 5 of Tables 2 and 3. The aggregated categorical responses take positive coefficients in both cross-sections but the coefficient sizes do not monotonically increase and none of these coefficients approaches even weak statistical significance.<sup>13</sup>

Panel C moves to the panel and combines the instrumental variable strategy with a fixed effect estimate. The monotonically increasing pattern of coefficients remains and the coefficient on the greatest level of importance retains statistical significance. The size of that coefficient falls between those estimated by IV in the two cross-sections (although closer to that in the 2004 survey). Again, the test statistic exceeds the critical value suggesting the absence of weak instruments.

As a further robustness check we implement the Limited Information Maximum Likelihood (LIML) estimator proposed by Bettin and Lucchetti (2012). This estimator

<sup>&</sup>lt;sup>12</sup> Stock and Yogo (2005) characterise instruments to be weak not only if they lead to biased IV estimates, but also if hypothesis tests of the IV parameters suffer from severe size distortions. The critical value of 10.81 reflects a Cragg-Donald eigenvalue statistic for which a Wald test at the 5 percent level will have an actual rejection rate of no more than 10 percent.

<sup>&</sup>lt;sup>13</sup> These estimates are available upon request.

generalises interval regression to allow for the presence of endogenous regressors. While the estimator cannot easily incorporate workplace fixed effects, the focus on intervals is potentially important. It essentially examines whether by ignoring the underlying intervals in the training measure, the earlier results may be misleading. The results are reported in the online Appendix Table OA6 and return coefficients closely in line with those reported in Table 8. The coefficients for quality importance 4 and quality importance 5 remain large, ordered and statistically significant across all three datasets. If anything, the coefficients of quality importance 4 and quality importance 5 are larger than those in Table 8. We find it reassuring that the fixed effect, 2SLS estimator does not present a misleading picture by ignoring the underlying intervals.

We again informally examine independence in the panel by including the aggregated IV measures directly into the single equation fixed effect estimate from Table 4. The coefficients show no monotonically increasing pattern and are individually and jointly insignificant with an average p-value exceeding 0.6. Even though not a formal test, one would be concerned if the IV was evidently correlated with the dependent variable.

As mentioned, few instrumental variable strategies are perfect but we take reassurance from these results as they reduce the likelihood that the previous estimates reflect endogeneity. Importantly, it remains evident throughout the estimates that establishments for which quality is more important engage in more training than those for which it is less important.

#### 6. Conclusions

This paper presents and tests the hypothesis that an individual firm that competes on quality will train its workforce more intensively than one that does not. Training is, of course, not the only element of worker quality. Establishments might also simply hire more competent or better educated workers, or use both recruitment and training policies to affect the behaviour of their employees through their career concern incentives [Bar-Isaac and Ganuza (2008)]. Worker quality is also not the only element of input quality. Yet, each establishment has a particular production process, particular non-labour inputs and, often, particular customers. Learning how to produce quality products in these circumstances seems likely to require very specific skills typically taught through training. Thus, we have been concerned with the large literature trying to explain the determinants of training and we emphasise the extent to which the establishment competes on quality.

In our theoretical model we showed that, when training investments improve product quality, an increase in the sensitivity of demand to relative quality will reinforce employers' incentives to train their workforce. This emphasis of the model on demand sensitivity dovetails nicely with the WERS question which asks specifically how much important is product quality in competing with rivals. We used this question to investigate our hypothesis.

In our empirical analysis we routinely found that establishments competing on quality train more intensively. This is true in two establishment level cross-sections when including a very extensive set of sensible controls. And it remains true in several variants of panel fixed effect estimates designed to hold constant time invariant establishment effects.

We conducted a series of robustness exercises that support our basic result. This basic result remains true for training on quality control procedures and for other types of training. It persists when holding constant the managers' perception of their product quality which helped to convince us that quality competition is the key. In a counterfactual analysis we found nearly mirror opposite results showing that establishments which compete with rivals on price do less training, thus suggesting that the key determinant is not competition in itself but specifically competition on quality. Critically, the fundamental relationship still holds when implementing a plausible instrumental variable strategy to control for endogeneity. We recognize limitations of our examination. First, the measure of sensitivity to quality remains the subjective view of the establishment's manager. Yet, we have shown that this subjective measure is correlated with firms' actual activities regarding quality that would seem far more objective. Further, controlling for the same managers' perception of actual quality and examining the role of price competition provide further support to the idea that the subjective view of the manager contains valuable information. Second, we have used a measure of training intensity that may not fully capture the value of what is learned. It certainly does not include informal training or learning by doing. Third, we recognize that an alternative study focusing on individual workers might hold constant individual worker effects and generate different results. Despite these imperfections, it seems sensible that product market characteristics are crucial determinants of training investments and that the intensity of quality competition should be among those determinants. Our robust evidence confirms this relationship and represents an important initial contribution on which further work can build.

Finally, our work fits with the broad idea that firms having to compete on quality will make use of high quality inputs as part of fulfilling this requirement. High quality materials and physical inputs are purchased in markets. Indeed, even more educated workers can be purchased in a market as mentioned. Yet, training seems to be a critical element of worker quality that is often provided by the firm itself.

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		WERS 2004	WERS 2011         Panel 2004-20           (3)         (4)         (5)         (6)         (7)         (8)           Sets targets         Strategic Plan         Keeps records         Sets targets         Strategic Plan         Keeps records           0.382         0.789         0.521         0.314         0.784         0.500           0.536         0.857         0.558         0.404         0.831         0.546           0.540         0.903         0.650         0.469         0.895         0.589           0.547         0.923         0.723         0.567         0.909         0.640           0.615         0.022         0.773         0.626         0.020         0.705		Panel 2004-2011				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Strategic Plan	Keeps records	Sets targets	Strategic Plan	Keeps records	Sets targets	Strategic Plan	Keeps records	Sets targets
Quality importance 1	0.754	0.473	0.382	0.789	0.521	0.314	0.784	0.500	0.500
Quality importance 2	0.811	0.543	0.536	0.857	0.558	0.404	0.831	0.546	0.542
Quality importance 3	0.863	0.592	0.540	0.903	0.650	0.469	0.895	0.589	0.558
Quality importance 4	0.914	0.650	0.547	0.923	0.723	0.567	0.909	0.640	0.573
Quality importance 5	0.929	0.710	0.615	0.932	0.778	0.626	0.930	0.705	0.661

Table 1. Quality Importance and Quality Sensitivity

Notes. In columns 1, 4 and 7 the variable "strategic plan" takes the value of one if the establishment has a strategic plan on improving quality product or service, zero otherwise. In columns 2, 5 and 8 the variable "keeps records" takes the value of one if the establishment keeps records on the quality of product or service, zero otherwise. In columns 3, 6 and 9, the variable "sets targets" takes the value of one if the establishment sets targets on quality of product or service, zero otherwise. Entries are percents. They show the number of ones for each variable in each quality importance category divided by the total number of observations in the respective quality importance category. Descriptive statistics of these three dummy variables are reported in Table OA1 in the on-line Appendix.

Table 2.	Training	Intensitv	and Ouali	tv Sensitivitv -	- WERS 2004

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Ordered	Ordered	Ordered	Ordered	OLS
	probit	probit	probit	probit	
Quality importance 2	0.025	0.065	0.024	0.058	0.081
	(0.142)	(0.143)	(0.145)	(0.146)	(0.199)
Quality importance 3	0.052	0.072	0.043	0.062	0.085
	(0.166)	(0.167)	(0.167)	(0.167)	(0.230)
Quality importance 4	0.178**	0.170**	0.167**	0.183**	0.275**
	(0.081)	(0.082)	(0.082)	(0.082)	(0.112)
Quality importance 5	0.214***	0.213**	0.214**	0.228***	0.310***
	(0.083)	(0.084)	(0.084)	(0.084)	(0.114)
% female employees	-0.100	-0.040	-0.031	0.055	0.060
	(0.144)	(0.146)	(0.147)	(0.156)	(0.211)
% part time employees	-0.973***	-0.873***	-0.903***	-0.909***	-1.160***
	(0.147)	(0.149)	(0.149)	(0.150)	(0.200)
% 18 to 21 year old employees	0.505**	0.484**	0.508**	0.477**	0.566**
	(0.204)	(0.206)	(0.206)	(0.207)	(0.280)
% over 50 year old employees	-0.811***	-0.742***	-0.750***	-0.751***	-1.040***
	(0.170)	(0.173)	(0.174)	(0.174)	(0.231)
Log number of employees		0.155***	0.157***	0.146***	0.199***
		(0.033)	(0.034)	(0.034)	(0.047)
Single independent establishment		-0.385**	-0.3/5**	-0.310*	-0.422*
		(0.176)	(0.177)	(0.178)	(0.242)
Part of a larger organization		0.073	0.089	0.074	0.124
0/i		(0.170)	(0.177)	(0.177)	(0.241)
% union membership		$(0.300^{*})$	0.243	0.194	0.248
Four competitors		(0.130)	(0.138)	(0.139)	(0.217)
rew competitors			-0.160	-0.117	-0.101
Many competitors			(0.157)	(0.138)	(0.164) 0.314*
Many competitors			(0.134)	(0.135)	(0.170)
Manager is male			(0.134)	0.060	(0.179)
Wanager is male				(0.064)	(0.090)
Manager is the owner				-0.362***	-0.450***
Wanager is the owner				(0.090)	(0.118)
Cutoff 1	-1 141***	-0 706	-0.935*	-0.897*	(0.110)
Cuton 1	(0.415)	(0.467)	(0.482)	(0.486)	
Cutoff 2	-0.935**	-0.486	-0.715	-0.675	
Cutoff 2	(0.415)	(0.467)	(0.482)	(0.485)	
Cutoff 3	-0.330	0.138	-0.089	(0.+65)	
Cutoff 5	(0.415)	(0.150)	(0.481)	(0.485)	
Cutoff 4	(0.413)	(0.407) 0.041**	(0.461)	(0.463)	
Cutoli 4	(0.445)	(0.4(7))	0.713	0.704	
Crete ff 5	(0.415)	(0.407)	(0.481)	(0.485)	
Cutoli 5	0.885**	1.5//****	1.132**	1.202**	
	(0.415)	(0.468)	(0.482)	(0.486)	0 400***
Constant					2.469***
Observations	1554	1554	1554	1554	(0.050)
Log likelihood	1334	1334	1334	267 580	1334
Deguarad	-2422.005	-2378.902	-2373.708	-307.389	0.270
Largest occupational group dummies	Vac	Vas	Vac	Vac	0.279 Vos
Industry dummies	Ves	Ves	Ves	Ves	Ves
Region dummies	Vec	Vas	Vas	I CS Vac	Vac
Firm characteristics	No	Ves	Ves	I CS Vec	I CS Vec
Competition dummies	No	No	Vas	I CS Vac	Ves
Manager characteristics	No	No	No	I CS Vac	Ves
Missing dummies	Yes	Yes	Yes	Yes	Yes
in a summer	1 00	100	100	100	100

Notes: For information on the sample and on the variables of interest, see Notes in Tables A1 and A2 in the Appendix. Since the dependent variable excludes establishments where the largest occupational group is managers/senior officials, we drop establishments where the largest occupational group is managers/senior officials and include seven dummies for the largest occupational group in the establishment (omitted category routine/unskilled). The omitted category of product quality competition is '*Quality Importance 1: Demand does not depend at all on product quality*'. Standard errors corrected for heteroscedasticity are in parentheses. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. The estimated coefficients of 'Quality Importance 4' and 'Quality Importance 5' in column 4 are significantly different from the estimated coefficients are statistically different from zero (F-test=12.25, p-value=0.019). The cutoffs represent the threshold parameters associated with the ordinal nature of the dependent variable.

Table et Training Interisity and gua	illy Sensitivity	() ERG 2011	(2)	(4)	( <b>m</b> )
	(1)	(2)	(3)	(4)	(5)
VARIABLES	Ordered	Ordered	Ordered	Ordered	OLS
	probit	probit	probit	probit	
Quality importance 2	0.079	0.103	0.026	0.037	0.146
	(0.175)	(0.176)	(0.178)	(0.178)	(0.251)
Quality importance 3	0.082	0.112	0.067	0.105	0.149
	(0.172)	(0.175)	(0.175)	(0.176)	(0.245)
Quality importance 4	0.194**	0.234***	0.233***	0.256***	0.352***
	(0.082)	(0.082)	(0.083)	(0.083)	(0.116)
Quality importance 5	0.25/***	0.282***	0.295***	0.305***	0.460***
	(0.083)	(0.084)	(0.084)	(0.084)	(0.118)
% female employees	-0.086	-0.035	-0.015	0.030	0.097
	(0.128)	(0.131)	(0.131)	(0.136)	(0.190)
% part time employees	-0.528***	-0.430***	-0.421***	-0.405***	-0.591***
	(0.114)	(0.116)	(0.116)	(0.117)	(0.163)
% 18 to 21 year old employees	0.245*	0.212	0.222	0.228	0.261
	(0.137)	(0.128)	(0.239)	(0.239)	(0.335)
% over 50 year old employees	-0.300**	-0.286*	-0.306**	-0.328**	-0.477**
	(0.145)	(0.146)	(0.147)	(0.147)	(0.202)
Log number of employees		0.090***	0.094***	0.076**	0.127***
		(0.033)	(0.033)	(0.034)	(0.048)
Single independent establishment		-0.649***	-0.652***	-0.623***	-0.898***
		(0.188)	(0.188)	(0.188)	(0.267)
Part of a larger organization		-0.224	-0.224	-0.265	-0.376
		(0.187)	(0.186)	(0.187)	(0.267)
% union membership		0.321*	0.288	0.294	0.374
		(0.184)	(0.186)	(0.187)	(0.262)
Few competitors			-0.346*	-0.343*	-0.430*
			(0.180)	(0.181)	(0.252)
Many competitors			-0.508***	-0. 498***	-0.661***
			(0.178)	(0.179)	(0.250)
Manager is male				0.054	0.102
				(0.059)	(0.083)
Manager is the owner				-0.320***	-0.423***
				(0.084)	(0.115)
Cutoff 1	-0.785**	-0.884**	-1.213***	-1.302***	
	(0.382)	(0.448)	(0.469)	(0.472)	
Cutoff 2	-0.612	-0.703	-1.030**	-1.118**	
	(0.382)	(0.448)	(0.469)	(0.471)	
Cutoff 3	-0.034	-0.108	-0.431	-0.517	
	(0.382)	(0.448)	(0.469)	(0.471)	
Cutoff 4	0.799**	0.742*	0.421	0.337	
	(0.382)	(0.448)	(0.469)	(0.471)	
Cutoff 5	1.373***	1.321***	1.002**	0.922*	
	(0.383)	(0.448)	(0.469)	(0.471)	
Constant	. ,		. ,		2.904***
					(0.661)
Observations	1688	1688	1688	1688	1688
Log-likelihood	-2724.538	-2686.782	-2680.051	-2672.612	
R-squared					0.168
Largest occupational group dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes
Firm characteristics	No	Yes	Yes	Yes	Yes
Competition dummies	No	No	Yes	Yes	Yes
Manager characteristics	No	No	No	Yes	Yes
Missing dummies	Yes	Yes	Yes	Yes	Yes

Table 3. Training Intensity and Quality Sensitivity - WERS 2011

Notes: For information on the sample and on the variables of interest, see Notes in Tables A1 and A2 in the Appendix. Since the dependent variable excludes establishments where the largest occupational group is managers/senior officials, we drop establishments where the largest occupational group is managers/senior officials, we drop establishments where the largest occupational group is managers/senior officials and include seven dummies for the largest occupational group in the establishment (omitted category routine/unskilled). The omitted category of product quality competition is '*Quality Importance 1: Demand does not depend at all on product quality*'. Standard errors corrected for heteroscedasticity are in parentheses. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. The estimated coefficients of 'Quality Importance 4' and 'Quality Importance 5' in column 4 are significantly different from the estimated coefficients of 'Quality Importance 3', but are not statistically significant different from each other. Jointly, all 'Quality Importance' coefficients are statistically different from zero (F-test=15.37, p-value=0.004). The cutoffs represent the threshold parameters associated with the ordinal nature of the dependent variable.

#### Table 4. Training Intensity and Product Quality Sensitivity Panel Data Analysis 2004-2011

	Ordered Probit Without		OLS with	nout FE	Ordered P	robit With	OLS w	ith FE	Poisson	with FE
	F	E			FE					
	(1	1)	(2	)	(3	?)	(4	1)	(.*	5)
	Coef.	<i>Std. E.</i>	Coef.	Std. E.	Coef.	Std. E.	Coef.	Std. E.	Coef.	Std. E.
Quality Importance 2	0.218	0.337	0.245	0.434	0.175	0.256	0.167	0.268	0.048	0.152
Quality Importance 3	0.326	0.243	0.436	0.318	0.290	0.338	0.434	0.327	0.096	0.088
Quality Importance 4	0.475**	0.241	0.621**	0.314	0.555**	0.242	0.697*	0.419	0.214**	0.087
Quality Importance 5	0.582**	0.254	0.791**	0.332	0.660***	0.245	0.872**	0.434	0.383**	0.163
Fixed Effects	N	ĺo	N	0	Yes		Yes		Yes	
Log-likelihood	-1313.032			-	-1406.910				-931.311	
R-squared			0.3	12		-	0.7	03		
Observations	8	78	87	8	87	'8	87	78	8	78
Workforce composition	Y	es	Ye	es	Y	es	Y	es	Y	es
Occupational composition	Y	es	Ye	es	Y	es	Y	es	Y	es
Largest occupational group dummies	Y	es	Ye	es	Y	es	Y	es	Y	es
Firm characteristics	Y	es	Ye	es	Y	es	Y	es	Y	es
Competition dummies	Y	es	Ye	es	Y	es	Y	es	Y	es
Manager characteristics	Y	es	Ye	es	Y	es	Y	es	Y	es
Industry dummies	Y	es	Ye	es	Ν	0	Ν	0	N	ίο
Region dummies	Y	es	Ye	es	Ν	0	N	0	N	ю
Missing dummies	Y	es	Ye	es	Y	es	Y	es	Y	es

Notes: For information on the sample and on the variables of interest, see Notes in Tables A1 and A2 in the Appendix. For reasons of brevity, we only present coefficients of the four variables of interest. Other controls are those shown in column 4 of Tables 2 and 3 as well as a year dummy. The rest of the estimates are available upon request. In columns 3, 4, 5 and 6 we exclude industry and region dummies as there is no variation of establishments between industries and regions. Heteroscedasticity corrected standard errors are reported across all specifications. There is no evidence of overdispersion in the Poisson fixed effect estimates. The fixed effects ordered probit model is estimated in LIMDEP. Levels of significance: \*\*\* p<0.01, \* p<0.05, \* p<0.1. The estimated coefficients of 'Quality Importance 4' and 'Quality Importance 5' in column 1 are significantly different from the estimated coefficients of 'Quality Importance 2' and 'Quality Importance 3', but are not statistically different from each other. Jointly, all 'Quality Importance' coefficients are statistically different from zero (F-test=12.83, p-value=0.003). "---" not relevant.

<u> </u>	Quality	Control Procedure	2 <i>S</i>	Other Types of Training			
	Ordered Probit	<b>OLS</b> Without	OLS With	<b>Ordered Probit</b>	OLS Without	OLS With	
	Without Firm FE	Firm FE	Firm FE	Without Firm FE	Firm FE	Firm FE	
	(1)	(2)	(3)	(4)	(5)	(6)	
Quality Importance 2	0.552*	0.577	0.567	0.604**	0.637**	0.794*	
	(0.318)	(0.376)	(0.495)	(0.259)	(0.300)	(0.419)	
Quality Importance 3	0.689**	0.698**	0.729	0.664**	0.739**	0.807*	
	(0.305)	(0.349)	(0.483)	(0.260)	(0.297)	(0.422)	
Quality Importance 4	0.719**	0.760**	0.877**	0.730***	0.847***	0.875**	
	(0.307)	(0.362)	(0.442)	(0.270)	(0.319)	(0.440)	
Quality Importance 5	0.964***	1.114**	1.842***	0.820**	0.947**	1.275**	
	(0.369)	(0.451)	(0.603)	(0.337)	(0.430)	(0.582)	
Log-likelihood	-1005.8			-990.5			
R-squared		0.143	0.613		0.119	0.593	
Observations	878	878	878	878	878	878	
Workforce composition	Yes	Yes	Yes	Yes	Yes	Yes	
Occupational	Yes	Yes	Yes	Yes	Yes	Yes	
composition							
Largest occupational	Yes	Yes	Yes	Yes	Yes	Yes	
group dummies							
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes	
Competition dummies	Yes	Yes	Yes	Yes	Yes	Yes	
Manager characteristics	Yes	Yes	Yes	Yes	Yes	Yes	
Industry dummies	Yes	Yes	No	Yes	Yes	No	
Region dummies	Yes	Yes	No	Yes	Yes	No	
Missing dummies	Yes	Yes	Yes	Yes	Yes	Yes	

Table 5. Training Intensity and Training for Quality and Other Types of TrainingPanel Data Analysis 2004-2011

Notes: For information on the sample and on the variables of interest, see Notes in Tables A1 and A2 in the Appendix. For reasons of brevity, we only present coefficients of the four variables of interest. The omitted category is "Quality Importance 1". Other controls are those shown in column 4 of Tables 2 and 3 as well as a year dummy. Estimates for the rest of the covariates are available upon request. In columns 3 and 6 we exclude industry and region dummies as there is no variation in industry and regions through time. Standard errors corrected for heteroscedasticity are in parentheses. Levels of significance: \*\*\* p<0.01, \*p<0.05, \* p<0.1. "---" not relevant.

	WERS 2004	WERS 2011	Panel 2004-2011	Panel 2004-2011
	Ordered	Ordered	Ordered	<b>Ordered Probit with</b>
	Probit	Probit	Probit	firm fixed effects
	(1)	(2)	(3)	(4)
Quality importance 2	0.022	0.056	0.125	0.089
	(0.167)	(0.178)	(0.338)	(0.256)
Quality importance 3	0.031	0.168	0.370	0.141
	(0.146)	(0.177)	(0.246)	(0.248)
Quality importance 4	0.156*	0.228***	0.434*	0.238*
	(0.083)	(0.083)	(0.243)	(0.127)
Quality importance 5	0.224***	0.289***	0.584**	0.327**
	(0.084)	(0.084)	(0.257)	(0.131)
Quality product or service: about	0.077	0.052	0.167	0.010
average for industry	(0.142)	(0.158)	(0.222)	(0.256)
Quality product or service: better	0.060	0.130	0.292	0.114
than average	(0.129)	(0.151)	(0.215)	(0.277)
Quality product or service: a lot	0.197	0.181	0.598***	0.307
better than average for industry	(0.136)	(0.156)	(0.223)	(0.275)
Log-likelihood	-2365.9	-2668.7	-1304.6	-940.7
Observations	1554	1688	878	878

Table 6. Keeping Perceived Quality Constant

Notes. Other controls are those shown in column 4 of Tables 2 and 3. The "quality product or service" controls are dummy variables capturing if the quality of product or service are: "about average for industry", "better than average for industry", "a lot better than average for industry". The omitted category is "below average for industry". Due to the very small number of observations of the "a lot below average for industry" category in each of the three samples, we recoded those observations to the omitted category. Standard errors corrected for heteroscedasticity are in parentheses. The fixed effects ordered probit model is estimated in LIMDEP. Levels of significance: \*\*\* p<0.01, \* \*p<0.05, \* p<0.1.

	WERS 2004	WERS 2011	Panel 2004-2011	Panel 2004-2011
	<b>Ordered Probit</b>	<b>Ordered</b> Probit	<b>Ordered Probit</b>	<b>Ordered Probit</b>
				firm fixed effects
	(1)	(2)	(3)	(4)
Price importance 2	-0.026	-0.035	-0.166	-0.101
	(0.110)	(0.089)	(0.107)	(0.170)
Price importance 3	-0.046	-0.038	-0.275**	-0.156
	(0.103)	(0.105)	(0.116)	(0.198)
Price importance 4	-0.178*	-0.093*	-0.300**	-0.345*
	(0.094)	(0.054)	(0.134)	(0.188)
Price importance 5	-0.230**	-0.231**	-0.415***	-0.493**
	(0.108)	(0.101)	(0.129)	(0.234)
Log-likelihood	-2348.3	-2668.2	-1229.0	-929.7
Observations	1542	1684	874	874

#### Table 7. Training Intensity and Price Competition

Notes. The price importance variables source from the following question: "Looking at the scale on this card, to what extent would you say that the demand for your (main) product or service depends upon offering lower prices than your competitors?" ranging from 1 (=demand does not depend at all on price) to 5(=demand depends heavily on offering lower prices). The omitted category is Price importance 1 (=demand does not depend at all on price). All the other controls are the same as those reported in column 4 of Tables 2 and 3. Standard errors corrected for heteroscedasticity are in parentheses. The fixed effects ordered probit model is estimated in LIMDEP. Levels of significance: \*\*\* p<0.01, \*\*p<0.05, \* p<0.1.

		First	Stage		Second Stage
	Quality importance 2	Quality importance 3	Quality importance 4	Quality importance 5	Training
	(1)	(2)	(3)	(4)	(5)
Quality importance 2					0.135
					(0.424)
Quality importance 3					0.163
					(0.158)
Quality importance 4					0.202***
					(0.062)
Quality importance 5					0.244***
					(0.085)
Instrument for quality importance 2	4.721***	-0.043	-0.168	-0.319	
	(0.792)	(0.054)	(0.243)	(0.384)	
Instrument for quality importance 3	-0.136	6.553***	-0.590	-0.442	
	(0.086)	(0.715)	(0.367)	(0.350)	
Instrument for quality importance 4	-0.614	-0.386	20.340***	-0.700	
	(0.454)	(0.235)	(3.949)	(0.628)	
Instrument for quality importance 5	-0.198	-0.138	-0.059	8.544***	
	(0.199)	(0.090)	(0.180)	(1.584)	
Cragg-Donald eigenvalue statistic					40.221
Observations	1554	1554	1554	1554	1554

#### Table 8. Panel A: Instrumental Variables (IV) Results-2004

Notes. For reasons of brevity we only report estimates of the four main variables of interest and their respective instruments. Other controls include those shown in column 4 of Tables 2 and 3. Full estimates are available upon request. Standard errors clustered at industry cells and heteroscedasticity corrected are reported in parentheses. Descriptive statistics of the instruments are provided in Table A1 in the Appendix. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. "---" not available or relevant.

#### Panel B: Instrumental Variables (IV) Results-2011

		First	Stage		Second Stage
	Quality importance 2	Quality importance 3	Quality importance 4	Quality importance 5	Training
	(1)	(2)	(3)	(4)	(5)
Quality importance 2					0.099
					(0.374)
Quality importance 3					0.141
					(0.354)
Quality importance 4					0.342***
					(0.101)
Quality importance 5					0.450***
					(0.116)
Instrument for quality importance 2	4.632***	-0.063	-0.193	-0.486	
	(0.661)	(0.066)	(0.286)	(0.456)	
Instrument for quality importance 3	-0.076	4.792***	-0.130	-0.558	
	(0.050)	(0.973)	(0.420)	(0.506)	
Instrument for quality importance 4	-0.382	-0.659	28.534***	-4.063	
	(0.247)	(0.442)	(4.027)	(2.844)	
Instrument for quality importance 5	-0.133**	-0.217	-0.043	9.734***	
	(0.091)	(0.170)	(0.304)	(1.045)	
Cragg-Donald eigenvalue statistic					60.425
Observations	1688	1688	1688	1688	1688

Notes. For reasons of brevity we only report estimates of the four main variables of interest and their respective instruments. Other controls include those shown in column 4 of Tables 2 and 3. Full estimates are available upon request. Standard errors clustered at industry cells and heteroscedasticity corrected are reported in parentheses. Descriptive statistics of the instruments are provided in Table A1 in the Appendix. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. "---" not available or relevant.

		First	Stage		Second Store
	Quality importance 2	Quality importance 3	Quality importance 4	Quality importance 5	Training
	(1)	(2)	(3)	(4)	(5)
Quality importance 2					0.148
					(0.119)
Quality importance 3					0.160
					(0.117)
Quality importance 4					0.169
					(0.122)
Quality importance 5					0.261**
					(0.112)
Instrument for quality importance 2	9.174***	-0.665	-0.578	-0.421	
	(2.176)	(2.014)	(0.923)	(0.452)	
Instrument for quality importance 3	-0.842	23.613***	-0.734	-0.296	
	(0.929)	(8.121)	(0.921)	(0.863)	
Instrument for quality importance 4	-0.497	-0.884	3.003***	-0.281	
	(0.595)	(1.762)	(0.796)	(0.589)	
Instrument for quality importance 5	-0.488	-0.328	-0.335	1.755***	
	(0.604)	(1.177)	(0.277)	(0.612)	
Cragg-Donald eigenvalue statistic					25.350
Observations	878	878	878	878	878

Panel C: Instrumental Variables (IV) Results -Panel 2004-2011(with establishment fixed effects)

Notes. For reasons of brevity we only report estimates of the four main variables of interest and their respective instruments. Other controls include those shown in column 4 of Tables 2 and 3, plus a year dummy and establishment fixed effects. Full estimates are available upon request. Standard errors clustered at industry cells and heteroscedasticity corrected are reported in parentheses. Descriptive statistics of the instruments are provided in Table A1 in the Appendix. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. "---" not available or relevant.

# **Appendix Tables**

		WERS 2004			WERS 2011		И	ERS Panel 2004-2	011
	Mean	Std. Error.	Obs.	Mean	Std. Error.	Obs.	Mean	Std. Error.	Obs.
No time	0.134	0.008	209	0.120	0.008	203	0.145	0.012	127
Less than one day	0.064	0.006	100	0.054	0.005	91	0.055	0.008	48
1 to less than 2 days	0.206	0.010	320	0.226	0.010	381	0.223	0.014	196
2 to less than 5 days	0.321	0.012	499	0.332	0.011	561	0.326	0.016	286
5 to less than 10 days	0.136	0.009	212	0.159	0.009	269	0.148	0.012	130
10 days or more	0.138	0.009	214	0.108	0.008	183	0.104	0.010	91
Total Observations		1554			1688			878	

#### Table A1. Distribution of Training Intensity

Notes: The samples for the two cross sections consist of trading sector establishments with 5 or more employees that provide their goods and services to the general public and/or to other organizations. We exclude establishments where the largest occupational group is managers or senior officials as the dependent variable does not apply to this group. For the panel dataset we apply the same restrictions as in the two cross sections and keep establishments observed twice. Thus, the panel is balanced and we observe 439 establishments which generate 878 observations. Standard errors for proportions are used. The training intensity question reads as follows: "On average, how many days of training did experienced employees in the largest non-managerial occupational group undertake over the past 12 months?" Establishments that offered no training were coded "No time".

#### Table A2. Distribution of Demand Dependence on Product Quality

ý 1		WEDS 2004			WEDC 2011			WEDS D		
		WEKS 2004			WEKS 2011			WEKS Panel 2004-2011		
	Mean	Std. Error.	Obs.	Mean	Error.	Obs.	Mean	Error.	Obs.	
1: Demand does not depend at all on quality	0.049	0.005	76	0.034	0.004	57	0.034	0.006	30	
2:	0.036	0.004	56	0.031	0.004	52	0.038	0.006	33	
3:	0.140	0.008	218	0.134	0.008	226	0.140	0.012	123	
4:	0.342	0.012	531	0.372	0.012	628	0.347	0.016	305	
5: Demand depends heavily on superior quality	0.433	0.013	673	0.430	0.012	725	0.441	0.017	387	
Total Observations		1554			1688			878		

Notes: For information on the sample, see Notes in Table A1. Standard errors for proportions are used. The question of demand dependence on product quality reads as follows "To what extent would you say that the demand for your (main) product or service depends upon you offering better quality than your competitors?

# **Worker Training and Quality Competition**

by Christos Bilanakos, John Heywood, John Sessions and Nikolaos Theodoropoulos

# **On-line Appendix**

We now allow for asymmetry by assuming that firm *i* faces a marginal cost  $C_i$  with  $C_1 < C_2$ (i.e. firm 1 is more efficient than firm 2). In this case, we get the following Bertrand equilibrium prices, quantities and profits in the second-stage pricing game:

$$(p_i^B, q_i^B, \pi_i^B) = \left(\frac{Y_{ij}}{4\beta^2 - \gamma^2} + \frac{\lambda(s_i - s_j)}{2\beta + \gamma}, \beta\left(\frac{Z_{ij}}{4\beta^2 - \gamma^2} + \frac{\lambda(s_i - s_j)}{2\beta + \gamma}\right), \frac{(q_i^B)^2}{\beta} - g(I_i)\right)$$
(A1)

where  $Y_{ij} \equiv \alpha(2\beta + \gamma) + \beta(2\beta c_i + \gamma c_j), Z_{ij} \equiv \alpha(2\beta + \gamma) - (2\beta^2 - \gamma^2)c_i + \beta\gamma c_j$ 

In stage one, the firms' reaction functions now become:

$$I_{i}(I_{j};\lambda) = \frac{2\lambda\beta}{\delta(2\beta+\gamma)^{2} - 2\beta\lambda^{2}} \cdot \left(\frac{Z_{ij}}{2\beta-\gamma} - \lambda I_{j}\right)$$
(A2)

Solving this system yields the asymmetric equilibrium in training investments:

$$I_{i}^{*} = \frac{2\beta\lambda}{\delta(2\beta + \gamma)^{2}(2\beta - \gamma)} \left[ Z_{ij} + \frac{2\beta\lambda^{2}(Z_{ij} - Z_{ji})}{\delta(2\beta + \gamma)^{2} - 4\beta\lambda^{2}} \right]$$
(A3)

Since  $Z_{12} > Z_{21}$  we immediately get  $I_1^* > I_2^*$ , i.e. the efficient firm provides more training and therefore offers a superior brand quality than the inefficient one.<sup>14</sup> Our primary interest lies in the investigation of the relationship between  $I_i^*$  and  $\lambda$ , which depends on the relative strength of the positive direct effect and the negative strategic effect (as explained in the body of the article). For this purpose, we derive:

<sup>14</sup> We also require  $\delta \geq \delta(Z_{12}+Z_{21})/Z_{21}$  to ensure that  $I_2^* \geq 0$ .

$$\frac{\partial I_{i}^{*}}{\partial \lambda} = \frac{2\beta}{\delta(2\beta+\gamma)^{2}(2\beta-\gamma)} \left\{ Z_{ij} + \frac{2\beta(Z_{ij}-Z_{ji})\left[3\lambda^{2}\left(\delta(2\beta+\gamma)^{2}-4\beta\lambda^{2}\right)+8\beta\lambda^{4}\right]}{\left[\delta(2\beta+\gamma)^{2}-4\beta\lambda^{2}\right]^{2}} \right\}$$

(A4)

This expression is unequivocally positive for firm 1 ( $\partial I_1^*/\partial \lambda > 0$ ) showing that any increase in the demand sensitivity to quality always strengthens the efficient firm's training incentives. For the inefficient firm, however, the overall impact of  $\lambda$  on  $I_2^*$  can be either positive or negative. This ambiguity can be illustrated by use of a numerical example with parameter values  $\alpha=1$ ,  $\beta=0.5$ ,  $\gamma=0.25$ ,  $c_1=1$ ,  $c_2=2$  and  $\delta=8$ . Then, (A3) implies:

$$I_{1}^{*}(\lambda) = \frac{8\lambda}{75} \left( 1.0625 + \frac{0.5625\lambda^{2}}{12.5 - 2\lambda^{2}} \right)$$
(A5)  
$$I_{2}^{*}(\lambda) = \frac{8\lambda}{75} \left( 0.5 - \frac{0.5625\lambda^{2}}{12.5 - 2\lambda^{2}} \right)$$
(A6)

where  $\lambda \in [0,2]$  to ensure that  $I_2^* \ge 0$ . The relationship between training and  $\lambda$  for firms 1 and 2 is graphically depicted in Figures 1 and 2 respectively. The curve  $I_1^*(\lambda)$  is increasing for all values of  $\lambda$ , whereas the curve  $I_2^*(\lambda)$  has an inverse-U shape reflecting the tradeoff between the direct and the strategic effect of  $\lambda$  on the inefficient firm's training incentives. For low values of  $\lambda$ , the direct effect dominates and thus the overall impact of  $\lambda$  on  $I_2^*$  is positive. For high values of  $\lambda$ , the strategic effect dominates and the relationship between  $\lambda$  and  $I_2^*$  becomes negative. These findings show that even under asymmetry we can identify a parameter range in which firms engage in more intensive training as the demand for their product becomes more sensitive to relative quality, thus providing further motivation to our empirical testing.



	WERS	S 2004	WERS	5 2011	Panel	204-2011
Variable	Mean	Std. dev.	Mean	dev.	Mean	Std. dev.
% female employees	0.458	0.296	0.471	0.286	0.493	0.295
% part time employees	0.265	0.287	0.265	0.279	0.291	0.283
% of employees 18-21 years old	0.087	0.130	0.071	0.115	0.083	0.121
% of employees over 50 years old	0.193	0.160	0.230	0.172	0.217	0.159
% of managers	0.104	0.090	0.114	0.095	0.095	0.080
% of professional staff	0.072	0.162	0.114	0.201	0.086	0.163
% of technical staff	0.081	0.165	0.088	0.178	0.074	0.155
% of sales staff	0.189	0.308	0.146	0.276	0.182	0.306
% of operative and assembly manual staff	0.114	0.232	0.095	0.224	0.104	0.230
% of clerical/secretarial staff	0.126	0.190	0.116	0.163	0.103	0.159
% of craft and skilled manual staff	0.089	0.187	0.082	0.177	0.076	0.156
% of personal service staff	0.067	0.211	0.098	0.251	0.122	0.276
Largest occupational group: Professional	0.082	0.274	0.094	0.292	0.072	0.258
Largest occupational group: Associate professional	0.097	0.296	0.088	0.283	0.075	0.264
Largest occupational group: Administrative	0.106	0.308	0.097	0.296	0.083	0.276
Largest occupational group: Skilled trades	0.086	0.281	0.118	0.323	0.154	0.361
Largest occupational group: Caring, leisure	0.218	0.413	0.174	0.379	0.211	0.408
Largest occupational group: Sales	0.163	0.370	0.121	0.326	0.145	0.352
Largest occupational group: Process, operative	0.172	0.377	0.174	0.379	0.170	0.376
Manufacturing	0.180	0.384	0.137	0.344	0.147	0.354
Utilities (electricity, gas, water)	0.025	0.156	0.027	0.161	0.032	0.176
Construction	0.054	0.226	0.044	0.206	0.030	0.170
Wholesale	0.192	0.394	0.155	0.362	0.185	0.388
Hotels and restaurants	0.069	0.253	0.092	0.289	0.091	0.288
Transport and communication	0.082	0.275	0.082	0.275	0.105	0.306
Financial services	0.072	0.259	0.024	0.154	0.040	0.196
Other business services	0.148	0.355	0.163	0.369	0.109	0.312
Education	0.028	0.166	0.061	0.239	0.038	0.190
Health	0.089	0.285	0.117	0.322	0.149	0.356
North East	0.044	0.205	0.056	0.229	0.042	0.201
North West	0.118	0.323	0.113	0.317	0.131	0.338
East Midlands	0.075	0.264	0.062	0.241	0.080	0.271
West Midlands	0.109	0.312	0.079	0.270	0.091	0.288
East Anglia	0.042	0.200	0.043	0.202	0.046	0.209
South East	0.320	0.467	0.334	0.472	0.326	0.469
South West	0.081	0.273	0.088	0.284	0.077	0.267
Wales	0.041	0.199	0.042	0.201	0.048	0.214
Scotland	0.083	0.276	0.098	0.298	0.093	0.291
Log number of employees	4.200	1.665	4.069	1.653	4.330	1.607
Single independent establishment	0.290	0.454	0.323	0.468	0.210	0.407
Part of a larger organization	0.683	0.466	0.649	0.477	0.759	0.428
% union membership	0.185	0.289	0.146	0.257	0.168	0.281

Table OA1 Descriptive	Statistics o	f All the	Variables	Used in	the Analysis
Tuble OAL Descriptive	Simistics 0	All the	variables	Useu m	ine Anaiysis

Continued

						Continued
	WERS	WERS 2004		5 2011	Panel	204-2011
	Mean	Std. dev.	Mean	dev.	Mean	Std. dev.
Few competitors	0.369	0.483	0.370	0.483	0.385	0.487
Many competitors	0.571	0.495	0.587	0.493	0.563	0.496
Respondent manager is male	0.519	0.500	0.476	0.500	0.476	0.500
Respondent manager is the owner	0.078	0.268	0.072	0.258	0.062	0.240
Dummy for missing percentage 18-21 years old	0.023	0.148	0.020	0.141	0.034	0.182
Dummy for missing percentage over 50 years old	0.020	0.140	0.021	0.143	0.032	0.176
Dummy for missing percentage union membership	0.019	0.138	0.033	0.179	0.117	0.322
Instrument for quality importance 1	0.011	0.029	0.008	0.029	0.008	0.035
Instrument for quality importance 2	0.009	0.024	0.007	0.025	0.008	0.034
Instrument for quality importance 3	0.049	0.079	0.036	0.064	0.049	0.116
Instrument for quality importance 4	0.087	0.071	0.095	0.075	0.092	0.084
Instrument for quality importance 5	0.107	0.063	0.105	0.057	0.114	0.090
Computing skills	0.015	0.121	0.012	0.109	0.010	0.100
Team working	0.001	0.027	0.005	0.072	0.001	0.035
Communication skills	0.004	0.066	0.008	0.089	0.012	0.112
Leadership skills	0.008	0.090	0.008	0.089	0.011	0.106
Operation of new equipment	0.028	0.166	0.021	0.144	0.019	0.137
Customer service/liaison	0.051	0.221	0.035	0.184	0.038	0.191
Health and safety	0.238	0.426	0.204	0.403	0.218	0.413
Problem-solving methods	0.034	0.182	0.031	0.174	0.020	0.141
Equal opportunities	0.063	0.243	0.115	0.319	0.089	0.285
Reliability and working to deadlines	0.062	0.242	0.044	0.206	0.053	0.225
Quality control procedures	0.463	0.498	0.469	0.499	0.491	0.500
None of these skills	0.031	0.172	0.045	0.208	0.034	0.182
Strategic plan	0.524	0.499	0.589	0.491	0.631	0.483
Keeps records	0.517	0.499	0.621	0.485	0.565	0.496
Sets targets	0.402	0.490	0.416	0.493	0.471	0.499
Price competition 1	0.164	0.370	0.144	0.352	0.150	0.357
Price competition 2	0.127	0.333	0.112	0.314	0.108	0.310
Price competition 3	0.302	0.459	0.321	0.466	0.322	0.467
Price competition 4	0.215	0.411	0.232	0.422	0.238	0.426
Price competition 5	0 192	0.394	0.190	0.392	0.181	0.385

Notes: Entries are means and standard deviations for each variable reported for the two cross sections and the panel samples. Means are weighted using establishment weights. Means for variables with missing observations are estimated on non-missing observations.

	WERS 2004	WERS 2011
	(1)	(2)
Quality importance 2	0.025	0.035
	(0.169)	(0.194)
Quality importance 3	0.087	0.126
	(0.180)	(0.209)
Quality importance 4	0.200**	0.268***
	(0.099)	(0.093)
Quality importance 5	0.222**	0.308***
	(0.101)	(0.092)
% of employees with GCSE (grades D-G)	0.127	0.145
	(0.262)	(0.272)
% of employees with GCSE (grades A-C)	0.304	0.206
	(0.209)	(0.200)
% of employees with A levels	0.402	0.282
	(0.265)	(0.299)
% of employees with first degree (BSc, BA)	0.616**	0.445*
	(0.287)	(0.249)
% of employees with higher degree (MSc, MA, PhD)	0.842*	0.704**
	(0.479)	(0.340)
% of employees with other academic qualifications	0.091	0.109
	(0.195)	(0.225)
Log-likelihood	-1735.986	-1819.759
Observations	1149	1178
Workforce composition	Yes	Yes
Occupational composition	Yes	Yes
Largest occupational group dummies	Yes	Yes
Firm characteristics	Yes	Yes
Competition dummies	Yes	Yes
Manager characteristics	Yes	Yes
Industry dummies	Yes	Yes
Region dummies	Yes	Yes
Missing dummies	Yes	Yes

Table OA2. R	obustness (	Check Table	- Controllin	g for Aver	rage Edu	cation L	evel in t	he
Establishmen	t							

Notes: The estimation method is an ordered probit model. Column 1(2) replicates column 4 of Table 2(3) in the main paper and adds six continuous variables capturing the average education level of employees in the establishment (omitted category: percentage of employees with no academic qualifications). Standard errors corrected for heteroscedasticity are in parentheses. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

	WERS 2004										WE	RS 2011				
	Que Import	ality tance 2	Que Import	ality tance 3	Quo Import	ality tance 4	Qual Importa	ity nce 5	Qı Impo	uality rtance 2	Que Import	ality tance 3	Quali Importa	ity nce 4	Qual Importa	ity nce 5
	(	1)	(2	2)	(3	3)	(4)			(5)	(	6)	(7)		(8)	1
Training	Coef.	Std. E.	Coef.	Std. E.	Coef.	Std. E.	Coef.	Std. E.	Coef.	Std. E.	Coef.	Std. E.	Coef.	Std. E.	Coef.	Std. E.
x = 0	-0.017	0.042	0.004	0.051	-0.054**	0.024	-0.066***	0.024	-0.010	0.048	-0.028	0.044	-0.071***	0.022	-0.082***	0.021
0 < x < 1	-0.003	0.007	0.001	0.007	-0.008**	0.003	-0.011***	0.004	-0.002	0.008	-0.004	0.008	-0.011***	0.004	-0.013***	0.004
$1 \le x < 2$	-0.003	0.008	0.001	0.007	-0.009**	0.004	-0.013**	0.005	-0.003	0.015	-0.009	0.017	-0.020***	0.007	-0.026***	0.008
$2 \le x < 5$	0.007	0.017	-0.002	0.022	0.024**	0.010	0.028***	0.009	0.004	0.018	0.009	0.014	0.026***	0.008	0.029***	0.008
$5 \le x < 10$	0.006	0.015	-0.001	0.017	0.019**	0.008	0.024***	0.008	0.005	0.024	0.014	0.024	0.035***	0.011	0.042***	0.011
$x \ge 10$	0.009	0.025	-0.002	0.026	0.030**	0.014	0.039***	0.015	0.006	0.028	0.017	0.030	0.040***	0.014	0.050***	0.014

Table OA3. Marginal Effects of Quality Importance on Training based on Column 4 of Tables 3 and 4

Notes: 1. *x* denotes number of days devoted to training;

2. Entries are marginal effects obtained from an ordered probit model based on the complete estimates model (i.e. column 4 of Table 2 (WERS 2004) and Table 3 (WERS 2011) respectively).

3. We only report the marginal effects of the four variables of interest. Marginal effects for the rest of the covariates are available upon request.

4. Robust standard errors are reported. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

	WERS 2004	WERS 2011	Panel 2004-2011	Panel 2004-2011
				with FE
	(1)	(2)	(3)	(4)
Quality importance 2	0.147	0.201	0.147	0.269
	(0.445)	(0.551)	(0.540)	(0.576)
Quality importance 3	0.468	0.503	0.574	0.616
	(0.515)	(0.551)	(0.650)	(0.831)
Quality importance 4	0.855***	0.756***	0.898**	0.792*
	(0.249)	(0.251)	(0.383)	(0.406)
Quality importance 5	0.891***	0.820***	0.952**	0.827**
	(0.255)	(0.247)	(0.403)	(0.411)
Log-likelihood	-4155.65	-4409.865	-2320.184	-1910.340
Observations	1554	1688	878	878
Workforce composition	Yes	Yes	Yes	Yes
Occupational composition	Yes	Yes	Yes	Yes
Largest occupational group	Yes	Yes	Yes	Yes
dummies				
Firm characteristics	Yes	Yes	Yes	Yes
Competition dummies	Yes	Yes	Yes	Yes
Manager characteristics	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	No
Region dummies	Yes	Yes	Yes	No
Missing dummies	Yes	Yes	Yes	Yes

Table OA4. Robustness Check Table - Interval Regression

Notes: For reasons of brevity, we only present coefficients of the four variables of interest. Other controls are those shown in column 4 of Tables 2 and 3 in the main paper, as well as a year dummy in columns 3 and 4. The rest of the estimates are available upon request. In column 4 we exclude industry and region dummies as there is no variation of establishments between industries and regions through time. Standard errors corrected for heteroscedasticity are in parentheses. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

	WERS 2	004	WERS 20	)11
	(1)	(2)	(3)	(4)
	Quality control	Other types of	Quality control	Other types of
	procedures training	training	procedures training	training
Quality importance 2	0.331	0.243	0.014	0.232
	(0.204)	(0.189)	(0.199)	(0.207)
Quality importance 3	0.393**	0.267	0.097	0.279
	(0.193)	(0.179)	(0.206)	(0.250)
Quality importance 4	0.432**	0.325**	0.176**	0.378**
	(0.189)	(0.164)	(0.087)	(0.188)
Quality importance 5	0.575**	0.570**	0.192**	0.410**
	(0.256)	(0.220)	(0.096)	(0.199)
Log-likelihood	-1396.1	-1879.2	-1934.8	-2205.8
Observations	1554	1554	1688	1688
Workforce composition	Yes	Yes	Yes	Yes
Occupational	Yes	Yes	Yes	Yes
composition				
Largest occupational	Yes	Yes	Yes	Yes
group dummies				
Firm characteristics	Yes	Yes	Yes	Yes
Competition dummies	Yes	Yes	Yes	Yes
Manager characteristics	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Missing Dummies	Yes	Yes	Yes	Yes

*Table OA5. Training Intensity and Product Quality by Type of Training Ordered Probit* 

Notes. For information on the sample and on the variables of interest, see Notes in Tables A1 and A2 in the Appendix of the paper. Other types of training include: "computing skills", "team working", "communication skills", "leadership skills", "operation of new equipment", "customer service/liaison", "health and safety", "problem solving methods", "equal opportunities", "reliability and working to deadlines", plus "none of these". Both "quality control" procedures and "other types" of training are recoded to zero if "none of these" equals to one. Other controls are those shown in column 4 of Tables 2 and 3 in the paper. Standard errors corrected for heteroscedasticity are in parentheses. Levels of significance: \*\*\* p<0.01, \* \*p<0.05, \* p<0.1. Descriptive statistics of these variables are reported in Table OA1 in the online Appendix.

	0	0	
	WERS 2004	WERS 2011	Panel 2004-2011
	(1)	(2)	(3)
	Training	Training	Training
Quality importance 2	0.161	0.114	0.174
	(0.123)	(0.099)	(0.154)
Quality importance 3	0.175	0.152	0.201*
	(0.114)	(0.125)	(0.114)
Quality importance 4	0.257**	0.315**	0.308**
	(0.109)	(0.123)	(0.155)
Quality importance 5	0.362***	0.458***	0.377**
	(0.114)	(0.152)	(0.149)
Sigma	1.59	1.29	0.99
Wald test	20.812	16.438	18.838
Wald test P value	0.00156	0.00248	0.00018

Table OA6. Second Stage Instrumental Variable Interval Regression (IV) Results

Notes. The estimation method is an IV interval regression model implemented using a Limited Information Maximum Likelihood Model as proposed by Bettin and Luchetti (2011). The estimation is performed in Gretl. Standard errors are clustered at industry cells and are corrected for heteroscedasticity. We report estimates only for the four main variables of interest. Other controls include those shown in column 4 of Tables 2 and 3 in the main paper, plus a year dummy in column 3. Full estimates are available upon request. Levels of significance: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.