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ABSTRACT

The Impact of a New Quality Management Practice on Firm Performance: Evidence from Pakistan*

This paper uses a novel firm level data set to investigate the impact of a unique quality management practice on the production and productivity of a large-scale garments manufacturer in Pakistan. The analysis provides evidence that production complexity is an important element in determining the impact of management practices, as there are sizeable differences in the effects between complex and basic lines of assembly. Most specifications show that the implementation of the new quality management practice has a negative impact on lines at the extreme ends of the complexity spectrum, while conversely it has a positive impact on those basic lines which exhibit the highest levels of complexity. We find evidence consistent with a quantity-quality trade off, in that whilst the implementation of the new management practice generally adversely impacted upon productivity it had the desired effect of reducing the number of daily quality defects observed after the intervention.

JEL Classification: L2, M2, O14, O32, O33

Keywords: quality management practice, productivity, production complexity

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* The dataset used herein has not been previously used for research. The dataset was acquired through personal visits to the firm. We are grateful that the firm agreed to share the information upon the understanding that the data will be used only for research purposes and will not be shared with any other party such as competitors and buyers. We would also like to thank Sarah Brown, Arne Risa Hole and Peter Wright for helpful comments.

1. Introduction and Background

One of the most important results that micro data research has found is that there is a significant degree of heterogeneity in firm productivity within industries (Syverson, 2011). Explanations such as differences in technology, research and innovation have been found to be associated with productivity differentials across firms. One explanation for productivity differences among firms and countries is the variation in management practices, where better management may be positively associated with firm productivity (Bloom and Van Reenen, 2007; Bloom and Van Reenen, 2010; Bloom et al., 2013). However, in a review by Siebers et al. (2008) the authors found that overall the literature is mixed on the relationship between management practices, productivity and firm performance. Some studies establish a positive association between the adoption of management practices and productivity, some negative, whilst others find no relationship. Hence additional work in this area is of paramount importance to ascertain the role of managerial interventions.

This study is motivated by the research strategy known as 'insider econometrics' which uses micro level data on worker, worker groups and firms to analyse the impact of management practices on productivity of firms.[1] The basic question that insider econometrics addresses is whether a new management practice increases productivity? This literature also examines why a practice may enhance performance among some entities within the same firm but not all (Ichniowski and Shaw, 2009). Building on this theme, the aim of this paper is to investigate the impact of a unique quality management practice on the line level productivity of a garments manufacturing firm in Pakistan.

There are limited studies on the management of firms in economics as compared to business and policy making. Economists have been sceptical of the importance of management due to the emphasis on profit maximisation and cost minimisation (Stigler, 1976). Management practices have also not been emphasized to a great degree in the economics literature as it is empirically challenging

[1] A related literature has explored whether HRM practices, specifically knowledge sharing and face-to-face communication, influence firm performance and productivity (e.g. Bryson et al., 2006; Salis and Williams, 2010).

to measure management (Bloom and Van Reenen, 2007). This research relates to the work on management practices by Bloom and Van Reenen (2007) as they measure management practices using survey instruments and discuss the implications of good and bad management practices in firms. The work also complements the analysis of Bloom et al. (2013) who used data from the Indian textile sector to establish a causal relationship of a set of management practices on various measures of firm performance. Across a large number of firms they found that the adoption of new management practices raised productivity by 17%. We analyse a quality management practice that was introduced by a large scale garments manufacturer in Pakistan. Adding to the literature for developing countries is important and one of our contributions as differences in productivity are typically larger in less developed countries, e.g. Hsieh and Klenow (2009), and hence additional evidence from a developing nation adds to the emerging literature for such economies. Moreover, the use of data from the garments sector is of relevance as the textile sector accounts for over a half of Pakistan's exports (Pakistan Economic Survey, 2019). As the readymade garments sector is at the top of the value chain, it is essential for developing countries, like Pakistan, to explore opportunities to increase manufacturing productivity to achieve higher economic growth.

Improving the quality of production throughout the assembly line is important as defects should be rectified during the earlier stages of stitching otherwise the cost of producing a garment increases if a defect is detected at the end of the assembly line. Therefore, one local firm implemented a new quality management practice in the stitching department to motivate workers to strike a balance between quantity and quality, while keeping piece rates intact. The new quality management practice was implemented on 15th September 2014. In this initiative, every time an in-line quality supervisor checks the pieces stitched by an operator, he/she places a card on the machine. Various cards are used to denote different quality levels maintained by each worker. The cards are ranked: a green card indicates that the worker is maintaining sufficient quality, a red card indicates that the worker has made serious quality defects and a yellow card indicates that the worker needs additional monitoring or is under observation. If a worker gets a red card, production at that point is stopped until the problem is resolved, and the worker is strictly monitored until he/she can get the task completed correctly.

The cards are visible to all workers on the factory floor and the new practice facilitates better management of the factory floor as supervisors can immediately identify workers where there are problems and can help eliminate any bottlenecks quickly. This new quality management practice may bring in an element of peer pressure onto the factory floor. Interaction between individuals in the workplace may lead to peer pressure, as workers compare themselves with their co-workers and may experience the pressure of matching up to the productivity of their peers (Cornelissen et al., 2017; Falk and Ichino, 2006; Mas and Moretti, 2009).

The operator who makes the least quality defects per line is also presented with a monetary reward once a month, however the reward is set only for certain operations. The reward can account for 5 percent to 15 percent of the worker's salary. The reward is ranked for each assembly line; the worker who makes the least quality defects on each line receives the first prize and gets a 15 percent bonus, the worker who comes second gets a bonus of 10 percent and the worker who comes third is rewarded with a 5 percent bonus. The idea behind this practice is to introduce differentiation between co-workers and recognize workers per the standards maintained. Consequently, this attaches a status to each operative and rewards the best worker. The unique aspect of this practice is that it aims to enhance quality and quantity simultaneously. Workers at the firm are paid piece rates throughout the period of the study. When a worker spends less time redoing defective pieces, it means he/she can spend more time on stitching new pieces, hence reducing quality defects should have a positive impact on productivity.

The research follows a similar theme as Boning et al. (2007) who provide evidence using data from steel manufacturing lines that the impact of human resource management practices varies by the complexity of production. However, a limitation of their analysis is that they did not have detailed information on the product mix of lines that is needed to control for cross line differences. Hence, an important feature of the data we use is that it also has detailed information on the complexity of the product mix for each line which enables us to control for any cross line differences. Using this information, this paper contributes to the literature by providing empirical evidence that the implementation of a new management practice may not be valued equally by all production settings as the effect on productivity varies with the complexity of production. The layout of this paper is as follows. Section 2 discusses the data and methodology, Section 3 illustrates the results providing a discussion in relation to the existing literature, and Section 4 presents the conclusion.

2. Data and Methodology

2.1 Organization of production at the firm

Personnel data was analysed from a large scale vertically integrated denim garments production facility located in Pindi Bhattian, the Hafizabad district, Pakistan.[2] As the firm is a vertically integrated unit, it buys cotton as raw material and sells finished garments. Workers at the firm are stage specific and the new quality management practice was introduced on 15th September 2014 only in the sewing department (stage three of production). The following introduces the different stages of production.

Firstly, the cotton goes through the spinning and weaving process and then it is finished and inspected at the Fabric Finishing and Grading department. The firm uses 85% to 90% of its fabric to produce garments, and the surplus is sold to other garment manufacturers. The second stage of the manufacturing process is cutting. The firm uses an automated machine to spread dozens of layers of fabric on a table so that the pieces can be cut simultaneously. The firm usually cuts more pieces than the pieces required by the supplier, to keep a cushion in case there are some defected garments at the

[2] The nearest other garments production facility to this firm is approximately 64 kilometres away. The firm does not operate in a cluster so the distance from similar firms operating in the same industry may signify the degree of geographical immobility for labour.

end of the process. After the fabric is cut, it is divided into bundles and transferred to the stitching unit. The third stage of the production process is stitching and it is at this stage of production that the management intervention took place. Under the production system of the firm, each worker produces a part of the garment and the garment takes shape along the assembly line. Each line comprises a small parts, a front, a back and an assembly 1 and assembly 2 sections. At the first stage, small parts are produced to be ready for the back and front section. The front and back of the jeans are stitched individually, but then the front and back are assembled during assembly 1 and assembly 2 to complete the garment. As production operations are interdependent, a bottleneck at any stage can reduce the productivity of the line. Data on production is recorded in real time. There are electronic screens along the assembly lines, which indicate the target achieved by each line and the percentage that need to be completed.

Line balancing is an important aspect of the way production is organised. The firm has an extensive industrial engineering department. The task of the industrial engineers is to set targets and balance the assembly line to minimise bottlenecks and any idle worker time. The industrial engineers visit the factory floor from time to time to monitor progress. The key measure used to balance the line is the standard minute value (SMV).[3] The standard minute value is the time it takes to complete one process or more commonly referred to as an operation of the garment. Fewer stitching operators are allocated to operations that have a low SMV and more stitching operators are allocated to operations with a higher SMV. Along the assembly line, it is common to see more than 2 workers working on the same operation side by side. The total SMV i.e. the total time it takes to produce one garment along the line is calculated by adding up the SMV of each operation. The supervisory structure of the assembly lines consists of quality supervisors and production supervisors. Each line has 5 sections, hence there are 5 quality supervisors at the end of each section, 2 quality supervisors

[3] The international standards of SMV were set by a consortium from the German, Swiss and Austrian National Associations.

for random in-line quality checking and 2 quality supervisors at the end of the line. The allocation of workers on the line is determined by the Industrial Engineering department but supervisors have some authority in moving operators around the line.

Dry and wet processes are the last stage of production and account for the largest share of value addition of denim garments. These include washing the fabric, and processes that damage the garment so that it looks more fashionable. The processes include stone washing, sand blasting, hand scrapping, permanent wrinkles, whiskers, application of potassium permanganate. Retailer tags are attached after the garment has gone through all the processes and the garments are shipped. The firm produces around 300 styles of denim garments and has the capacity to perform 200 different denim washes. Finished items include skirts, shorts, jeans, and trousers.

2.2 Summary statistics

Daily line level data was collected before (pre 15/09/2014) and after (15/09/2014) the introduction of the new quality management practice. The new quality management practice was announced the same day it was implemented. Also, importantly for the empirical analysis which follows no other organisational change took place during the period of data collection. The measure of productivity used in the analysis is the total production at the firm i.e. the number of garments stitched per day per line, and alternatively output per worker i.e. labour productivity. Data on other variables includes the number of workers employed per line per day, target per line per day, the standard minute value of the product being produced per line per day which denotes the complexity of the product, and the materials (intermediate inputs) loaded on each line per day. The data collection period is from 1st August 2013 to 30th May 2016, where the sample covers 867 (t) days across 9 assembly lines (i).[4]

[4] All data are recorded electronically by the firm.

The study uses an unbalanced panel as some line-day level observations were missing so the total sample contains 7,031 line-day level observations.[5]

Table 1 presents the summary statistics of the sample. Total production denotes the total number of garments stitched where the mean per assembly line is 2,246 and the average number of workers present per line is 121, with large variation around the mean due to the different styles produced per line and line balancing aspects. Workers are allocated to each task keeping in mind the time it takes to perform a task, hence tasks that take longer may require two or more workers so that the garment is produced within the allocated time, bottlenecks are avoided and targets are achieved. Labour productivity also shows substantial variation around the mean of 20 units per worker. The target represents the desired output per line, whilst the standard minute value is the time it takes to stitch a garment at the firm. On average, it takes approximately 18 minutes to stitch a garment. The standard minute value is also an indication of the style and complexity of the garment. More tasks are involved while producing a complex garment as compared to a basic garment. For example, more complex denim jeans would have different kinds of rivets or fancier pockets or embroidery.

The complexity of production varies across lines and the complexity also changes within lines. Three lines operate double shifts, therefore, data for 9 assembly lines is available. The firm has dedicated different assembly lines for producing basic and complex products, details of which are presented in Table 2. Some lines were coded with 'A' and 'B' as they operate double shifts, where the day shift was coded as 'A' and the night shift as 'B'. Those lines that produce simple products for the majority of the time are referred to as basic lines and lines that produce more complicated products are termed as complex lines. The complicated products will require a combination of different tasks and will use more sophisticated machinery as compared to basic products although some tasks will be common across all products. Lines 1A, 1B, 2A, 2B, 3A and 3B are all basic lines, while lines 4, 5

[5] Some line-day level observations were missing as the line did not operate due to issues at the firm such as delayed inputs or other technical issues.

and 6 are complex lines. Lines 3A and 3B produce slightly more complicated goods as compared to other basic lines. As expected, the average standard minute value of production lines that mostly produce basic products is lower than the average standard minute value of the lines that produce more complicated products as can be seen from Table 2. Table 3 provides the mean of key variables by assembly line. The average output and target for line 6 is the highest compared to all other lines, although noticeably productivity is higher for more basic lines (1B and 2B). The average number of workers present per line is highest for lines 4, 5 and 6 as compared to the other lines which produced simpler products.

Table 4 shows the average production and productivity by assembly line before and after the implementation of the new quality management practice. Lines 1A and 4 experienced statistically significant lower average levels of output and productivity following the introduction of the management practice. Conversely, the average output and productivity of lines 3A, 3B and 6 was found to be significantly higher after the implementation of the quality management practice. Interestingly, lines 4, 5 and 6 produce more complicated products so the analysis of the raw means suggests there is not a clear cut picture emerging by line complexity. The distribution of output and labour productivity before and after the management intervention are shown in Figures 1 and 2 respectively.

2.3 Empirical methodology

Management practices have been shown to be an important component in measuring firm performance, e.g. Bloom and Van Reenen, (2007); Bloom et al., (2013). However, there is a need to understand the reasons why effects may differ among entities within the same firm, e.g. across different assembly lines. To explore this the following panel data equation is estimated incorporating line specific effects to investigate the impact of the new quality management practice, where the general function form estimated is as follows:

$$\log(Y_{it}) = \beta_0 + \beta_1 QMP_t + \boldsymbol{\phi}'\boldsymbol{X}_{it} + \sum_{i=1}^{9} \theta_i line_i + \sum_{i=1}^{9} \gamma_i (QMP_t \times line_i) + \boldsymbol{\pi}'\boldsymbol{T}_t + \epsilon_{it} \qquad (1)$$

Productivity is denoted by $\log(Y_{it})$ and is initially defined by the natural logarithm of daily firm production, i.e. the number of garments stitched at line i on day t, consistent with Bloom and Van Reenen (2010).[6] In alternative specifications productivity is defined as output per worker on each line per day. A binary indicator QMP_t equals one when the new management practice is in place and is zero otherwise, following Ichniowski and Shaw (2009) and Bandiera et al. (2005).[7] The vector $\boldsymbol{X}_{it}$ includes the following factor inputs: the natural logarithm of the materials (intermediate inputs) loaded on each line per day and the natural logarithm of the number of workers.[8] We also control for the natural logarithm of the target of each line per day.[9] Boning et al. (2007) found that management practices are not equally valued in all production environments and there were differences in the impact of a management practice due to the complexity of production. Therefore, a variable that captures the complexity of production across and within lines was also included in the vector $\boldsymbol{X}_{it}$. This is defined as the natural logarithm of the standard minute value (SMV) which is the total time it takes to produce the product at line i on day t, where the SMV represents the style and complexity of production with a higher value denoting greater complexity. The vector $\boldsymbol{T}_t$ controls for time in order to account for learning curve effects and is specified in two different ways for flexibility: by a quadratic time trend and then in alternative specifications year specific time dummies are included.

Line specific fixed effects are incorporated into equation (1), where $line_i$ is a binary line specific indicator for each line ($i = 1, \dots, 9$).[10] The line dummies also control for the type of capital used on the line, as some machines will be common among all lines but the lines that produce complex

[6] In Bloom and Van Reenen (2010) a direct measure of production was not available so deflated sales was used as a proxy for output.

[7] Ichniowski and Shaw (2009) capture the impact of a management practice by a binary indicator equal to unity when the practice is present and zero otherwise. Similarly, Bandiera et al. (2005) also used a dummy variable to examine the impact of piece rates on worker productivity.

[8] In specifications where productivity is defined as output per worker labour input is omitted as a control.

[9] Broszeit et al. (2019) and Bryson and Forth (2018) investigate the role of target setting for determining firm level productivity in Germany and the UK respectively. Whilst, Scur et al. (2021) consider the role of target setting more generally as a managerial practice.

[10] Where $line_i$ ($i = 1, \dots, 9$) denotes: $line_1$ = Line 1A; $line_2$ = Line 1B; $line_3$ = Line 2A; $line_4$ = Line 2B; $line_5$ = Line 3A; $line_6$ = Line 3B; $line_7$ = Line 4; $line_8$ = Line 5 and $line_9$ = Line 6. The base category is line 1A.

garments will use more sophisticated machines in order to perform complex tasks that will not be performed on basic lines.[11] An interaction term between the new management practice and the line dummy variables is included to analyse the impact of the new quality management practice for each line and whether the productivity of lines changes after the introduction of the intervention.

With regards to the specification of the error term in equation (1), in their analysis Boning et al. (2007) used a fixed effects specification with line specific autoregressive errors to analyse the impact of an innovative management practice. Cameron and Trivedi (2010) explain that for short panel data sets, it is possible to control for serial correlation in the error term without explicitly stating a model for serial correlation. However, with a long panel data set i.e. when the time dimension is large relative to the cross-sectional dimension, it is necessary to specify a model for serial correlation in the error term to account for any potential autocorrelation. As the cross-sectional dimension is small in a long panel data set, the assumption that the error term is uncorrelated between groups or individuals is unlikely to hold.

Ignoring the potential correlation of regression disturbances over time will lead to biased standard errors and statistical tests would lose their validity. Unobserved factors may lead to complex forms of spatial and temporal dependence. Hence the standard errors should be adjusted for the potential dependence in the residuals. Also, it would be more natural to assume that residuals are correlated both within lines and between assembly lines (Hoechle, 2007). One of the methods to adjust the standard errors is to allow the error term to follow a line specific autoregressive process of order 1 as was used by Boning et al. (2007). One way to incorporate this into the methodology is to use ordinary least squares with panel corrected standard errors. This allows the error term to be heteroscedastic, autocorrelated of order 1 and correlated over the cross-sectional units (i.e.

[11] Whilst we do not have information on capital input, given the high frequency of the data it seems a reasonable assumption that capital is fixed on a daily basis and over a short annual time horizon. Hence, arguably capital differences within the firm by assembly line can be captured by job complexity according to line specific fixed effects.

contemporaneous spatial dependence). An alternative approach is to use OLS or fixed effects with standard errors as proposed by Driscoll and Kraay (1998) that are assumed to be heteroscedastic and robust to very general forms of spatial and temporal dependence. Hence, these standard errors allow autocorrelation in the error term of a more general form rather than restricting the errors to follow a first order autoregressive process. The cross-sectional dependence in the disturbance term arises due to the presence of an unobserved factor, which is common to all cross-sectional units. It follows an autoregressive process so both contemporaneous and lagged spatial dependence is present.

Following on from the above discussion the disturbance term from equation (1) is defined in in two alternative ways. Firstly, in a model with Driscoll and Kraay standard errors the disturbance term is given as follows:

$$\epsilon_{it} = \lambda_i f_t + \nu_{it}, \qquad f_t = \sum_{\rho=1}^{z} \delta f_{t-\rho} + \omega_t \tag{2a}$$

where there is an autoregressive process δ, with autocorrelation parameters λ_i, and ν_{it} is an idiosyncratic error term which is uncorrelated over time and across lines. These specifications are similar to those employed by Boning et al. (2007), where equation (2a) allows ρ to vary between 1 to z and incorporates both contemporaneous and lagged spatial dependence. In the results which follow the optimal lag length for autocorrelation is $z = 6$.[12] Secondly, in alternative models based upon panel corrected standard errors we restrict the error term to follow an autoregressive process of order one which only allows for contemporaneous spatial dependence, i.e. the error term is defined as:

$$\epsilon_{it} = \rho_i \epsilon_{it-1} + \omega_{it} \tag{2b}$$

[12] The optimal lag length is calculated from: $m(T) = floor\left[4(T/100)^{\frac{2}{9}}\right]$, where $m(T)$ denotes the maximum lag length to which the residuals are autocorrelated and T represents time where in the analysis herein there are 867 days in the sample. Hence, the optimal lag length is 6.46 which the $floor$ function rounds down to the nearest integer of 6 lags, i.e. $z = 6$ in equation (2a). The results which follow are generally robust to alternatively specifying the lag length from $z = 1,2,..,10$ and are available upon request.

where ω_{it} is serially uncorrelated but are correlated over i. The following section discusses the results of estimating the above productivity equations where our primary focus is on the estimates in terms of sign, statistical significance and economic magnitude, of the β_1 and γ_i.

3. Results and Analysis

Table 5 illustrates the impact of the implementation of the new quality management practice on total production, i.e. output, (columns 1-2) and labour productivity (columns 3-4) using the estimates from equation (1), but excluding line fixed effects ($line_i$) and interactions with the binary indicator for the presence of the management intervention (QMP_t) – i.e. imposing the constraint that $\theta_i = \gamma_i = 0$. Table 7 estimates the impact of the new management practice on total production (columns 1 and 2) and labour productivity (columns 3 and 4), but now incorporating line specific fixed effects, i.e. equation (1). In Tables 5 to 7 the models incorporate Driscoll and Kraay standard errors with the autocorrelation lag length defined as by equation (2a). In an alternative specification Table 8 provides estimates of equation (1) for the impact of the implementation of the new management practice on production (columns 1 and 2) and labour productivity (columns 3 and 4) with panel corrected standard errors and the error term defined by equation (2b).

The analysis is divided into sub-sections where we discuss the results for: (1) the baseline effect of the quality management practice prior to accounting for the complexity of the production task, i.e. excluding line fixed effects and interactions; (2) the impact of the introduction of the new practice on productivity after allowing for heterogeneity across lines and differential effects of the management intervention; and (3) a discussion of the results in relation to the existing literature.

3.1 Baseline impact of quality management practice ignoring job complexity

The estimated coefficients for workers, materials and target output in Table 5 suggest a positive and significant relationship with production in all specifications (columns 1 and 2). Setting higher targets is associated with increasing levels of output and labour productivity which is consistent with Bryson and Forth (2018). Similarly, material inputs have a positive association with labour productivity, i.e.

output per worker (columns 3 and 4). The estimates reveal that the standard minute value has an inverse relationship with labour productivity, e.g. column (4) shows that a one percent increase in the standard minute value is likely to reduce labour productivity by 0.1 percent. This result is not surprising, given a fixed 480-minute shift, an increase in the time it takes to produce a garment on the line will reduce the number of garments that can be produced during that shift. The coefficients for the quadratic time trend indicate that productivity is increasing over time but at a decreasing rate (columns 1 and 3, for production and output per worker respectively). The time dummies show that firm production and labour productivity in 2014, 2015 and 2016 is higher than the base year which is 2013 (columns 2 and 4, for production and output per worker respectively).

Prior to controlling for the complexity of the production process the analysis in Table 5 suggests that the implementation of the new quality management practice significantly decreases both firm output and labour productivity. In columns (1) and (2), which differ by how time is incorporated into the model, implementation of the new quality management practice is found to significantly reduce firm production by 4.9 and 5.5 percent respectively. Similar sized effects are also found when considering output per worker in columns (3) and (4) with corresponding estimates of a reduction in labour productivity of 6.1 and 6 percent respectively. Hence, the baseline estimates imply that the new management practice had a negative impact upon productivity at the firm.

Although there were no other major changes in the organisation over the sample period, in the absence of a control group, we explore the sensitivity of the results reported so far to different window lengths pre and post the management intervention. The idea here is that a shorter period either side of the intervention should help to minimise the impact of any unknown factors which could affect firm performance. Table 6 shows the impact of the quality management practice on output (panel A) and productivity (panel B) for intervals of 25, 50, 75 and 100 days around the intervention date (15^{th} September 2014), excluding line fixed effects and interactions as in Table 5. The analysis reveals that for alternative windows pre and post treatment the negative effects of the management practice on both output and productivity are still evident up to 75 days. This suggests that the adverse impact of the quality management practice on performance is larger closer to the intervention date and dissipates over time.

3.2 Impact of the new quality management practice by lines of production and task complexity

We now allow for line heterogeneity by estimating equation (1) but fully incorporating line specific effects and interactions with the quality management practice. This enables an investigation of the type of production by line and task complexity, and whether the effect of the management practice varies across assembly lines.

Focusing upon output, columns (1) and (2) of Tables 7 and 8, the results show that within the category of basic lines the implementation of the new quality management practice significantly reduces productivity for lines 1A, 1B, 2A and 4 but increases the productivity of lines 3A and 3B.[13] Lines 1A and 1B are the most basic lines at the firm with the lowest average standard minute value and produce similar goods. The direction of the impact of the new management practice is the same for both, although the magnitude is marginally higher for line 1B. For example, in column (1) of Table 7, the introduction of the new quality management practice reduces the productivity of line 1A by 12.2 percent and reduces the productivity of line 1B by 13.1 percent.[14] Lines 2A and 2B are also basic lines but with a higher average standard minute value as compared to lines 1A and 1B (see Table 2). Both lines 2A and 2B produce similar goods but the direction of the impact of the management practice differs across specifications.

Lines 3A and 3B are basic lines with a higher average standard minute value as compared to the rest of the basic lines. Both these lines produce similar products with both the direction and magnitude of the impact of the new quality management practice being quite similar in most

[13] In equation (1) this is a test of the null hypothesis that $\beta_1 + \gamma_i = 0$. Clearly at the 5% level this is rejected for the aforementioned assembly lines in Tables 7 and 8 (see final rows in the tables).

[14] The impact on line 1B is found from the estimates of equation (1) as $(\widehat{\beta_1} + \widehat{\gamma_2}) \times 100\%$. Hence, based on the estimates in Table 7 column (1) the effect of 13.1% is calculated as follows: $(-0.122 - 0.009) \times 100\% = -13.1\%$.

specifications. In columns (1) and (2) of Tables 7 and 8 the estimates show that the implementation of the new practice increased the production of lines 3A and 3B. For example, in column (1) of Table 7, the introduction of the practice increases the output of line 3A by 8.4 percent and of line 3B by 8.6 percent.

Turning to labour productivity in the final two columns of Tables 7 and 8 a comparable pattern of results is revealed. For example, focusing upon Table 7 column (3) output per worker is reduced following the implementation of the new management practice in lines 1A, 1B and 2A. For example, for lines 1A and 1B productivity falls by 14.4 and 20.2 percent respectively. Conversely, productivity increases in lines 3A and 3B following the introduction of the new management practice by 12.6 and 8.8 percent respectively.

The effect of the management intervention on complex lines is mixed for both output and productivity as revealed from Tables 7 and 8. For example, considering column (1) of Table 7 the estimates show that within the category of complex lines, the implementation of the new quality management practice significantly reduces the production of line 4 by approximately 20 percent. However, there is no significant impact on productivity (see column 3). We also find mixed results for lines 5 and 6. Whether considering output (columns 1 and 2) or productivity (columns 3 and 4) the estimates of Tables 7 and 8 show that there is no significant difference in the impact of the new quality management practice between line 5 and line 1A. Tables 7 and 8 show that the new management practice increases both output and productivity of line 6 but the magnitude is small, but opposite in sign. For example, considering output (labour productivity) the results in column (1) (column 3) show that following the management intervention the corresponding increase (decrease) in output (productivity) is 0.1 (2.3) percent.

Overall, these findings contribute to the literature on insider econometrics which aims to find how management practices impact productivity and identify areas where new practices have smaller or larger effects (see Ichniowski and Shaw, 2009). The results can also be linked to the study by

Bloom and Van Reenen (2007) in which they distinguish between good and bad management practices. The above analysis provides evidence that whether the implementation of the new quality management practice constitutes good practice or not varies by assembly line. Most of the previous work on management and firm performance has used cross sectional data where management is time invariant and the results emphasize that production complexity is an important element in determining the impact of management practices. We find strong evidence that the implementation of the new management practice increases productivity of lines 3A and 3B and this is supported by all specifications. Hence, it has a positive effect on basic lines with the highest complexity (denoted by the highest standard minute value) as compared to the rest of the basic lines. Most specifications show that the implementation of the new quality management practice has an adverse effect on lines at the extreme ends of the complexity spectrum as it has a negative impact on very basic lines and on complex lines. Therefore, in these lines, the standard management practices seem to suffice. These findings can also be linked to the evidence provided by Boning et al. (2007) such that the complexity of production is an important determinant of the success of new management practices.

During the production of denim jeans, there are five stages of production: small parts, back, front, assembly 1 and assembly 2. At the first stage small parts are produced to be ready for the back and front sections. The front and back of the jeans are stitched individually but then the front and back are assembled during assembly 1 and assembly 2 to complete the garment. As production operations are interdependent, a bottleneck at any stage can reduce the productivity of the line. Hence, even if the productivity of certain workers increases, it does not ensure that line productivity will also increase as the productivity of the line is dependent on all the stages of the production process. Most specifications provide evidence that the implementation of the new management practice reduces production and output per worker for certain lines.

3.3 Discussion and potential explanations

The motivation behind introducing the new quality management practice was to incentivize workers to reduce quality defects and enhance productivity (workers were paid piece rates throughout). Less quality defects mean that workers spend less time on re-doing defective pieces, hence this should translate into higher productivity. The result that the implementation of the new quality management practice significantly impacts the productivity of assembly lines whether positively or negatively highlights two alternative theories.[15] The principal-agent theory suggests that an external intervention is expected to improve effort levels of a self-interested agent, as he/she would minimise the possibility of a sanction if caught shirking (Alchian and Demsetz, 1972; Prendergast, 1999; Laffont and Martimort, 2002). However, the crowding out hypothesis derived from social psychology (Frey, 1993) illustrates an alternative view. An external intervention may reduce an agent's self-esteem as the worker may feel that his/her intrinsic motivation is not being appreciated hence would reduce effort. Agents who have high intrinsic motivation may also see external interventions as a sign of distrust. External interventions may have two opposing effects on the performance of workers. The benefit of the intervention to the principal depends upon the relative magnitudes of both the disciplining and crowding out effects (Frey and Jegen, 2001). The evidence for the performance of lines before and after the implementation of the new quality management practice highlights a point that has not been well emphasized in the previous studies on providing external incentives to workers i.e. the complexity of production also plays a role in determining the benefit of the intervention to the agent.

The decrease in productivity after the implementation of the new quality management practice also complements the theory by Holmstrom and Milgrom (1994) such that when workers perform

[15] Other work has also reported unforeseen impacts from new workplace practices, e.g. Cappelli and Neumark (2001) who found that the introduction of a high performance work practice had negligible effects on productivity and labour efficiency. Also see the review of Siebers (2008) which found mixed evidence of a positive relationship between the adoption of new management practices and productivity enhancement.

multiple tasks, increasing an incentive for one task would lead to workers focusing just on that particular task while neglecting the rest. This theory is particularly relevant as the quantity-quality trade off exists while workers are paid piece rates (Paarsch and Shearer, 1999). Higher stitching speed means that workers may skimp on quality. In our case, the incentive for quality changes while the incentive for productivity remains the same. Although we do not have data on quality defects per line so we cannot comment on how quality defects changed at the line level, one potential reason for the slowdown in productivity could be that overall lines were trying to produce slowly in order to produce better quality products and minimize quality defects after the new management incentive was introduced. Increasing incentives for all tasks is likely to minimize this problem and incentives should be complementary in nature.[16]

Whilst data on quality defects per line is not available we do have information on the total number of daily defects made by workers. Hence, we can estimate a model over each of the 867 days of the sample period (t) of the following form to ascertain whether or not the number of daily defects (D_t) decreased after the implementation of the quality management practice (QMP_t) as defined above:

$$D_t = \alpha + \psi QMP_t + \boldsymbol{Z}_t'\boldsymbol{\beta} + \epsilon_t \tag{3}$$

where $\boldsymbol{Z}_t$ is a vector of control variables which includes: the total number of workers; average worker tenure in the firm; average worker age; the proportion of female workers; and a quadratic time trend. If the estimate of ψ is negative and statistically significant then this would be consistent with the new management practice decreasing the number of quality defects made at the factory, which was the primary purpose of the intervention, but this impinged upon line productivity as found in the results discussed above resulting in a quantity-quality trade-off.

Table 9 shows the results of estimating equation (3) by: OLS (column 1); with Newey-West

[16] Milgrom and Roberts (1995) suggest that bonuses for quality and piece rates are complementary practices but they also emphasize that these practices should be paired with policies that provide job security as employees may be threatened that productivity enhancement may culminate in job loss. A proper channel of communication needs to be present between workers and management that enhances the trust needed to make the system work, e.g. Ichniowski et al. (1997).

standard errors with a heteroscedastic error structure and the presence of autocorrelation (column 2); and as a count outcome allowing for over-dispersion, i.e. a negative binomial regression, incorporating heteroscedasticity and autocorrelation consistent standard errors (column 3).[17] The analysis shows that the quality management practice led to a reduction in the number of defects and this finding is robust across alternative estimators, i.e. $\hat{\psi} < 0$ and statistically significant (see Table 9). For example, columns (1) and (2) show that after the new management intervention the number of defects fell by 59.[18, 19] However, modelling the number of daily defects via a linear specification (as in columns 1 and 2) implies that an increase in defects from twelve to thirteen is equivalent to that of an increase from fifty to fifty-one defects. This is arguably inappropriate given that defects are a count outcome and not normally distributed (see Figure 3).[20] As such, in the final column of Table 9 we model the number of defects via a negative binomial estimator allowing for autocorrelation and heteroscedasticity.[21] Again, the effect of the management practice on defects is to reduce them – the intended outcome of the intervention – where the estimates in column (3) imply a decrease on average of 25 defects per day.[22, 23]

4. Conclusion

This paper has contributed to the literature on the role of management practices and productivity where existing evidence in the economics and management literature is mixed (e.g. Siebers et al., 2008), using unique data for a garment producing firm in Pakistan. The analysis complements the studies by Bloom and Van Reenen (2007) and Bloom et al. (2013). The answer to the question of

[17] Defects are found to be increasing in the number of total workers, average tenure and age, whilst conversely decreasing in the proportion of female workers. The results are robust, in terms of the sign and significance of $\hat{\psi}$, to incorporating a polynomial functional form in the number of workers, tenure and age.
[18] The d-statistic from the OLS results shown in column (1) reveals that autocorrelation is problematic.
[19] The estimate of ψ is statistically significant at the 1% level in the Newey-West estimates for any lag length specified.
[20] The number of daily defects has kurtosis of 3.8 and the Shapiro-Wilk test for normality rejects the null at the 1% level.
[21] The deviance statistic in column (3) reveals that a poisson estimator would be inappropriate due to over-dispersion.
[22] This is calculated from $e^{(\hat{\psi}-1)} \times 100\%$.
[23] Alternatively we modelled the number of daily defects as a proportion of the number of employees, treating the outcome as continuous with Newey-West standard errors. The results show that the implementation of the new quality management practice was associated with a fall in daily defects per worker of 6.8% (*p-value=0.000*).

whether this new management practice turns out to be a good or bad management intervention is not straight forward as the impact of the new practice varies by assembly line. The results provide evidence consistent with Boning et al. (2007) such that the impact of new management practices is contingent upon the complexity of production as there are sizeable differences in the impact of the new quality management practice between complex and basic lines. In the context of this manufacturing firm the standard management practices seem to suffice for very basic lines and complex lines, while the new practice is beneficial for lines 3A and 3B. Whilst the results of the intervention are mixed for output and productivity, we find evidence that the total number of daily defects falls following the implementation of the new management practice which is consistent with a quantity-quality trade off.

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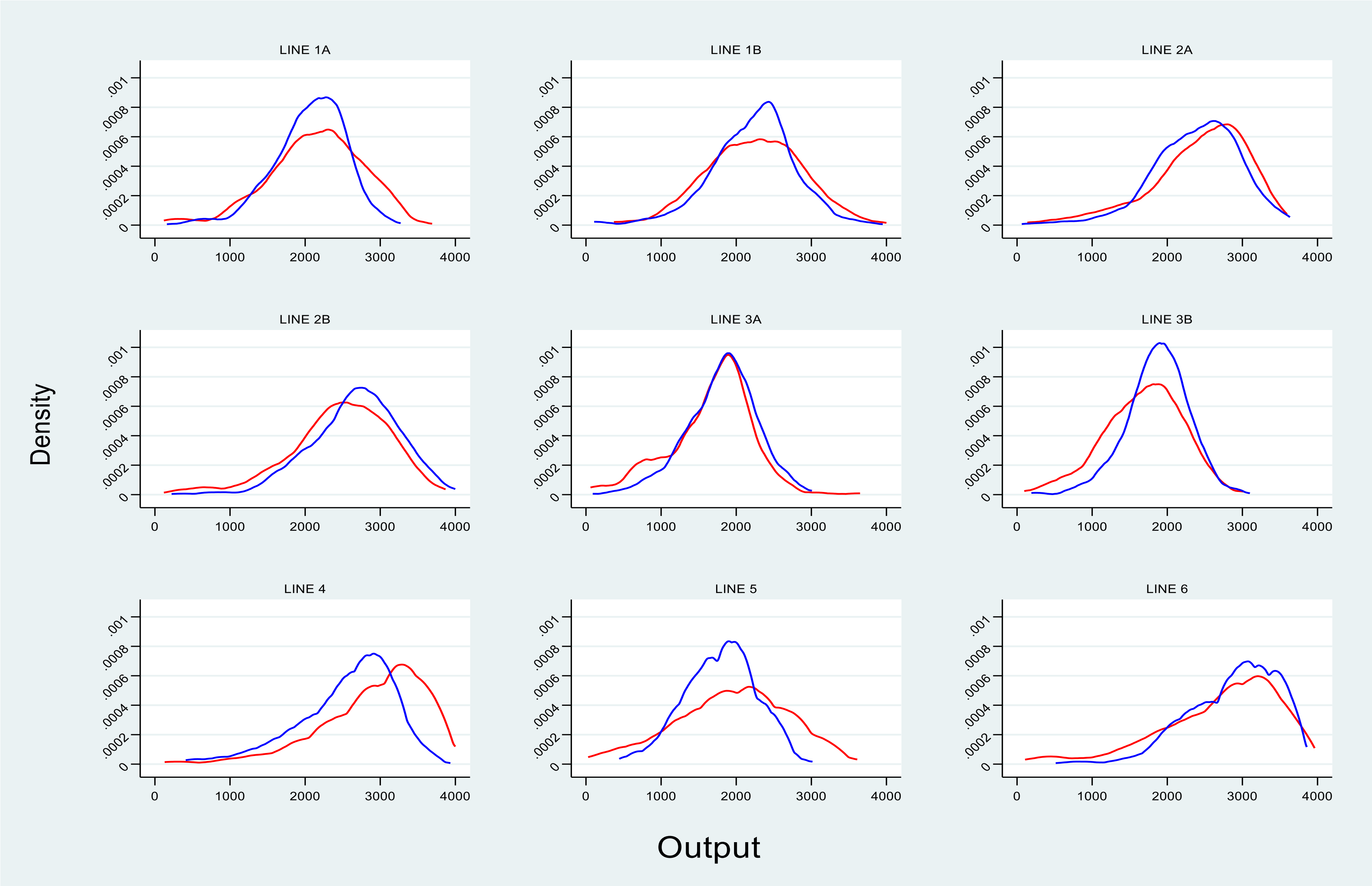
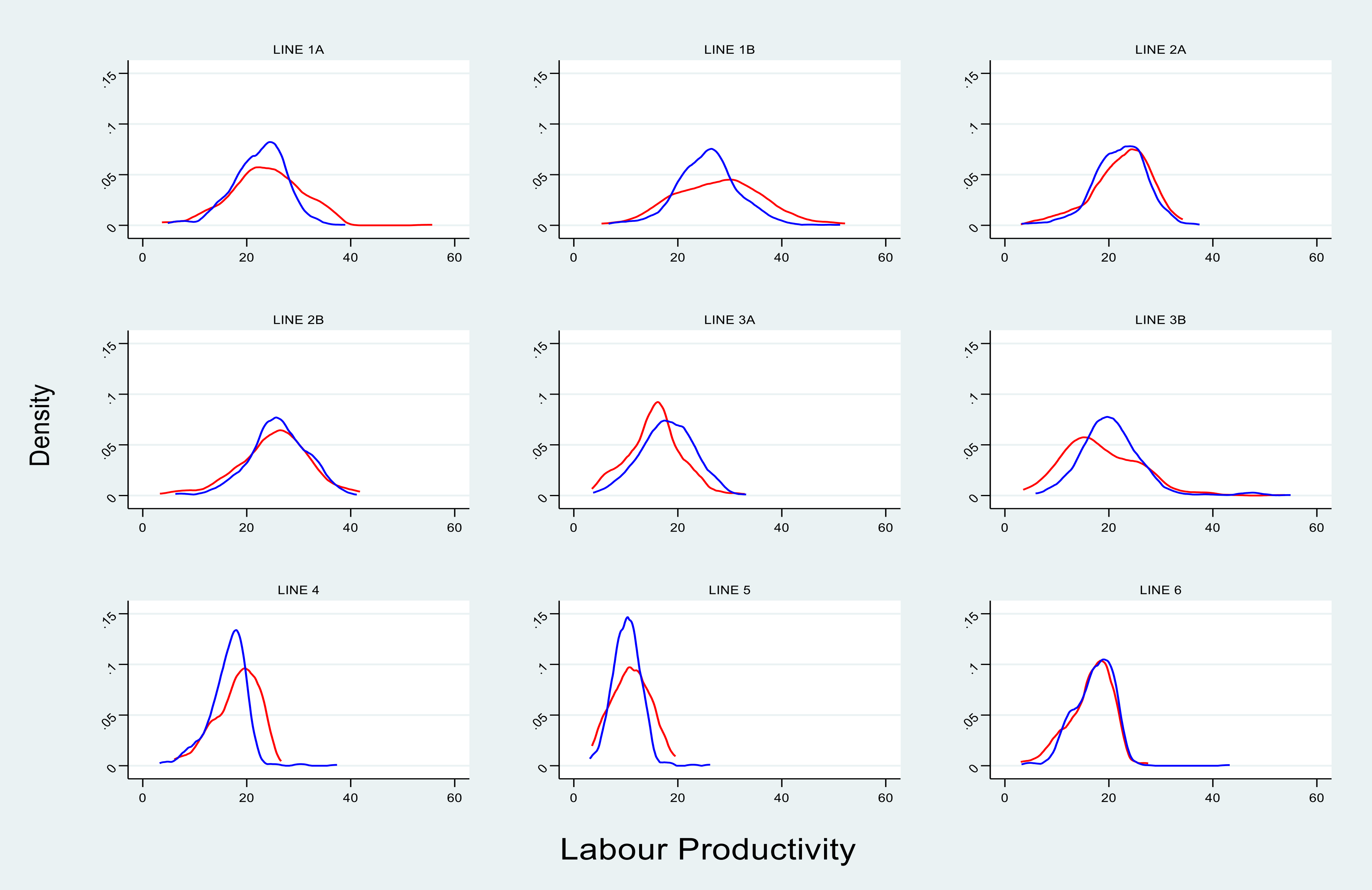
FIGURE 1: Distribution of output per line before and after the new quality management practice



Note: red line distribution pre intervention and blue line distribution post intervention.

FIGURE 2: Distribution of labour productivity per line before and after the new quality management practice



Note: red line distribution pre intervention and blue line distribution post intervention.

FIGURE 3: Number of daily quality defects

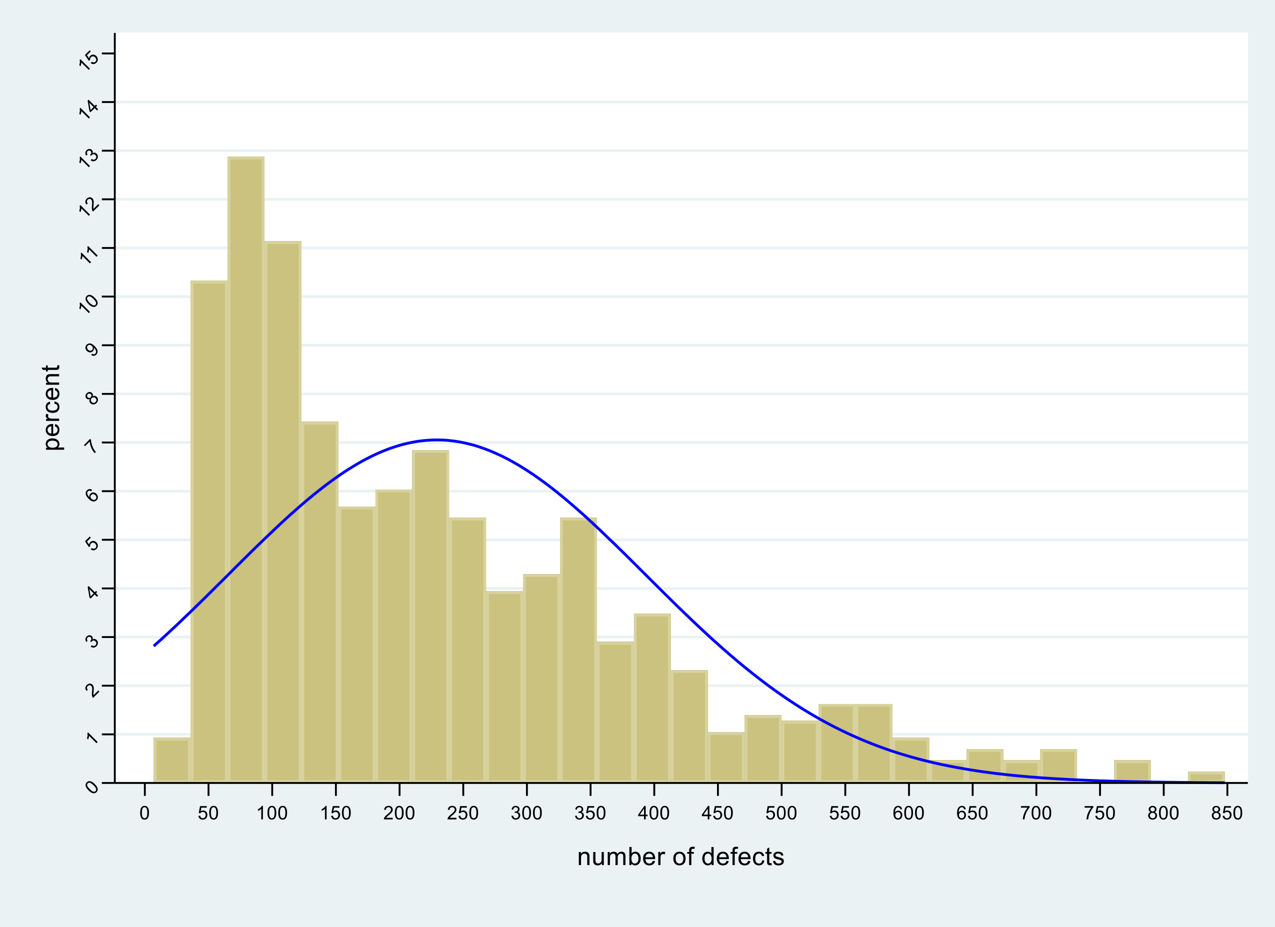


TABLE 1: Summary statistics

	Mean	Standard Deviation	Min.	Max.
Total Production	2245.69	701.98	29	4000
Number of workers	121.23	36.38	19	218
Output per worker	19.83	7.63	0.15	96.72
Standard Minute Value (SMV)	18.46	4.45	4.28	34.99
Target per line	2540.57	495.61	1500	3500
Materials	2433.34	659.41	31	5736
Observations		7,031		

TABLE 2: Standard minute value (SMV) by line of production

Line code	Mean SMV	Min. SMV	Max. SMV	Complexity
1A	14.95	11.69	21.95	Basic
1B	14.93	4.63	21.95	Basic
2A	16.45	11.54	25.90	Basic
2B	16.38	4.28	25.90	Basic
3A	17.67	11.55	26.68	Basic
3B	17.62	11.54	26.68	Basic
4	21.09	12.88	30.70	Complex
5	25.66	11.26	34.99	Complex
6	21.56	11.68	33.52	Complex

TABLE 3: Summary statistics by assembly line

	Line 1A MEAN	Line 1B MEAN	Line 2A MEAN	Line 2B MEAN	Line 3A MEAN	Line 3B MEAN	Line 4 MEAN	Line 5 MEAN	Line 6 MEAN
Total Production	2095.25	2229.24	2406.10	2587.71	1756.30	1800.12	2685.70	1845.18	2815.18
Workers	91.99	84.56	108.28	100.87	105.52	95.00	159.41	179.81	169.03
Output per worker	22.92	26.62	22.30	25.77	16.95	19.69	16.84	10.31	16.74
Standard Minute Value	14.95	14.93	16.45	16.45	17.67	17.66	21.09	25.66	21.56
Target	2383.04	2378.57	2474.88	2476.28	2068.77	2068.13	3168.46	2472.37	3417.62
Materials	2430.08	2429.91	2586.61	2579.92	1884.46	1888.93	2827.74	2189.29	3109.98
Observations	746	770	816	801	807	800	742	760	789

TABLE 4: Differences in production and output per worker by line before and after the introduction of the management practice

	PRODUCTION			OUTPUT PER WORKER		
	After	Before	Difference	After	Before	Difference
Line 1A	2062.16	2141.03	-78.87*	22.36	23.69	-1.32***
			(40.24)			(0.47)
Line 1B	2220.80	2241.76	-20.95	25.57	28.18	-2.60***
			(43.58)			(0.56)
Line 2A	2390.96	2430.30	-39.34	22.09	22.64	-0.55
			(43.59)			(0.45)
Line 2B	2671.40	2455.86	215.54***	26.02	25.37	0.66
			(44.69)			(0.48)
Line 3A	1809.42	1665.10	144.32***	17.94	15.26	2.68***
			(36.58)			(0.39)
Line 3B	1870.69	1678.67	192.02***	20.51	18.31	2.19***
			(33.43)			(0.50)
Line 4	2553.19	2925.62	-372.43***	16.26	17.89	-1.63***
			(50.37)			(0.32)
Line 5	1787.65	1937.90	-150.25***	10.17	10.53	0.36
			(44.58)			(0.25)
Line 6	2886.72	2701.62	185.10***	17.15	16.09	1.06***
			(49.06)			(0.31)

Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 5: The impact of the new quality management practice on firm productivity

	(1) Log of Production	(2) Log of Production	(3) Log of Output per Worker	(4) Log of Output per Worker
Log of Workers	0.226***	0.202**		
	(0.087)	(0.086)		
Log of Materials	0.207***	0.199***	0.195***	0.187***
	(0.021)	(0.021)	(0.021)	(0.021)
Log of SMV	-0.068	-0.060	-0.103**	-0.097**
	(0.043)	(0.043)	(0.041)	(0.043)
Log of Target	0.171**	0.236***	0.216***	0.266**
	(0.084)	(0.087)	(0.083)	(0.089)
QMP	-0.049**	-0.055***	-0.061**	-0.060***
	(0.023)	(0.021)	(0.025)	(0.020)
Trend ($\times 10^3$)	0.766***		0.588***	
	(0.163)		(0.169)	
Trend squared ($\times 10^6$)	-0.716***		-0.404**	
	(0.157)		(0.160)	
2014		0.091***		0.063**
		(0.025)		(0.028)
2015		0.211***		0.193***
		(0.033)		(0.037)
2016		0.117***		0.141***
		(0.035)		(0.038)
Constant	3.711***	3.383***	-0.114	-0.422
	(0.820)	(0.831)	(0.719)	(0.763)
R-squared	0.0622	0.0714	0.0476	0.0526
Observations		7,031		

All models are estimated with Driscoll and Kraay standard errors, i.e. equation (1) but excluding line fixed effects and interactions – hence imposing the constraint that $\theta_i = \gamma_i = 0$, with the disturbance term specified in equation (2a) and $z = 6$.
Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 6: The impact of the new quality management practice on firm productivity – window length

PANEL A: Log of Production	(1) 25 days	(2) 50 days	(3) 75 days	(4) 100 days
QMP	-0.179**	-0.156***	-0.155***	-0.059
	(0.089)	(0.058)	(0.055)	(0.054)
R-squared	0.0530	0.0510	0.0773	0.0418
Observations	334	618	996	1,358
PANEL B: Log of Output per Worker	(1) 25 days	(2) 50 days	(3) 75 days	(4) 100 days
QMP	-0.203***	-0.155***	-0.157***	-0.056
	(0.084)	(0.057)	(0.054)	(0.053)
R-squared	0.0474	0.0293	0.0463	0.0243
Observations	334	618	996	1,358

Each column reports a different interval pre and post intervention. All models are estimated with Driscoll and Kraay standard errors, i.e. equation (1) but excluding line fixed effects and interactions – hence imposing the constraint that $\theta_i = \gamma_i = 0$, with the disturbance term specified in equation (2a) and $z = 4$. Other controls as in Table 5 incorporating a quadratic time trend. Standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 7: The impact of the new quality management practice on firm productivity – line specific effects

	(1) Log of Production	(2) Log of Production	(3) Log of Output per Worker	(4) Log of Output per Worker
Log of Workers	0.237***	0.219**		
	(0.087)	(0.086)		
Log of Materials	0.206***	0.199***	0.197***	0.190***
	(0.021)	(0.021)	(0.021)	(0.021)
Log of SMV	-0.124***	-0.114**	-0.165***	-0.159***
	(0.045)	(0.046)	(0.042)	(0.044)
Log of Target	0.158*	0.224**	0.181*	0.240**
	(0.092)	(0.095)	(0.092)	(0.096)
QMP	-0.122***	-0.133***	-0.144***	-0.149***
	(0.038)	(0.036)	(0.037)	(0.035)
Line 1B	0.087***	0.085***	0.181***	0.181***
	(0.027)	(0.027)	(0.025)	(0.025)
Line 2A	0.064	0.062	-0.067*	-0.070*
	(0.039)	(0.039)	(0.038)	(0.038)
Line 2B	0.101***	0.098***	0.0525	0.049
	(0.036)	(0.036)	(0.036)	(0.036)
Line 3A	-0.257***	-0.251***	-0.394***	-0.392***
	(0.053)	(0.053)	(0.049)	(0.049)
Line 3B	-0.192***	-0.189***	-0.217***	-0.215***
	(0.046)	(0.046)	(0.050)	(0.049)

TABLE 7 (cont.): The impact of the new quality management practice on firm productivity – line specific effects

	(1) Log of Production	(2) Log of Production	(3) Log of Output per Worker	(4) Log of Output per Worker
Line 4	0.141**	0.110*	-0.302***	-0.333***
	(0.066)	(0.066)	(0.046)	(0.048)
Line 5	-0.248***	-0.249***	-0.763***	-0.774***
	(0.082)	(0.081)	(0.057)	(0.058)
Line 6	0.010	-0.004	-0.447***	-0.466***
	(0.068)	(0.067)	(0.045)	(0.045)
Line 1B × QMP	-0.009	-0.007	-0.058	-0.057
	(0.034)	(0.034)	(0.034)	(0.034)
Line 2A × QMP	0.043	0.046	0.050	0.057
	(0.042)	(0.042)	(0.042)	(0.042)
Line 2B × QMP	0.139***	0.145***	0.106**	0.113***
	(0.041)	(0.041)	(0.041)	(0.041)
Line 3A × QMP	0.206***	0.209***	0.270***	0.277***
	(0.052)	(0.052)	(0.051)	(0.051)
Line 3B × QMP	0.208***	0.213***	0.232***	0.239***
	(0.048)	(0.048)	(0.052)	(0.052)
Line 4 × QMP	-0.079*	-0.061	-0.028	-0.018
	(0.046)	(0.045)	(0.045)	(0.045)
Line 5 × QMP	0.028	0.033	0.069	0.072
	(0.055)	(0.055)	(0.056)	(0.056)
Line 6 × QMP	0.123***	0.120**	0.121**	0.120**
	(0.047)	(0.048)	(0.048)	(0.048)

TABLE 7 (cont.): The impact of the new quality management practice on firm productivity – line specific effects

	(1) Log of Production	(2) Log of Production	(3) Log of Output per Worker	(4) Log of Output per Worker
Constant	3.960***	3.593***	0.526	0.202
	(0.844)	(0.854)	(0.774)	(0.816)
Quadratic time trend	✓	X	✓	X
Time dummies	X	✓	X	✓
R-squared	0.2485	0.2555	0.3645	0.3634
Line 1A, $H_0: \beta_1 = 0$; *p-value*	*0.0333*	*0.0166*	*0.0142*	*0.0086*
Line 1B, $H_0: \beta_1 + \gamma_2 = 0$; *p-value*	*0.0003*	*0.0152*	*0.0034*	*0.0018*
Line 2A, $H_0: \beta_1 + \gamma_3 = 0$; *p-value*	*0.0455*	*0.0248*	*0.0255*	*0.0105*
Line 2B, $H_0: \beta_1 + \gamma_4 = 0$; *p-value*	*0.7717*	*0.8118*	*0.5067*	*0.4674*
Line 3A, $H_0: \beta_1 + \gamma_5 = 0$; *p-value*	*0.0402*	*0.0980*	*0.0439*	*0.0692*
Line 3B, $H_0: \beta_1 + \gamma_6 = 0$; *p-value*	*0.0496*	*0.0472*	*0.0478*	*0.0403*
Line 4, $H_0: \beta_1 + \gamma_7 = 0$; *p-value*	*0.0003*	*0.0021*	*0.0076*	*0.0070*
Line 5, $H_0: \beta_1 + \gamma_8 = 0$; *p-value*	*0.1555*	*0.1469*	*0.2740*	*0.2817*
Line 6, $H_0: \beta_1 + \gamma_9 = 0$; *p-value*	*0.9851*	*0.8298*	*0.7069*	*0.6499*
Observations		7,031		

All models are estimated using fixed effects with Driscoll and Kraay standard errors, i.e. equation (1) with the disturbance term specified in equation (2a) and $z = 6$.
Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 8: The impact of the new quality management practice on firm productivity – alternative specification

	(1) Log of Production	(2) Log of Production	(3) Log of Output per Worker	(4) Log of Output per Worker
Log of Workers	0.286***	0.272***		
	(0.047)	(0.046)		
Log of Materials	0.094***	0.090***	0.089***	0.085***
	(0.011)	(0.011)	(0.012)	(0.011)
Log of SMV	-0.125***	-0.116***	-0.132***	-0.128***
	(0.036)	(0.036)	(0.037)	(0.036)
Log of Target	0.156**	0.227***	0.156*	0.215**
	(0.079)	(0.079)	(0.083)	(0.083)
QMP	-0.109***	-0.139***	-0.132***	-0.151***
	(0.042)	(0.039)	(0.043)	(0.040)
Line 1B	0.093***	0.091***	0.181***	0.181***
	(0.034)	(0.033)	(0.035)	(0.035)
Line 2A	0.072*	0.0689*	-0.051	-0.055
	(0.039)	(0.039)	(0.038)	(0.038)
Line 2B	0.114***	0.108***	0.068*	0.062*
	(0.037)	(0.036)	(0.038)	(0.037)
Line 3A	-0.286***	-0.280***	-0.419***	-0.416***
	(0.045)	(0.045)	(0.046)	(0.046)
Line 3B	-0.213***	-0.208***	-0.240***	-0.238***
	(0.042)	(0.041)	(0.049)	(0.048)
Line 4	0.144**	0.112**	-0.276***	-0.308***
	(0.056)	(0.056)	(0.050)	(0.050)

TABLE 8 (Cont.): The impact of the new quality management practice on firm productivity – alternative specification

	(1) Log of Production	(2) Log of Production	(3) Log of Output per Worker	(4) Log of Output per Worker
Line 5	-0.279***	-0.281***	-0.778***	-0.786***
	(0.064)	(0.064)	(0.057)	(0.057)
Line 6	0.017	-0.003	-0.418***	-0.438***
	(0.057)	(0.057)	(0.050)	(0.051)
Line 1B × QMP	-0.011	-0.008	-0.056	-0.054
	(0.044)	(0.043)	(0.045)	(0.045)
Line 2A × QMP	0.033	0.039	0.041	0.049
	(0.049)	(0.048)	(0.049)	(0.049)
Line 2B × QMP	0.128***	0.137***	0.096**	0.105**
	(0.048)	(0.046)	(0.048)	(0.047)
Line 3A × QMP	0.200***	0.205***	0.258***	0.266***
	(0.055)	(0.055)	(0.057)	(0.057)
Line 3B × QMP	0.199***	0.206***	0.219***	0.227***
	(0.052)	(0.051)	(0.061)	(0.060)
Line 4 × QMP	-0.096*	-0.080	-0.048	-0.036
	(0.052)	(0.051)	(0.053)	(0.052)
Line 5 × QMP	0.013	0.018	0.055	0.058
	(0.066)	(0.066)	(0.068)	(0.069)
Line 6 × QMP	0.115**	0.112**	0.117**	0.117**
	(0.053)	(0.054)	(0.055)	(0.056)
Constant	4.623***	4.196***	1.470**	1.088
	(0.684)	(0.678)	(0.673)	(0.681)
Quadratic time trend	✓	X	✓	X
Time dummies	X	✓	X	✓

TABLE 8 (Cont.): The impact of the new quality management practice on firm productivity – alternative specification

	(1) Log of Production	(2) Log of Production	(3) Log of Output per Worker	(4) Log of Output per Worker
ρ_{1A}	0.298	0.286	0.306	0.301
ρ_{1B}	0.273	0.252	0.318	0.305
ρ_{2A}	0.388	0.371	0.433	0.419
ρ_{2B}	0.356	0.325	0.354	0.328
ρ_{3A}	0.381	0.388	0.404	0.414
ρ_{3B}	0.420	0.416	0.503	0.497
ρ_{4}	0.403	0.397	0.491	0.489
ρ_{5}	0.534	0.539	0.518	0.523
ρ_{6}	0.501	0.517	0.496	0.514
R-squared	0.7914	0.8313	0.5788	0.6138
Line 1A, $H_0: \beta_1 = 0$; *p-value*	*0.0098*	*0.0003*	*0.0022*	*0.0002*
Line 1B, $H_0: \beta_1 + \gamma_2 = 0$; *p-value*	*0.0043*	*0.0001*	*0.0000*	*0.0000*
Line 2A, $H_0: \beta_1 + \gamma_3 = 0$; *p-value*	*0.0047*	*0.0122*	*0.0368*	*0.0110*
Line 2B, $H_0: \beta_1 + \gamma_4 = 0$; *p-value*	*0.6409*	*0.9461*	*0.3895*	*0.2306*
Line 3A, $H_0: \beta_1 + \gamma_5 = 0$; *p-value*	*0.0483*	*0.0406*	*0.0205*	*0.0280*
Line 3B, $H_0: \beta_1 + \gamma_6 = 0$; *p-value*	*0.0497*	*0.0332*	*0.0476*	*0.0541*
Line 4, $H_0: \beta_1 + \gamma_7 = 0$; *p-value*	*0.0000*	*0.0000*	*0.0001*	*0.0000*
Line 5, $H_0: \beta_1 + \gamma_8 = 0$; *p-value*	*0.1218*	*0.0440*	*0.2226*	*0.1370*
Line 6, $H_0: \beta_1 + \gamma_9 = 0$; *p-value*	*0.9036*	*0.5703*	*0.7761*	*0.5055*
Observations		7,031		

All models are estimated using OLS with panel corrected standard errors, i.e. equation (1) with the disturbance term specified in equation (2b).
Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 9: The impact of the new quality management practice on the number of daily quality defects

	(1) OLS		(2) NEWEY-WEST		(3) NEGATIVE BINOMIAL	
QMP	-59.084	(8.993)***	-59.084	(8.693)***	-0.384	(0.042)***
Number of workers	0.309	(0.020)***	0.309	(0.022)***	0.002	(0.000)***
Average worker tenure	0.091	(0.024)***	0.091	(0.024)***	0.004	(0.000)***
Average worker age	0.037	(0.016)**	0.037	(0.017)**	0.003	(0.000)***
% employees female	-25.296	(0.721)***	-25.296	(1.786)***	-0.117	(0.017)***
Constant	1745.969	(150.139)***	1745.969	(254.172)***	11.937	(2.296)***
Quadratic time trend	✓		✓		✓	
d-statistic (8, 867)	2.3272					
R-squared	0.6306					
F-statistic (7, 856); *p-value*			225.35; *0.000*			
LR, $\chi^2(7)$; *p-value*					851.29; *0.000*	
Deviance statistic, $\chi^2(7)$; *p-value*					38,302.16; *0.000*	
Observations			867			

In column (2) the maximum lag length specified is 1. Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.