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THE EFFECT OF A MANAGEMENT INTERVENTION ON FIRM PERFORMANCE AND QUALITY DEFECTS#

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Abstract

Using a novel firm level data set from a garment manufacturer in Pakistan we investigate the effect of a new quality management monitoring practice on firm performance and daily defects. We provide evidence that the intervention generally had a negative correlation with firm performance for those lines at the extreme ends of the complexity spectrum. Evidence consistent with a quantity-quality trade-off is also found, in that whilst the implementation of the new management practice was generally adversely associated upon all aspects of firm performance 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: management intervention, firm performance, production complexity, output quality.

1. Introduction and Background

The aim of this paper is to investigate how a unique quality management practice effected line level firm performance of a garments manufacturing firm in Pakistan. The analysis undertaken herein is related to Menzel (2021) who considered the effect of organizational learning in three Bangladeshi garment factories and Adhvaryu et al. (2023) who employed garment production data from six Indian factories across 120 production lines to explore the role of managerial quality on productivity. Our analysis also complements the work 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 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. The motivation behind introducing the new quality management practice was to incentivize workers to reduce quality defects and enhance productivity (where workers were paid piece rates throughout). 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 particular 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 crucial 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 intervention in the stitching department to motivate workers to strike a balance between quantity and quality, while keeping piece rates intact. The purpose of the practice was to increase product quality by reducing the number of defects in the production process whilst improving performance, i.e. with fewer defects workers spend less time on re-doing defective pieces and this should translate into higher productivity. The 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 potentially brings in an element of peer pressure onto the factory floor, as workers compare themselves with their co-workers and may experience the pressure of matching up to the performance of their peers (Cornelissen et al. 2017; Falk and Ichino 2006; Mas and Moretti 2009).

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 firm performance varies with the complexity of production. However, the implementation of the new quality practice had the desired effect of reducing the total number of daily quality defects.[1] Hence, the evidence is consistent with a quantity-quality trade-off.

In summary we make four contributions to the literature: (i) we examine the effect of the new quality management practice on both quantity (firm performance metrics) and quality (the number of defects);[2] (ii) provide new evidence for a developing economy; (iii) allow for the complexity of the task performed; and (iv) adopt multiple measures of firm performance are adopted, including productivity measures which are arguably more appropriate for the garment sector. 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 concludes.

2. Data and Methodology

2.1 Organization and overview 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.[3] 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 outlines 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 what is required by the supplier, this is in order to keep a cushion in case there are defect garments at the 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, an assembly 1 and assembly 2 section. 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 needs 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) and represents the time it takes to complete one process.[4] 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 two 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 five sections, hence there are five quality supervisors at the end of each section, two quality supervisors for random in-line quality checking and two 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 final 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. 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 data includes information on the number of workers employed per line per day, target output per line per day, material inputs, the standard minute value of the product being produced per line per day which denotes the complexity of the product the materials (intermediate inputs) loaded on each line per day, and the number of daily quality defects (the aggregate across all lines). We adopt four alternative of measures of firm performance in the analysis, specifically: (i) total production at the firm, i.e. the number of garments stitched per day per line; (ii) output per worker per line, i.e. labour productivity, we also consider measures which are arguably more specific and appropriate to the garment sector (and have been used in the existing literature), i.e.; (iii) following Adhvaryu et al. (2023) daily target efficiency per line defined by: [5]

$$\text{target efficiency} = \left(\frac{Target\ Output \times SMV}{No.\ Workers \times Daily\ Hours \times 60^{mins}}\right) \qquad (1)$$

and; (iv) alternatively following Menzel (2021) line level productivity (i.e., actual efficiency) is calculated as follows:

$$\text{productivity} = \left(\frac{Daily\ Output \times SMV}{No.\ Workers \times Daily\ Hours \times 60^{mins}}\right) \qquad (2)$$

These are our primary measures of firm performance where efficiency is equivalent to the actual (or target) number of garments produced taking line complexity into account for that line order 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).[6] Hence, the data is a high-frequency panel across the different production lines. The panel is unbalanced as some line-day level observations were missing, so the total sample contains 7,031 line-day level observations.

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 average number of daily defects over the period was 232 per day with a minimum of 7 and maximum of 848. The average daily target efficiency is above the average productivity level (i.e., actual efficiency) achieved, 82% compared to 73%, but has slightly less variation around the mean.

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 predominantly produce simple products are referred to as basic lines, whilst 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 in comparison to basic products, although some tasks will be common across all products.[7] Lines 1A, 1B, 2A, 2B, 3A and 3B are all basic lines, while lines 4, 5 and 6 are deemed complex lines. Lines 3A and 3B produce slightly more complicated goods as compared to the 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.

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 effect of the new quality management practice, where the model estimated is of the following general form:

$$\log(Y_{it}) = \beta_0 + \beta_1 QMP_t + \boldsymbol{\phi}'\boldsymbol{X}_{it} + \sum_{i=1}^{9} \theta_i line_i + \sum_{i=2}^{9} \gamma_i (QMP_t \times line_i) + \mu_t + \epsilon_{it} \qquad (3)$$

Firm performance 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).[8] In alternative specifications firm performance is defined as: output per worker;[9] target efficiency, see equation (1); and also by a measure of productivity, see equation (2). 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). 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.[10] We also control for the natural logarithm of the target of each line per day.[11] Boning et al. (2007) found that management practices are not equally valued in all production environments and that 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. Time fixed effects are denoted by μ_t.

Line specific fixed effects are incorporated into equation (3), where $line_i$ is a binary line specific indicator for each line ($i = 1, \dots, 9$).[12] The line dummies also control for the type of capital used on the line, as some machines will be common among all lines but those lines that produce complex garments will use more sophisticated machines in order to perform complex tasks that will not be performed on basic lines.[13] An interaction term between the new management practice and the line dummy variables is also included to analyse the effect of the new quality management practice for each line and whether there is a change in line productivity after the introduction of the intervention.

With regards to the specification of the error term in equation (3), 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 the residuals are correlated both within and across assembly lines, Hoechle (2007). Consequently, the disturbance term from equation (3) is defined with Driscoll and Kraay standard errors as follows:

$$\epsilon_{it} = \lambda_i f_t + \nu_{it}, \qquad f_t = \sum_{\rho=1}^{z} \delta f_{t-\rho} + \omega_t \tag{4}$$

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. The standard errors proposed by Driscoll and Kraay (1998) 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.

These specifications are similar to those employed by Boning et al. (2007), where equation (4) 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 $z = 6$.[14] The following section discusses the results of estimating the above baseline productivity equation where our primary focus is on the estimates in terms of sign, statistical significance, and economic magnitude, of the β_1 and γ_i parameters.

3. Results and Analysis

Table 3 illustrates the effect of the implementation of the new quality management practice on total production, i.e. output (column 1), labour productivity, i.e. output per worker (column 2), target efficiency as defined in equation (1) (column 3), and productivity as defined in equation (2) (column 4), using the estimates from equation (3). Line fixed effects are incorporated throughout but without interactions (i.e. imposing the constraint that $\gamma_i = 0$).[15] Table 5 estimates the correlation between the new management practice and: total production (column 1); output per worker (column 2); target efficiency (column 3) and productivity (column 4), but now incorporating line specific fixed effects and interactions, i.e. equation (3). In Tables 3 to 5 the models incorporate Driscoll and Kraay standard errors with the autocorrelation lag length as defined by equation (4).

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 interactions with line fixed effects; (2) the effect of the introduction of the new practice on firm performance after allowing for heterogeneity across lines and differential effects of the management intervention; (3) a consideration of the potential line specific heterogeneous effects of the new management practice across the line specific standard minute value; (4) difference-in-difference analysis in an attempt to move beyond correlations; and (5) a discussion of the results in relation to the existing literature, followed by an exploration of how the management intervention influenced the number of daily defects and daily firm performance net of daily defects.

3.1 Baseline effect of quality management practice ignoring job complexity

The estimated coefficients for workers, materials and target output in Table 3 suggest a positive and significant relationship with production. 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 all aspects of firm performance, except for target efficiency. The estimates reveal that the standard minute value has an inverse relationship with labour productivity, e.g. column (2) shows that a one percent increase in the standard minute value is associated with a fall in labour productivity by approximately 0.1 percent. This result is perhaps 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, although arguably to some extent the inclusion of the production target as a covariate should account for this. The time fixed effects show that firm performance in 2015 and 2016 is generally higher than the base year which is 2013. The exception to this is target efficiency which is lower each year compared to 2013.

Prior to controlling for the complexity of the production process the analysis in Table 3 suggests that the implementation of the new quality management practice significantly decreases all measures of firm performance, although the economic magnitudes differ in size. In column (1) the implementation of the new quality management practice is found to significantly reduce firm production by 5.5 percent. Similar sized effects are also found when considering output per worker in column (2) with a corresponding estimate of a reduction in labour productivity of 6 percent. In terms of actual productivity (equation 2) the estimate in column (4) also reveals that the management intervention had an inverse effect upon this firm performance metric by approximately 3 percent. The smallest effect is upon target efficiency where there is a negative albeit negligible effect at just below 2 percent (column 3). Hence, the baseline estimates imply that the new management practice had a significant association with all firm performance metrics, and this was unequivocally a negative impact throughout.

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 influence firm performance. Table 4 shows the effect of the quality management practice on production (column 1), output per worker (column 2), target efficiency (column 3), and productivity (column 4), for intervals of 5, 15, 30, 45, 60, 75, 90, 105 and 120 days around the intervention date (15th September 2014), including line fixed effects but excluding interactions (i.e. imposing the constraint that $\gamma_i = 0$). The analysis reveals that for alternative windows pre and post treatment that the negative effects of the management practice on each alternative measure of firm performance are still evident up to 60 days. The exception to this is target efficiency where for a window pre and post treatment of up to 45 days the management practice has a negative coefficient. Taken as a whole, these results suggest that the effect of the quality management practice on all aspects of firm performance is larger closer to the intervention date and then dissipates monotonically over time. In sub-section 3.2 we consider the effect of the new management practice around the same window of intervention as in Table 4 for each performance metric but by specific lines of production.

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

We now allow for line heterogeneity by estimating equation (3) 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. For brevity we report the estimate of the parameters associated with the quality management practice and the line specific interaction, i.e.: $\beta_1 + \gamma_i$. Table 5 reports the results for the full sample period before we consider different windows pre and post intervention.

Focusing upon output, column (1) in Table 5, the results show that within the category of basic lines the implementation of the new quality management practice significantly reduces production for lines 1A, 1B and 2A but increases the output of lines 3A and 3B. 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 effect 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 5, the introduction of the new quality management practice reduces the output of lines 1A and 1B by 13.3 percent and 14 percent respectively. 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 estimate associated with the management practice is only statistically significant for line 2A, and is noticeably smaller in magnitude compared to lines 1A and 1B. Lines 3A and 3B are basic lines with a higher average standard minute value compared to the other basic lines and both these lines produce similar products. The estimates show that the implementation of the new practice increases the output of lines 3A and 3B by 12.8 percent and 8 percent respectively.

Turning to labour productivity, i.e. output per worker, in column (2) of Table 5 a comparable pattern of results is revealed. For example, output per worker is reduced following the implementation of the new management practice in lines 1A, 1B and 2A. To be specific, for lines 1A and 1B productivity falls by 14.8 and 20.6 percent respectively. Conversely, labour productivity increases in lines 3A and 3B following the introduction of the new management practice by 12.8 percent and 9.1 percent respectively (see column 2). Similar findings are also revealed for target efficiency and productivity, see columns (3) and (4) of Table 5 respectively, although the estimated magnitudes where statistically significant are generally smaller than found previously.

We now consider the effect of the management intervention on complex lines of production for each alternative measure of firm performance. The estimates in column (1) of Table 5 show that within the category of complex lines, the implementation of the new quality management practice significantly reduces the output of line 4 by approximately 19 percent. Similarly, output per worker falls following the intervention by 16.6 percent (column 2), as does productivity by 8.8 percent (column 4). No differential effects are found regarding target efficiency for line 4. Mixed results are revealed for lines 5 and 6. The new management practice decreases most aspects performance metrics of line 5 – this is the assembly line with the highest average SMV (see Table 2) – but the magnitude is smaller in comparison to other lines. For example, considering output (labour productivity) the results in column 1 (2) show that following the management intervention the corresponding decrease in output (labour productivity) is 10

(11.5) percent. Only target efficiency improves after the management intervention on line 5 by just under 4 percent.

To put the analysis thus far which has considered job complexity into more context we focus upon specific operations. Table A4 in the Appendix shows the number of operations and total SMV by product across each line. For example, take product 2 in the second row. The SMV for line 1 for producing this product is 11.3 compared to an SMV of 19.4 for line 3, so it takes around 71% more time to produce the product on line 3 as it includes more operations 61 compared to 49, hence it is more complex process. Similarly, in comparing line 1 (3) to line 6 the relative time difference to produce the product is 90% (11%) more time. Whilst it is important to note that there are some tasks that are common across lines (see Table A1), typically the more complex lines perform more operations for each product as can be seen from the final row of Table A4. On average across all products manufactured over the 867 days, 51 tasks are completed for line 1 compared to 68 tasks on line 6 and hence the average SMV is higher (see Table 2).[16]

The next thing we do is consider different windows pre/post intervention as in Table 4 to investigate the sensitivity of line specific results reported so far. The analysis of Table 4 is redone but now for each line to accommodate job complexity.[17] The results are shown graphically for ease of interpretation in Figures 1A through to 1D for each alternative measure of firm performance. Within each figure there are nine sub-plots each for a different assembly line. We provide estimates for the effect of the management intervention upon firm performance, i.e. the estimate of γ across different windows, along with 95% confidence intervals shown in grey. Figure 1A focuses upon the results for output. Clearly across the different window lengths pre and post management intervention significant negative effects are found for line 1A, only becoming statistically insignificant at 120 days. Similar effects are found for line 2A, although only up to a window of 75 days. There is also evidence that output is reduced for line 6 up to a window of 30 days. Overall, the largest negative effect of the management practice is upon line

1A. Figure 1B considers output per worker and generally reveals the same pattern of results as found in Figure 1A. Focusing upon Figure 1D which looks at the impact of the new management practice of productivity around different window lengths, again there is evidence of negative effects on the least complex (i.e. lines 1A and 1B) and most complex assembly lines (line 6). As found previously for other measures of performance considered so far, the largest effects of the intervention in terms of economic magnitude are for line 1A. Figure 1C considers target efficiency and it is for this firm performance metric where there are some noticeable differences. Firstly, although the findings for lines 1A and 1B are comparable with the other firm performance metrics, evidence is found of positive relationship between the intervention and target efficiency on lines 2A, 3A and 3B. Taken as a whole, the line specific results which consider the impact of the management intervention by job complexity would generally appear to be robust to varying window lengths. For each alternative measure of firm performance across the different lines of production complexity, where statistically significant the magnitude of the estimate falls as the window length increases, i.e. as expected the management intervention had a larger effect closer to the date the new practice was implemented, (the exception to this is target efficiency, see Figure 1C lines 3A and 3B).

3.3 Effect of the new quality management practice and heterogeneity by SMV

The next exercise that we undertake in exploring the role of the management intervention on firm performance is to focus on an alternative dimension of heterogeneity. Specifically, whether the effect of intervention differs along average SMV and across different assembly lines by forming an interaction with the treatment dummy, i.e. QMP.[18] We do this as the SMV is also an indication of the style and complexity of the garment process beyond the assembly line. Models of the following form are estimated with the error term as defined in equation (4):

$$\log(Y_{it}) = \beta_0 + \beta_1 QMP_t + \boldsymbol{\phi}'\boldsymbol{X}_{it} + \sum_{i=1}^{9} \theta_i line_i + \sum_{i=2}^{9} \gamma_i (QMP_t \times line_i) + \tau(QMP_t \times g(SMV)_{it})$$

$$+ \sum_{i=2}^{9} \xi_i (QMP_t \times line_i \times g(SMV)_{it}) + \mu_t + \epsilon_{it} \qquad (5)$$

The results of estimating equation (5) are shown graphically for ease of interpretation and reveal identical patterns for each measure of firm performance, consequently in Figure 2 we report the results for labour productivity (i.e. output per worker). Each sub-plot is for a different assembly line.[19] We provide estimates for the effect of the management intervention upon labour productivity along with 95% confidence intervals shown in grey. Where statistically significant there is clear evidence of non-linear effects of the management intervention across average SMV, most noticeably for lines 1A, 3A, 3B, 4, 5 and 6. For example, for lines 3A and 3B at the lowest SMV value of 12 the management intervention reduces output per worker by 50 and 25 percent respectively, whilst conversely at a maximum SMV value of 22 productivity increases by around 12 percent for both lines. Interestingly, for line 6 – where generally no line heterogeneous effects were found (Table 5) – at the lowest and highest levels of SMV the effect of the quality management practice is to reduce output per worker by approximately 40 percent.

3.4 Difference-in-difference analysis

A potential issue with the above analysis is that all lines were simultaneously exposed to the new management routine. Moreover, the estimates are based upon conditional regression analysis and hence represent correlations or average treatment effects rather than causal estimates. In our final part of the investigation into the effect of the management intervention on firm performance we implement something closer to a difference-in-differences (DD) specification.

Based upon the findings of Table 5, and a priori expectations, there are arguably some processes that may be more affected by the new management routine than others. From the evidence presented so far it would appear that more basic lines are affected to a greater extent compared to line 6. Hence, in a quasi-experimental framework lines 1A and 1B effectively become the treatment group, $T_i = 1$, whilst the most complex line 6 is the control group (in both the pre- and post-implementation period), $T_i = 0$. In what follows in order to obtain the average treatment effect on the treated (ATET) we estimate a DD model on a sub-sample of production lines at the two extremes of task complexity (lines 1A, 1B and 6) of the form:

$$\log(Y_{it}) = \pi_0 + \pi_1 T_i + \pi_2 QMP_t + \pi_3 (T_i \times QMP_t) + \boldsymbol{\phi}'\boldsymbol{X}_{it} + \epsilon_{it} \quad (6)$$

While the estimated effects may be upwardly biased if the intervention also had an effect on the more complex garments, it arguably allows us to estimate more robustly whether there were any effects at all from the intervention and obtain the ATET, i.e. π_3. The sub-sample comprises 2,305 daily-line observations over the 867-day period across the most basic and complex lines.

The results are shown in Table 6 for each firm performance metric where we report the ATET associated with the quality management practice intervention. Clearly, for each alternative measure of firm performance the ATET is statistically significant. Consistent, with our previous findings the causal effect of the management intervention is to decrease all aspects of firm performance. To be specific the DD estimates show that production, output per worker, target efficiency and productivity fall by 10.7, 14.5, 7.1 and 5.9 percent respectively. In rows A and B at the bottom of Table 6 for each measure of firm performance we test the parallel trends assumption and test for anticipation effects of the treatment.

The null hypothesis that the linear trends are parallel can only be accepted for target efficiency and productivity (see row A). For production and output per worker where the test for parallel trends was rejected before the treatment took place this could indicate a treatment effect prior to the implementation of the management intervention. Hence, we also consider the parallel trends assumption by testing that there should be no treatment effect in anticipation of the treatment by implementing a Granger-type causality test. This analysis supports the linear parallel trends test in that we can only accept the null hypothesis of no anticipatory effects prior to treatment for target efficiency and productivity (see row B). Hence, given the tests for parallel trends and anticipation effects the identification of the ATET for production and output per worker should be treated with caution.[20, 21]

Target efficiency and productivity (actual efficiency), as defined in equations (1) and (2) above, are arguably more comprehensive firm performance metrics and of greater applicability given the industrial setting. This is because actual and target efficiency measures explicitly take into context any systematic variation which arises due to the complexity of the job task by utilising the SMV information. This is important since the quantity produced is likely to diverge by the complexity of the garment and hence it is common to normalize productivity across assembly lines of varying complexity in this industry. In the factory setting these measures of efficiency are the globally accepted standard performance proxies for productivity in the garment industry, e.g. Adhvaryu et al. (2023). Moreover, these are also the metrics commonly used in the existing academic literature which focuses upon the garment sector (rather than the measures of output, i.e. number of textile units produced, and labour productivity which are used more commonly in the wider economics literature), e.g. see Adhvaryu et al. (2020), Somanathan, et al. (2021), Menzel (2021) and Adhvaryu et al. (2023).

Overall, the findings reported in Section 3 contribute to the literature on insider econometrics which aims to find how management practices effect firm performance and identify areas where new practices have smaller or larger effects (Ichniowski and Shaw 2009). The above analysis provides evidence that whether the implementation of the new quality management practice constitutes good practice or not varies by assembly line, and within assembly line depending on the complexity of the task (SMV) – see Figure 2. 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 evidence that the implementation of the new management practice increases all measures of firm performance for lines 3A and 3B. 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. The implementation of the new quality management practice typically has an adverse effect on lines at the extreme ends of the complexity spectrum as it has a negative association with the most basic lines and those undertaking the most complex processes (i.e. lines 5 or 6). The analysis 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.

3.5 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).[22] Fewer quality defects should mean that workers spend less time on re-doing defective pieces, hence this ought to translate into better firm performance. The result that the implementation of the new quality management practice effects performance, whether positively or negatively, highlights two alternative theories. 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 illustrates an alternative view (Frey 1993). 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 potentially 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 pivotal role in determining the benefit of the intervention to the agent.

The decline in firm performance after the implementation of the new quality management practice also complements the theory by Holmstrom and Milgrom (1994) such that when workers perform 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 to produce better quality products and minimize quality defects after the new management incentive was introduced.[23] We now explore this in greater detail.

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 the 867 days of the sample period (t) of the following form to ascertain whether the number of daily defects (D_t) decreased after the implementation of the quality management practice (QMP_t) as defined above:

$$D_t = \alpha + \psi QMP_t + \boldsymbol{Z}_t'\boldsymbol{\beta} + \epsilon_t \qquad (7)$$

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 firm performance as found in the results discussed above resulting in a quantity-quality trade-off.

Table 7 shows the results of estimating equation (7) by: OLS (column 1); with Newey-West standard errors allowing for both 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). 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 7). For example, columns (1) and (2) show that after the new management intervention the number of defects fell by 59.[24, 25] 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, as can be seen from Figure 3. Moreover, the number of daily defects has kurtosis of 3.8 and the Shapiro-Wilk test for normality rejects the null at the 1% level. As such, in the final column of Table 7 we model the number of defects via a negative binomial estimator allowing for autocorrelation and heteroscedasticity.[26] 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 around 1 defect per day or a reduction of 32% compared to the pre-intervention period.[27]

Alternatively, we have modelled the number of daily defects, firstly as a proportion of the number of employees, and secondly per unit of firm output. In both cases given there are potentially non-integer values the outcome is treated as continuous with Newey-West standard errors, allowing for a heteroscedastic error structure and the presence of autocorrelation (as is evident from the OLS d-statistic reported in Table 8). The results of this analysis are shown in Table 8 columns 1 and 2 respectively. The analysis reveals that the implementation of the new quality management practice was associated with a fall in daily defects per worker of around 7 units and a reduction in defects per unit of output of 3 units over the entire sample period.

Next, we explore the sensitivity of the results reported so far to different window lengths pre and post the management intervention, given that a shorter period either side of the intervention should help to minimise the impact of any unknown factors which could affect quality defects. To do this we specify the following model:

$$D_t = \alpha + \psi QMP_t + \sum_{w=1}^{22} \kappa_w \left(QMP_t \times Win_w\right) + \boldsymbol{Z}_t'\boldsymbol{\beta} + \epsilon_t \qquad (8)$$

Where $Win_w \in (0,1)$ are a set of twenty-two binary indicators equal to unity if the window length either side the intervention is 15, 30, 45, through to, 330 days. The number of defects is modelled via a negative binomial estimator allowing for autocorrelation and heteroscedasticity, where we report the effect of the QMP across the window length. We also model the number of daily defects per employee and the number of daily defects per unit of output using a Newey-West estimator across the different window lengths. For example, the effect of the intervention around a 15-day window, is given by $\psi + \kappa_1$, through to the effect of the intervention around a 330-day window, given by $\psi + \kappa_{22}$.[28]

The results are shown in Figure 4 along with 95% confidence intervals shown in grey. Focusing upon the upper left-hand pane, the analysis for the total number of daily defects reveals that the effect of the intervention is positive over the entire period in that the number of daily defects fall, but the magnitude dissipates slowly over time. This starts from a fall of around 34% at 15-days either side the intervention through to 21% at a 285-day window pre/post the new management practice.[29] Turning to the number of defects per unit of output, the upper right-pane, whilst the number of defects per unit of production fall, they remain positive and statistically significant up until a one-month window, and thereafter become negative culminating in a fall of around 5 defects per unit of output at a 330-day window. Conversely, for defects per worker no statistically significant effects are found close to when the management intervention occurred. The estimates only become statistically significant after a 75-day window pre/post intervention and then fall monotonically over most of the period declining to approximately 9 defects per worker at around a 270-day window.

The final part of analysis that we undertake investigates the effect of the quality management practice upon aggregate daily firm performance metrics net of defects. As stated above it is important to note that it is not possible to do this analysis at the line level (i.e. re-estimate equation 3 on the sample of 7,031 line-day level observations for net performance outcomes) because only total daily defects are reported, i.e. there is no information recorded on defects per line. Having considered the effect of the new management intervention on defects across different window lengths, a tentative conclusion from the results shown in Figure 4 is that this may imply that the long term net effect on the firms profitability will ultimately be positive given that any adverse effects observed on quantity (firm performance) were generally only observed up to a window of 60 days either side the intervention (see Table 4).[30] Conversely, the intervention has a much longer lasting effect in terms of the quality of output where the total number of daily defects (defects as a proportion of the number of employees and/or unit of output) continue to fall throughout (Figure 4).

Hence, we now investigate daily firm performance metrics net of daily defects, equations (1) and (2) are now re-defined as:

$\left(\frac{(\sum_i Target\ Output_t - D_t)\times\sum_i SMV_t}{\sum_i No.\ Workers_t \times Daily\ Hours \times 60^{mins}}\right)$ and $\left(\frac{(\sum_i Daily\ Output_t - D_t)\times\sum_i SMV_t}{\sum_i No.\ Workers_t \times Daily\ Hours \times 60^{mins}}\right)$ for target efficiency and productivity respectively. We estimate the following daily aggregate (across lines) of equation (3), where $\tilde{Y}_t$ denotes a firm performance metric net of defects:

$$\log(\tilde{Y}_t) = \eta_0 + \eta_1 QMP_t + \boldsymbol{\psi}'\boldsymbol{X}_t + \epsilon_t \qquad (9)$$

The controls $\boldsymbol{X}_t$ are as defined in Section 2.3 and equation (9) is estimated with Newey-West standard errors to allow for a heteroscedastic error structure and the presence of autocorrelation. The results are shown in Table 9, where for each outcome the d-statistic reveals that autocorrelation would be problematic with an OLS estimator. The key finding is that even taking defects into account the quality management practice has a negative impact on all daily net firm performance metrics as previously found in Table 3.

We also explore the effect of the intervention on net firm performance around an intervention window pre/post treatment of 15-days, through to 330-days, with the analysis shown in Figure 5 where 95% confidence intervals shown in grey.[31] It is apparent that for each measure of firm performance there are negative effects in a short window (although the point estimates typically include zero in the confidence interval). However, as conjectured above, positive effects from the new management practice are only evident at or after a 225-day window pre/post intervention. This is consistent with any adverse effects observed on quantity (firm performance) occurring within a relatively short window (generally up to 60 days) whilst the impact of the intervention quality of output is long lasting. Hence, a tentative conclusion based upon aggregate daily net performance metrics is that any positive impact of the management practice upon outputs once defects are taken into consideration are only apparent in the longer term.

4. Conclusion

This paper has contributed to the literature on the role of management practices and productivity using unique detailed within-firm data for a garment producing firm in Pakistan. We have provided a comprehensive before-after comparison by reporting conditional correlational analysis. However, a caveat and limitation of the work is that a causal interpretation cannot be provided as the empirical framework is not a quasi-experimental set-up (apart from the analysis of section 3.4).

Whether this new management practice turns out to be a good or bad management intervention is not straight forward as the effect 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 effect 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. Across each performance metric there is also evidence that the management intervention had non-linear effects over the standard minute value which reflects the style and complexity of the garment process.

Whilst the results of the intervention are negative for all alternative measures of firm performance (including metrics net of daily defects), we find evidence that the total number of daily defects (as well as defects as a proportion of the number of employees and defects as a proportion of output) falls following the implementation of the new management practice which is consistent with a quantity-quality trade off.

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TABLE 1: Summary statistics

	Mean	Standard Deviation	Min.	Max.
Number of workers	121.23	36.38	19	218
Standard Minute Value (SMV)	18.46	4.45	4.28	34.99
Target output per line	2,540.57	495.61	1,500	3,500
Materials	2,433.34	659.41	31	5,736
Total production	2,245.69	701.98	29	4,000
Output per worker	19.83	7.63	0.15	96.72
Target efficiency	82.39	20.24	23.81	543.31
Productivity	73.01	25.02	0.73	329.66
Number of defects	232.20	165.39	7	848
Observations	7,031			

Notes: The table provides summary statistics for the estimation sample. This includes the control variables X_{it}: number of workers; standard minute value (SMV); target output per line; materials, and outcome, i.e. dependent variables. Specifically, for the latter (1) firm performance metrics: total production; output per worker; target efficiency; and productivity, and (2) the total number of daily defects at the firm level.

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

Notes: The table shows the standard minute value (SMV), i.e. the time it takes to produce a product, across the 9 assembly lines, where the firm has dedicated assembly lines for producing basic and complex products.

TABLE 3: The impact of the new quality management practice on firm performance – line fixed effects

	(1) Production	(2) Output per Worker	(3) Target Efficiency	(4) Productivity
QMP	-0.055**	-0.060**	-0.017***	-0.028***
	(0.027)	(0.028)	(0.006)	(0.010)
Log of Workers	0.202**	–	–	–
	(0.095)			
Log of Materials	0.201***	0.187***	-0.001	0.065***
	(0.022)	(0.023)	(0.006)	(0.008)
Log of SMV	-0.060**	-0.097**	–	–
	(0.033)	(0.047)		
Log of Target	0.236*	0.266**	–	0.080*
	(0.124)	(0.126)		(0.036)
2014	0.091***	0.063	-0.040***	0.014**
	(0.034)	(0.039)	(0.009)	(0.007)
2015	0.211***	0.193***	-0.077***	0.049***
	(0.046)	(0.051)	(0.011)	(0.018)
2016	0.117**	0.141***	-0.056***	0.030*
	(0.047)	(0.052)	(0.012)	(0.018)
Constant	3.383***	-0.422	0.646***	0.331
	(1.103)	(1.064)	(0.052)	(0.366)
R-squared	0.0714	0.0533	0.0482	0.0433
Observations	7,031			

Notes: The table shows the effect of the implementation of the new quality management practice on total production, i.e. output (column 1), labour productivity, i.e. output per worker (column 2), target efficiency (column 3), and productivity (column 4). In specifications where firm performance is defined as output per worker labour input is omitted as a control variable. Similarly, when modelling target efficiency or productivity, covariates which were used to construct the dependent variable are excluded as controls.
All models are estimated with Driscoll and Kraay standard errors, i.e. equation (3). In all columns line fixed effects included, but excluding interactions – i.e. $\gamma_i = 0$. Throughout the disturbance term is as specified in equation (4) and $z = 6$.
Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 4: The impact of the new quality management practice on firm performance – window length

		(1) Production		(2) Output per Worker		(3) Target Efficiency		(4) Productivity	
Window length	Observations	Coef.	R-squared	Coef.	R-squared	Coef.	R-squared	Coef.	R-squared
5 days	75	-0.083**	0.0987	-0.107***	0.1067	-0.032***	0.0957	-0.039***	0.1266
		(0.037)		(0.037)		(0.011)		(0.015)	
15 days	236	-0.075**	0.0258	-0.096***	0.0372	-0.043***	0.0922	-0.035***	0.1552
		(0.034)		(0.034)		(0.012)		(0.013)	
30 days	486	-0.067**	0.0419	-0.085***	0.0203	-0.025***	0.0378	-0.031***	0.1377
		(0.032)		0.032)		(0.012)		(0.012)	
45 days	734	-0.059**	0.0459	-0.073**	0.0212	-0.021**	0.0520	-0.027**	0.1507
		(0.030)		(0.029)		(0.011)		(0.011)	
60 days	995	-0.049*	0.0557	-0.062**	0.0244	0.008	0.0854	-0.022**	0.1525
		(0.028)		(0.028)		(0.007)		(0.011)	
75 days	1,262	-0.042	0.0332	-0.051*	0.0207	0.011	0.0867	-0.018*	0.1463
		(0.028)		(0.027)		(0.012)		(0.010)	
90 days	1,479	-0.033	0.0327	-0.039	0.0229	0.013	0.0793	-0.014	0.1436
		(0.028)		(0.027)		(0.012)		(0.010)	
105 days	1,738	-0.025	0.0386	-0.028	0.0348	0.016	0.0816	-0.010	0.1528
		(0.029)		(0.028)		(0.011)		(0.011)	
120 days	2,003	-0.017	0.0406	-0.017	0.0552	0.018	0.0882	-0.006	0.2038
		(0.030)		(0.030)		(0.012)		(0.011)	

Notes: The table shows the effect of the quality management practice on production (column 1), output per worker (column 2), target efficiency (column 3), and productivity (column 4), for intervals of 5, 15, 30, 45, 60, 75, 90, 105 and 120 days around the intervention date. In specifications where firm performance is defined as output per worker labour input is omitted as a control variable. Similarly, when modelling target efficiency or productivity, co-variates which were used to construct the dependent variable are excluded as controls.
Each row reports a different interval pre and post intervention.
All models are estimated with Driscoll and Kraay standard errors, i.e. equation (3) including line fixed effects but excluding interactions – i.e. $\gamma i = 0$, with the disturbance term specified in equation (4) and $z = 4$. Other controls as in Table 3.
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 performance – line specific effects

	(1) Production	(2) Output per Worker	(3) Target Efficiency	(4) Productivity
QMP Line 1A: β_1	-0.133^{***}	-0.148^{***}	-0.007	-0.064^{***}
	(0.044)	(0.043)	(0.011)	(0.017)
QMP Line 1B: $\beta_1 + \gamma_2$	-0.140^{***}	-0.206^{***}	-0.038^{***}	-0.082^{***}
	(0.045)	(0.045)	(0.014)	(0.020)
QMP Line 2A: $\beta_1 + \gamma_3$	-0.087^{*}	-0.092^{**}	-0.013	-0.036^{**}
	(0.053)	(0.040)	(0.012)	(0.017)
QMP Line 2B: $\beta_1 + \gamma_4$	0.012	-0.036	-0.040^{***}	-0.010
	(0.050)	(0.047)	(0.013)	(0.020)
QMP Line 3A: $\beta_1 + \gamma_5$	0.128^{***}	0.128^{**}	0.085^{***}	0.080^{***}
	(0.053)	(0.061)	(0.15)	(0.018)
QMP Line 3B: $\beta_1 + \gamma_6$	0.080^{**}	0.091^{**}	0.064^{***}	0.075^{***}
	(0.042)	(0.045)	(0.19)	(0.021)
QMP Line 4: $\beta_1 + \gamma_7$	-0.194^{***}	-0.166^{***}	0.009	-0.088^{***}
	(0.043)	(0.046)	(0.016)	(0.023)
QMP Line 5: $\beta_1 + \gamma_8$	-0.100^{*}	-0.115^{**}	0.039^{***}	-0.057^{***}
	(0.060)	(0.058)	(0.013)	(0.021)
QMP Line 6: $\beta_1 + \gamma_9$	-0.013	-0.028	0.047^{***}	-0.017
	(0.057)	(0.060)	(0.013)	(0.022)
Constant	3.555^{***}	0.134^{***}	0.621^{***}	0.640^{***}
	(1.165)	(0.051)	(0.053)	(0.258)
R-squared	0.0856	0.0707	0.1002	0.0884
Observations	7,031			

Notes: The results in the tables allow for heterogeneity across assembly lines by incorporating line specific effects and interactions with the quality management practice, in order to ascertain whether the effect of the management practice varies across assembly lines. Estimates are shown for production (column 1), output per worker (column 2), target efficiency (column 3), and productivity (column 4). In specifications where firm performance is defined as output per worker labour input is omitted as a control variable. Similarly, when modelling target efficiency or productivity, covariates which were used to construct the dependent variable are excluded as controls.

All models are estimated using fixed effects and interactions with Driscoll and Kraay standard errors, i.e. equation (3) with the disturbance term specified in equation (4) and z=6. Controls as in Table 3. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 6: Difference-in-difference analysis of the impact of the new quality management practice on firm performance

	(1) Production	(2) Output per Worker	(3) Target Efficiency	(4) Productivity
ATET of QMP	-0.1070*** (0.017)	-0.1447*** (0.028)	-0.0715*** (0.019)	-0.0585*** (0.012)
<u>A: Parallel trends</u> H_0: Trends parallel F(1, *d*); *p-value*	179.68; *p=0.000*	41.17; *p=0.000*	2.58; *p=0.108*	1.77; *p=0.185*
<u>B: Granger causality</u> H_0: No anticipation of treatment F(3, *e*); *p-value*	15.89; *p=0.000*	108.89; *p=0.000*	1.28; *p=0.280*	2.07; *p=0.102*
Observations	2,305			

Notes: The table shows the results of a difference-in-difference specification, where the control group comprises line 6 and the treatment group lines 1A and 1B. Estimates are shown for production (column 1), output per worker (column 2), target efficiency (column 3), and productivity (column 4), based upon equation (6), where the reported statistic is the average treatment effect on the treated (ATET). Controls as in Table 3. In specifications where firm performance is defined as output per worker labour input is omitted as a control variable. Similarly, when modelling target efficiency or productivity, covariates which were used to construct the dependent variable are excluded as controls.

In panel B the parallel trends assumption is tested. Degrees of freedom for denominator of the F-statistic for the test of parallel trends in columns 1, 2, 3 and 4 are as follows: *d*=1,438; *d*=1,439; *d*=1,441 and *d*=1,440, respectively.

In panel C anticipation effects are tested by implementing a Granger-type causality test. Degrees of freedom for denominator of the F-statistic for the test of anticipation of the treatment in columns 1, 2, 3 and 4 are as follows: *e*=1,160; *e*=1,161; *e*=1,163 and *e*=1,162, respectively.

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

TABLE 7: 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, 860); *p-value*			225.35; *p=0.000*			
LR, $\chi^2(7)$; *p-value*					851.29; *p=0.000*	
Deviance statistic, $\chi^2(7)$; *p-value*					38,302.16; *p=0.000*	
Observations	867					

Notes: Whilst data on quality defects per line is not available, the analysis in this table shows the results of modelling the total number of daily defects made by workers, by estimating equation (7). Column (1) reports OLS results, column (2) incorporates Newey-West standard errors allowing for heteroscedasticity and autocorrelation, where the maximum lag length specified is 1, and column (3) models the number of defects as a count outcome allowing for over-dispersion dispersion, i.e. a negative binomial regression, incorporating heteroscedasticity and autocorrelation consistent standard errors. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 8: The impact of the new quality management practice on defects per worker and defects per unit of output

	(1) Defects per worker		(2) Defects per unit of output	
QMP	-6.817	(0.892)***	-2.960	(0.473)***
Number of workers	–		0.012	(0.001)***
Average worker tenure	0.009	(0.002)***	0.005	(0.001)***
Average worker age	0.006	(0.017)**	0.001	(0.000)*
% employees female	-2.943	(0.079)***	-1.121	(0.093)***
Constant	250.772	(15.786)***	81.726	(12.894)***
Quadratic time trend	✓		✓	
d-statistic (*m*, 867)	2.516		2.118	
F-statistic (*q*, 860); *p-value*	379.16; *p=0.000*		167.25; *p=0.000*	
Observations	867			

Notes: In this table we have modelled daily defects, firstly as a proportion of the number of workers (column 1), and secondly, per unit of firm output (column 2). In column 1 when modelling defects per employee the number of workers is omitted as a control.
Models are estimated with Newey-West standard errors where the maximum lag length specified is 1.
In column 1 (2) m=7 and $q=6$ (m=8 and $q=7$).
Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 9: The impact of the new quality management practice on daily firm performance net of defects

	(1) Net Daily Production	(2) Net Daily Output per Worker	(3) Net Daily Target Efficiency	(4) Net Daily Productivity
QMP	-0.071***	-0.056***	-0.033**	-0.060***
	(0.018)	(0.016)	(0.018)	(0.016)
Log of Daily Workers	0.290***	–	–	–
	(0.092)			
Log of Daily Materials	0.418***	0.345***	0.558***	0.354***
	(0.054)	(0.055)	(0.027)	(0.045)
Log of Daily SMV	-0.138**	-0.425**	–	–
	(0.070)	(0.074)		
Log of Daily Target	0.465***	0.148*	–	0.432***
	(0.115)	(0.075)		(0.059)
Constant	-0.327***	0.287***	-3.516***	-5.798
	(0.069)	(0.066)	(0.261)	(0.341)
Quadratic time trend	✓	✓	✓	✓
d-statistic (*m*, 867)	1.1231	1.1790	0.9258	0.9963
F-statistic (*q*, 860); *p-value*	121.56; *p=0.000*	18.12; *p=0.000*	100.24; *p=0.000*	149.09; *p=0.000*
Observations			867	

Notes: In this table firm performance metrics are modelled net of daily defects. In specifications where firm performance is defined as net output per worker labour input is omitted as a control variable. Similarly, when modelling net target efficiency or net productivity, covariates which were used to construct the dependent variable are excluded as controls.
Models are estimated with Newey-West standard errors where the maximum lag length specified is 1. In: column 1 m=8 (q=7); column 2 m=7 (q=6); column 3 m=5 (q=4); and column 4 m=6 (q=5).
Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

APPENDIX: ADDITIONAL TABLES

TABLE A1: Common operations across all lines (1-6)

OPERATION CODE	DESCRIPTION OF OPERATION	TOTAL SMV
200	Hem watch pocket	0.150
203	Attach watch pocket (SS)	0.150
207	Attach facing to pocket bag (cover)	0.300
208	Trim watch pocket	0.106
213	Mock stitch back pocket	0.240
228	Attach slider & stopper	0.090
240	Attach zip To left fly	0.070
243	Gap zipper	0.051
252	Hem back pocket (DNCS)	0.150
253	Keep label in polybag	0.120
269	Make & fuse loop-5	0.147
284	Serge round left fly from bottom	0.053
301	Set left fly	0.140
317	Tack label	0.150
318	Tack fly	0.120
325	Attach zip to right fly	0.250
334	Tack loop strip	0.120
371	Attach back pocket (auto)	0.521
379	Join seat seam	0.300
381	Join yoke	0.290
421	Serge back panel	0.500
470	Second seam crotch	0.200
481	Top stitch right fly	0.275
483	Bartack inner fly-2	0.140
486	Bartack inner side	0.140
488	Bartack label (CL1,CL2,CL3,CL4)	0.140
493	Close pocket bag	0.700
495	Top stitch left fly edge side	0.210
501	J-Stitch	0.170
504	Join crotch	0.280
529	Serge front panel	0.700
536	Set front pocket	0.450
543	Serge right panel with fly	0.200
544	Stay front pocket	0.421
546	Turn & top stitch front pocket	0.466
592	Top stitch waist band bottom side	0.900
602	Attach woven label	0.260
603	Bartack hip stitch -6	0.480
608	Close band ends	0.150
609	Close inseam (Safety stich)	0.580
610	Fell inseam	0.640
611	Close outseam by keeping tape busted	0.730
622	Marking for hip stitch	0.240
635	Press busted seam	0.350
661	Top stitch inseam	0.345
662	Hip stitch	0.300

664	Turn garment	0.140
695	Bartack belt loop	0.400
698	Hem bottom	0.400
712	Trimming	1.200
723	Button hole	0.075
806	Fly stud helper	0.150
808	Attach stud manual	0.170
975	Align fusing to waist band	0.230
976	Paste fusing to waist band	0.120

Notes: This table shows common operations across all lines (of which there are 55), providing: the operation code; the description of the task; and the associated total SMV.

TABLE A2: Unique operations per line

LINE	OPERATION CODE	DESCRIPTION OF OPERATION	TOTAL SMV
1			
	613	Fell outseam	0.900
	634	Press outseam (busted)	0.350
	886	Turn garment for fell inseam	0.280
2			
	285	Close pocket bag serge from inside	0.250
	604	Bartack inseam	0.140
	659	Attach waist band (top seam with close band)	1.250
3			
	295	Edge stitch left fly 1st and 2nd seam	0.225
	336	Marking for set pleat	0.200
	384	Set pleat	0.150
	409	Top stitch side slit	0.600
	429	Bartack side slit-2	0.200
	434	Top stitch pleat	0.350
	457	Attach watch pocket outseam side	0.150
	476	Mark for fly stud	0.120
	605	Bartack side seam	0.200
	689	Tack both panels from watch pocket	0.150
	737	Centre seam back pocket	0.200
	777	Marking for attach inside lining at back pocket	0.200
	778	Marking for 2nd seam crotch	0.120
	814	Marking for close outseam	0.240
	822	Trim left panel	0.100
	826	Attach watch pocket CF side	0.150
	836	Attach inside lining at back pocket	0.400
4			
	266	Top stitch top pleat back panel	0.400
	330	Marking for Attaching label	0.120
	456	Top stitch bottom pleat back panel	0.300
	532	Secure facing from outseam side	0.120
	596	Brand and fit label (Patrick supper slim stretch)-2 sided	0.260
	601	Attach waist band	0.730
	621	Marking for show stitch at HB	0.240
	652	Tack yoke pleat from top & bottom	0.300
	696	Bartack belt loops-side	0.200
	740	Bartack belt loops-front	0.200
	758	Mark 2nd seam	0.120
	824	Marking for hem watch pocket	0.120
	944	Set waist band pieces from CB	0.150
	961	Set top pleat back panel	0.350

	985	Attach CB/ label at inside waist band	0.260
5			
	222	Close pocket bag	0.450
	232	Hem bottom-SNLS	0.200
	235	Attach hem front bottom patch pieces	0.400
	236	Serge hem front bottom patch pieces	0.200
	249	Bartack bone pocket-2	0.200
	254	Diagonal cut & turn for bone opening	0.510
	257	Make crease lock loop	0.150
	274	Marking for hem watch pocket	0.120
	287	Top stitch bone pocket	0.250
	291	Top stitch HB back panel pieces DNLS	0.500
	292	Top stitch flap edge seam	0.750
	299	Attach hem back bottom patch pieces	0.400
	303	Set bone strip with front panel	0.250
	304	Set flap on panel DNLS	0.520
	314	Cut elastic	0.150
	323	Button hole flap	0.200
	332	Marking at outseam	0.200
	333	Turn & top stitch front pocket	0.450
	341	Zig zag stitch at facing patch	0.400
	343	Cut & turn lock loop	0.240
	348	Cut flap	0.200
	351	Attach rounded patch	0.825
	352	Press rounded patch	0.550
	366	Bartack at back pocket-2	0.150
	369	Marking for Bartack hip stitch	0.200
	375	Bartack flap	0.350
	389	Marking for fly stud attachment	0.150
	392	Press flap	0.510
	393	Press reinforcement patch	0.240
	402	Join back pocket pieces	0.400
	403	Set flap from sides	0.350
	410	Set lock loop	0.300
	436	Top stitch back panel knee pieces	0.400
	446	Join back panel knee pieces	0.375
	450	Bartack belt loops-v shape	0.240
	467	Bartack lock loop (5)	0.380
	474	Fold & top stitch front panel at side	0.750
	494	Set & close right pocket bag	0.500
	505	Top stitch right facing pieces	0.120
	507	Join front panel yoke pieces	0.350
	511	Marking on facing for set bone pocket	0.120
	514	J-Stitch from waist band side	0.130
	517	Marking for attach patch at back panel	0.240
	531	Set front panel pleat	0.300
	538	Set front panel CF	0.400
	542	Serge front panel at pocket bag area	0.200
	561	Marking for show stitch on bone	0.200
	569	Secure facing with bottom inner pocket bag	0.300
	606	Marking for back pocket	0.200

	618	Marking on elastic for tacking	0.240
	626	Marking for show seam front panel	0.240
	647	Serge crotch area	0.150
	650	Bartack waist band lock loop (2)	0.140
	667	Join waist band pieces	0.200
	678	Serge back pocket pieces	0.400
	718	Top stitch bone pocket-top side	0.290
	735	Set pocket bag	0.645
	751	Cut for bone opening	0.150
	771	Cut reinforcement patch	0.240
	776	Turn pocket bag inside out	0.180
	780	Cut on facing	0.200
	789	Secure facing with bottom inner pocket bag	0.110
	800	Set lining with left upper facing strip	0.275
	818	Fold & press facing upper and lower	0.320
	926	Turn flap	0.320
	946	Tack elastic belly ring	0.300
	971	Marking for set front pocket	0.120
	990	Attach waist band binding	0.500
6			
	216	Set pleat left watch pocket	0.150
	218	Marking for show stitch watch pocket	0.150
	244	Marking for button hole	0.240
	275	Marking for Bartack at left fly panel	0.120
	312	Top stitch left watch pocket hem	0.150
	313	Centre seam hem back pocket	0.300
	328	Attach back pocket (SS side hidden seam)	0.500
	359	Serge bottom facing mouth	0.100
	428	Tack facing from side	0.200
	479	Attach leather on watch pocket	0.175
	490	Bartack left fly panel-2	0.175
	527	Press waist band tab strips	0.240
	528	Inner seam J	0.150
	552	Turn & top stitch front pocket	0.466
	599	Twill tape at out seam side	0.600
	617	Make crease bottom facing mouth	0.120
	629	Marking on waist band tab strips-2	0.150
	670	Secure twill tape ends	0.400
	679	Overlock back pocket mouth strip	0.240
	684	Top stitch back pocket mouth strip	0.550
	685	Top stitch back pocket mouth strip	0.400
	708	Fold & press label	0.150
	710	Cut waist band tab strips	0.200
	722	Button hole-2	0.175
	730	Bartack watch pocket inner seam-2	0.200
	745	Top stitch watch pocket mouth	0.200
	757	Turn garment	0.100
	781	Turn waist band tab strips	0.240
	834	Serge right fly from bottom & side	0.150
	920	Bartack stitch back pocket corner	0.500

921	Marking for Bartack stitch back pocket corner	0.200
924	Marking on bone strip & facing	0.200
952	Set back pocket hem strip	0.300

Notes: This table shows line specific operations (of which there are 140), providing: the operation code; the description of the task; and the associated total SMV.

TABLE A3: Common operations across a subset of lines

LINE	OPERATION CODE	DESCRIPTION OF OPERATION	TOTAL SMV
3,4,5,6	201	Marking for inner seam watch pocket CF side	0.100
2,3,4,5,6	202	Press watch pocket	0.120
3,4,5,6	204	2nd seam attach watch pocket	0.250
3,4,6	205	Attach watch show stitch	0.200
1,3,4,5,6	206	Bartack watch pocket-1	0.120
2,3,4,5,6	209	Button hole left fly	0.300
2,6	210	Cutting zip tape manually	0.100
3,4,5,6	212	Make crease watch pocket	0.120
4,5,6	214	Set strip with watch pocket	0.150
3,4,5,6	217	Serge watch pocket mouth	0.050
1,3,4,5,6	219	Tack watch pocket	0.120
4,5,6	220	Top stitch watch pocket hem area	0.180
3,4,5,6	221	Paste fusing to fly	0.100
1,3,4,5,6	225	Tack size label	0.150
4,5	231	Bartack show seam watch pocket	0.200
5,6	245	Bartack bone pocket-4	0.350
4,5	250	Bartack show seam front pocket	0.200
3,4,5,6	251	Cut loop	0.150
4,5,6	255	Cut & turn	0.150
2,5	256	Keep label in polybag	0.120
4,5,6	259	Press facing	0.240
1,2,6	262	Serge round left fly	0.073
4,5,6	267	Press facing	0.240
3,4,5,6	271	Tucking & make right fly	0.210
4,5	272	Attach binding to left fly	0.250
3,4,5,6	277	Marking for show stitch watch pocket	0.120
5,6	279	Serge bone strip-all around	0.150
3,4,5,6	281	Serge facing	0.250
4,5,6	288	Top stitch coin pocket inside	0.175
3,4,5	289	Centre seam front pocket	0.400
5,6	293	Top stitch bone bottom seam	0.550
3,4,5,6	294	Top stitch & fuse loop-5	0.250
5,6	296	Set bone strip with back panel	0.400
5,6	297	Attach strips to front pocket bag	0.100
5,6	300	Attach left facing strip on panel	0.450
3,5,6	302	Marking for angle seam at back pocket corner	0.240
5,6	309	Turn bone opening	0.120
3,4	324	Mock stitch right back pocket	0.150
5,6	335	Set lining to yoke	0.800
1,2,3,4,5	370	Attach back pocket auto	0.521
3,4,5,6	372	Attach care label at outseam side	0.150
2,3,4,5,6	374	Bartack back pocket	0.350
1,2,3	376	Attach back pocket auto (Left)	0.310
1,4,6	377	Press busted seam back pocket	0.320
1,3,4,5,6	383	Make crease back pocket	0.200
2,5	385	Marking for hem back pocket	0.200
2,3,4,5,6	386	Marking for attach back pocket	0.320
1,3,4,5,6	387	Marking for back pocket pleat	0.240

5,6	390	Marking on back panel	0.240
2,3,4,5,6	391	Press back pocket	0.480
4,6	395	Press busted seam	0.120
1,3,4,5,6	405	Set back pocket Pleat	0.325
3,5,6	413	Angle seam at back pocket corner	0.480
1,3,4,5,6	416	Serge back pocket	0.400
1,3,4,5,6	418	Serge back pocket mouth	0.200
4,5,6	425	Set pleat at yoke	0.250
4,5,6	432	Top stitch hem back pocket strip	0.400
4,5,6	440	Top stitch seat seam	0.250
4,5,6	441	Top stitch yoke	0.430
5,6	442	Press bone opening	0.150
2,3,4,5,6	452	Mark 2nd seam	0.300
3,4,5,6	454	Secure pocket bag for stone wash	0.450
3,4,6	455	Marking for pleat height	0.200
5,6	459	Attach facing to front pocket	0.350
4,5,6	466	Join back pocket	0.400
4,5,6	472	Centre seam front pocket	0.400
3,4,5,6	473	2nd seam J	0.220
2,3,4,5	477	Attach fly stud-4	0.300
3,5	480	Fly stud helper	0.150
5,6	482	Bartack crotch at inseam	0.120
4,5,6	484	Bartack front pocket & watch pocket OS side	0.450
2,3,4,5,6	485	Bartack fly	0.120
2,3,4,5,6	487	Bartack J seam	0.120
4,5,6	489	Bartack pocket bag	0.120
3,4,5,6	498	Hang swing pocket tape	0.450
5,6	512	Set pleat watch pocket	0.150
5,6	516	Marking on front panel	0.200
5,6	518	Marking for attach patch at front panel	0.240
3,4,5,6	519	Marking for 2nd seam J	0.120
3,5,6	520	Show seam at right fly	0.200
4,5,6	525	Press back pocket pleat	0.240
2,6	534	Set crotch	0.250
5,6	535	Top stitch facing with front pocket scoop	0.500
4,5,6	540	Tack front pocket	0.240
3,5	541	Serge crotch area	0.150
2,5	545	Top stitch crotch	0.500
5,6	547	Top stitch front panel yoke	0.400
3,5	550	Top stitch pleat watch pocket	0.150
4,5,6	593	Set twill tape at shell	0.500
3,4,5,6	594	Set band to shell	0.700
3,4,5	600	Attach CB label	0.120
2,3,4,5,6	612	Top seam waist band top side with close band end	1.250
3,4,6	619	Hip stitch SNLS left side	0.200
5,6	623	Marking for attach binding OS die back & front panel	0.320
3,4,5,6	627	Marking for attach waist band label	0.120
4,6	633	Tacking pocket bag overlock	0.160
5,6	640	Set band with shell	0.800
2,3,4,5	645	Close band end angular	0.140
2,3,4,5,6	651	Tack bottom	0.200

5,6	657	Tack elastic with waist band vertically	0.550
3,4,5	660	Top stitch out seam	0.650
4,5	673	Attach binding to right fly	0.200
3,5,6	676	Mark 2nd seam crotch	0.120
1,2,3,6	692	Attach leather patch	0.200
1,2,3,4,6	693	Rivets-6	0.300
2,6	694	Attach stud	0.100
2,5	700	Marking on leather patch	0.120
3,4,5,6	701	Marking for tack loop with shell	0.240
4,5,6	709	Show seam at denim string DNLS	0.375
3,4,5,6	711	Tack loop with shell	0.500
2,3,4,5,6	724	Marking for loop attach	0.240
1,3,4,5,6	727	Marking for CB loop placement	0.120
5,6	742	Serge facing with panel scoop	0.300
3,6	752	Attach care label at outseam side	0.150
3,4,5,6	756	Attach 4 hole plastic button	0.150
3,4,5,6	763	Marking on facing	0.120
4,5	764	Marking for set pleat	0.100
4,6	785	Chain stitch at front panel overlock	0.350
1,3,4,5,6	805	Attach rivits-6	0.250
3,4,5	810	Attach horse logo rivet (before wash)	0.240
4,5,6	811	Feeding helper	0.150
3,5	816	Unpick out seam for slit	0.320
4,5,6	817	Turn up HB and tack from sides	0.300
4,5,6	873	Angle Bartack at back pocket seat seam side	0.200
1,3,6	901	Align fusing to waist band	0.230
3,5,6	902	Paste fusing to waist band	0.120
1,4	936	Mark for hem back pocket	0.200
5,6	945	Make band ring (set)	0.240
5,6	956	Press binding	0.350
2,4,5,6	968	Remove Stkr-4	0.244
4,6	970	Fold & press watch pocket hem area	0.120
3,5,6	977	Marking for waist band centre	0.200
1,3,4,5,6	978	Press band bottom	0.300
1,3,4,5,6	979	Set band pieces	0.400
1,3,4,5,6	980	Marking for band ends	0.240
3,4,5,6	981	Tack band ends	0.150
3,4,5,6	982	Cut band ends	0.120
3,4,5,6	983	Turn band ends	0.240
5,6	984	Marking for Attach main label	0.120
3,4,5,6	987	Make crease end	0.500
1,3,4,5,6	988	Top Stitch waist band topside	0.550

Notes: This table shows operations that occur across a subset of lines (of which there are 145), providing: the operation code; the description of the task; and the associated total SMV.

TABLE A4: Number of operations and total SMV by product across each line

	LINE 1		LINE 2		LINE 3		LINE 4		LINE 5		LINE 6	
PRODUCT	**# OPS**	**SMV**	**# OPS**	**SMV**	**# OPS**	**SMV**	**# OPS**	**SMV**	**# OPS**	**SMV**	**# OPS**	**SMV**
1	50	15.300	50	14.963	65	21.357	63	19.984	68	19.095	65	19.309
2	49	11.348	50	15.820	61	19.404	74	23.266	93	32.830	65	21.459
3	49	11.348	48	12.555	50	14.780	60	18.637	93	32.850	60	19.095
4	62	17.258	44	12.871	70	21.878	53	16.508	94	33.050	53	18.203
5	47	13.605	45	13.186	64	19.589	63	20.156	56	18.389	64	20.638
6	49	10.823	65	18.167	81	25.141	73	23.869	54	17.329	59	19.623
7	54	16.463	65	18.167	59	19.363	52	17.293	64	19.319	76	22.347
8	54	16.552	65	18.167	56	16.993	48	15.883	64	19.319	71	21.668
9	54	16.582	65	18.167	67	19.637	68	21.721	78	24.557	56	18.323
10	49	12.720	62	16.077	50	12.820	66	19.236	83	24.615	97	28.090
11	49	12.620	49	12.700	49	12.954	92	25.999	57	18.848	65	20.054
12	49	12.720	50	12.700	50	14.960	65	21.328	79	29.079	59	18.457
13			48	12.505	48	14.570	64	21.078	88	28.458	69	22.081
14			50	12.900	51	15.390	51	13.723	88	28.458	69	0.000
15			47	13.585	57	15.943	49	15.524	61	19.508	76	23.517
16			47	13.740	66	19.666	67	20.905	62	21.414	64	20.563
17			54	16.005	61	18.984	60	18.306	65	22.419	64	19.164
18			54	14.955	75	21.866		0.700	58	19.508	64	19.164
19			53	16.045	51	12.028			58	19.508	75	22.953
20			53	16.005	48	13.579			87	28.330	75	22.953
21			53	16.140	52	14.700			54	17.371	66	19.749
22			50	14.700	51	15.043			100	31.410	75	24.471
23			50	14.750	43	12.240			101	30.651	78	22.742
24			53	16.100	45	12.590			74	22.228	74	23.921
25			48	13.575	45	12.590			65	19.569	88	27.235
26			50	13.339	43	12.240					78	22.996
27			48	12.840	44	12.440					80	24.179
28			53	16.872	46	12.790					68	21.705
29			50	15.014	46	12.790					75	23.551

30			42	12.531	44	12.840					78	24.557
31			42	12.476	55	16.155					47	16.163
32											56	18.518
33											57	18.848
34											61	19.919
35											55	18.007
36											77	27.247
37											65	23.263
38											80	25.910
39											65	21.069
MEAN	**51**		**52**		**55**		**59**		**74**		**68**	

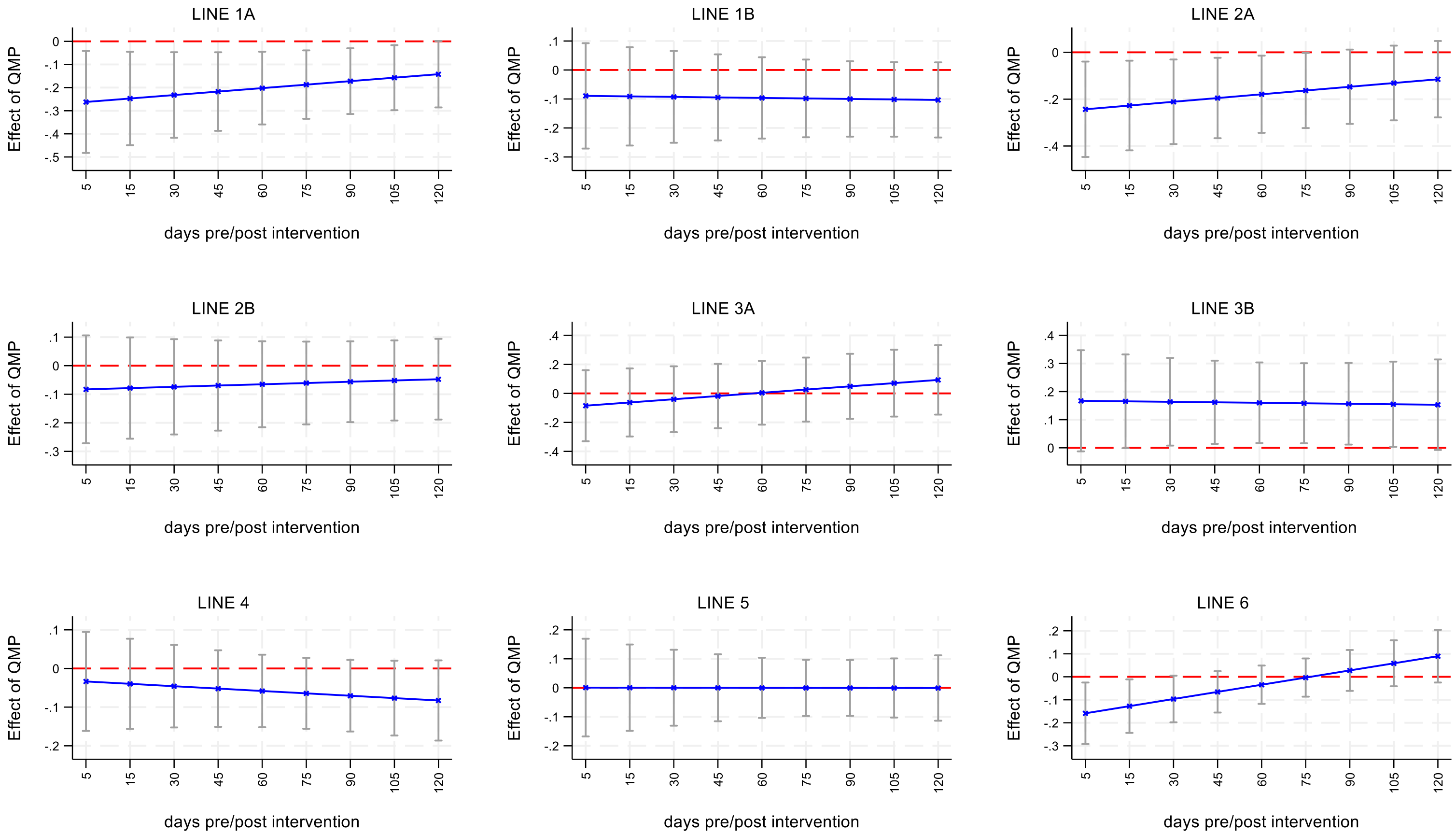
Notes: This tables shows the number of operations (#OPS) and the total SMV by product (each row represents a different product), across each assembly line (denoted by column heading for lines 1-6).

TABLE B1: The effect of the quality management practice and defects on daily wages of workers

	(1) FIXED EFFECTS		(2) RANDOM EFFECTS	
QMP	0.0803***	(0.004)	0.0799***	(0.004)
Number of daily defects	-0.0106***	(0.001)	-0.0107***	(0.001)
Age	0.0627***	(0.007)	0.0788***	(0.006)
Age squared	-0.0014***	(0.000)	-0.0013***	(0.000)
Tenure	0.0496***	(0.004)	0.0753***	(0.003)
Tenure squared	-0.0047***	(0.000)	-0.0042***	(0.000)
Male	–	–	0.1770***	(0.021)
Constant	4.3089***	(0.119)	3.6381***	(0.096)
<u>Fixed effects</u>				
Year	✓		✓	
Month	✓		✓	
Day	✓		✓	
R-squared	0.0593		0.0590	
Observations	459,094			

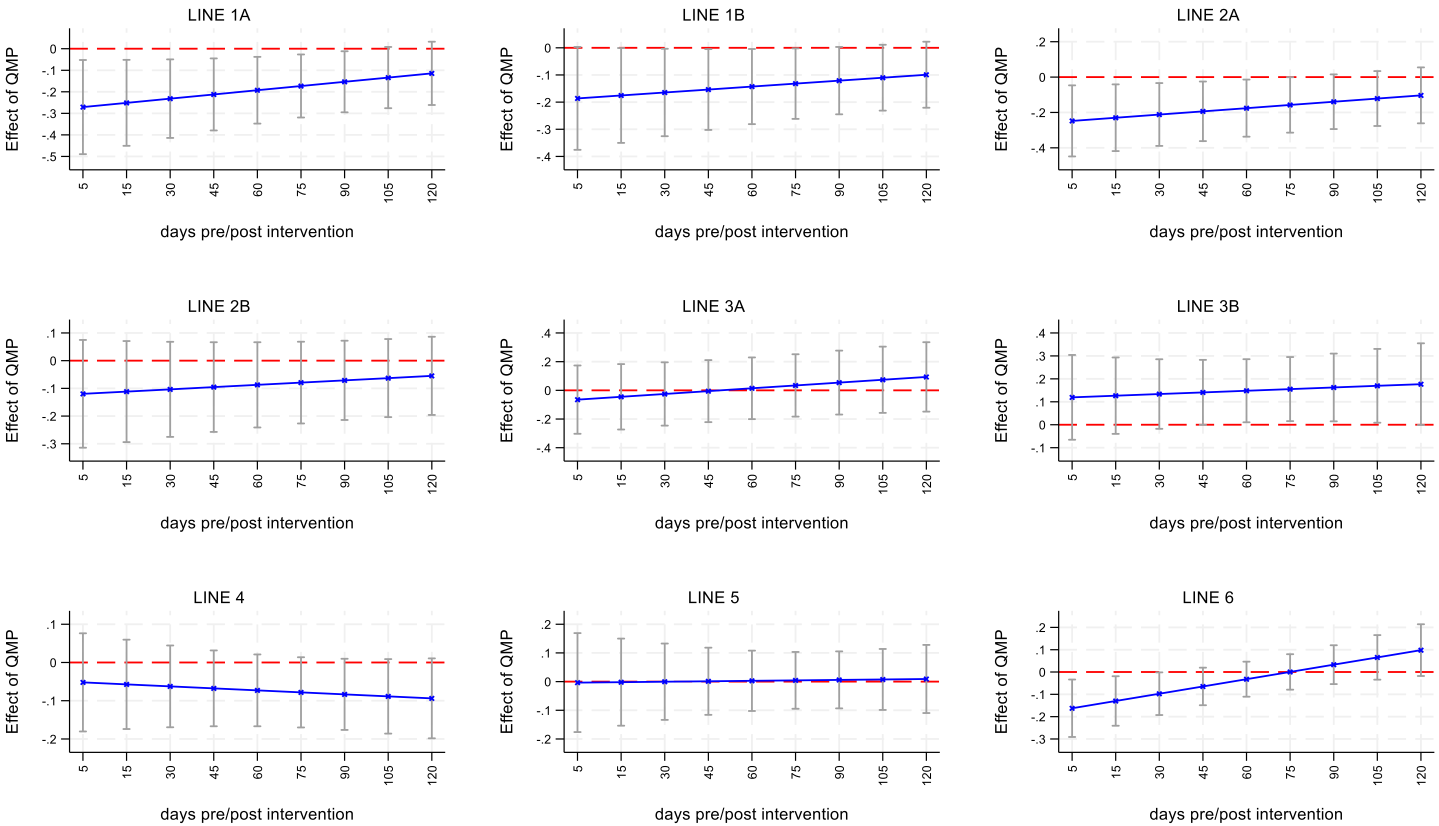
Notes: This table shows the results of using worker-day level data to investigate the impact of the quality management practice and the number of defects on the natural logarithm of the employee's daily wage rate. The daily wage rate is modelled as a semi-logarithmic Mincerian wage equation.
Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

FIGURE 1A: The impact of the new quality management practice on production around window of intervention for each line



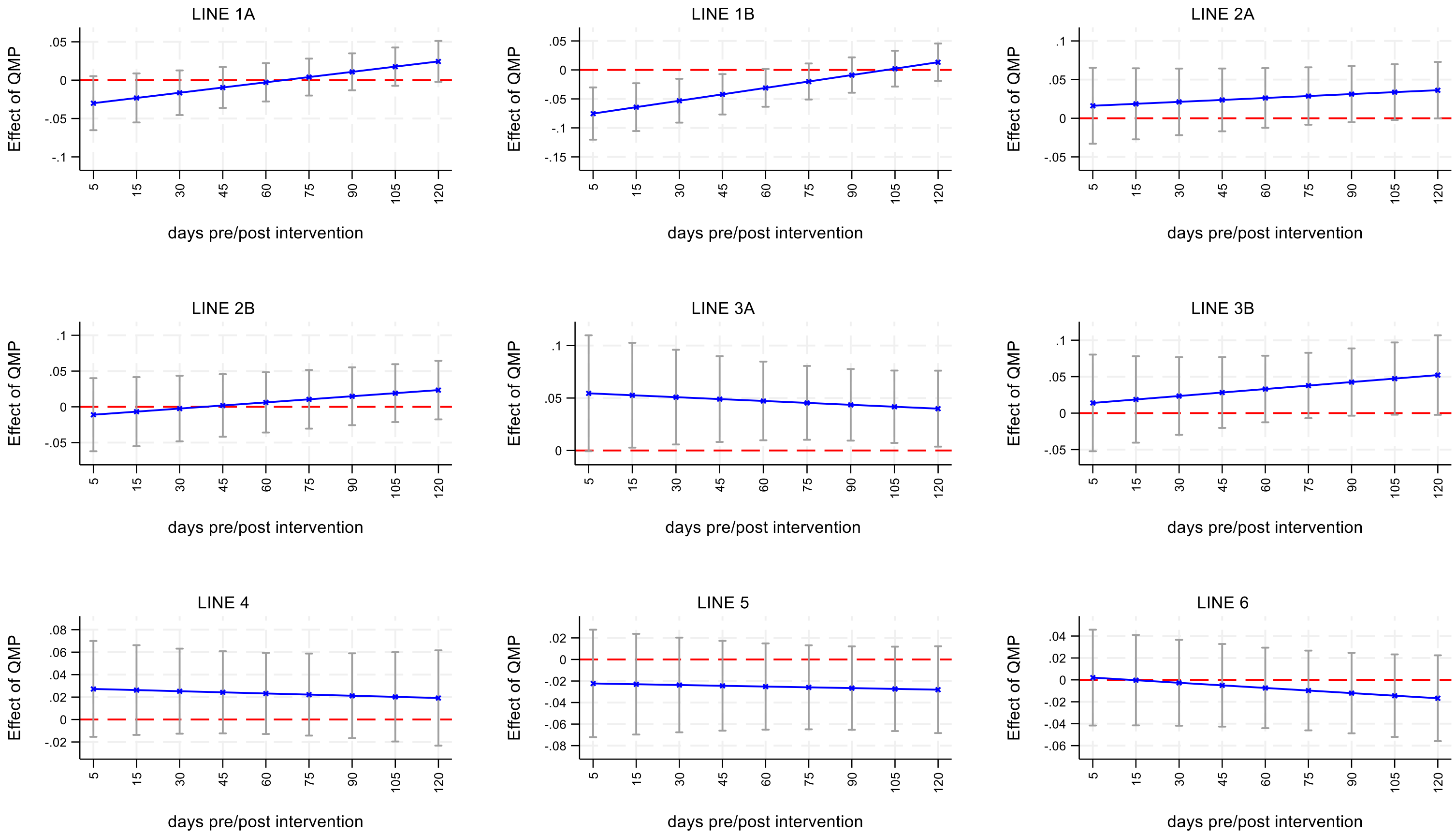
Notes: This figure focuses upon production, providing estimates shown in blue for the effect of the management intervention across different windows around the intervention. There are nine sub-plots each for a different assembly line. A red horizontal reference line from the vertical axis at zero is shown as we are looking for effects that are different to zero and 95% confidence intervals are shown in grey.

FIGURE 1B: The impact of the new quality management practice on output per worker around window of intervention for each line



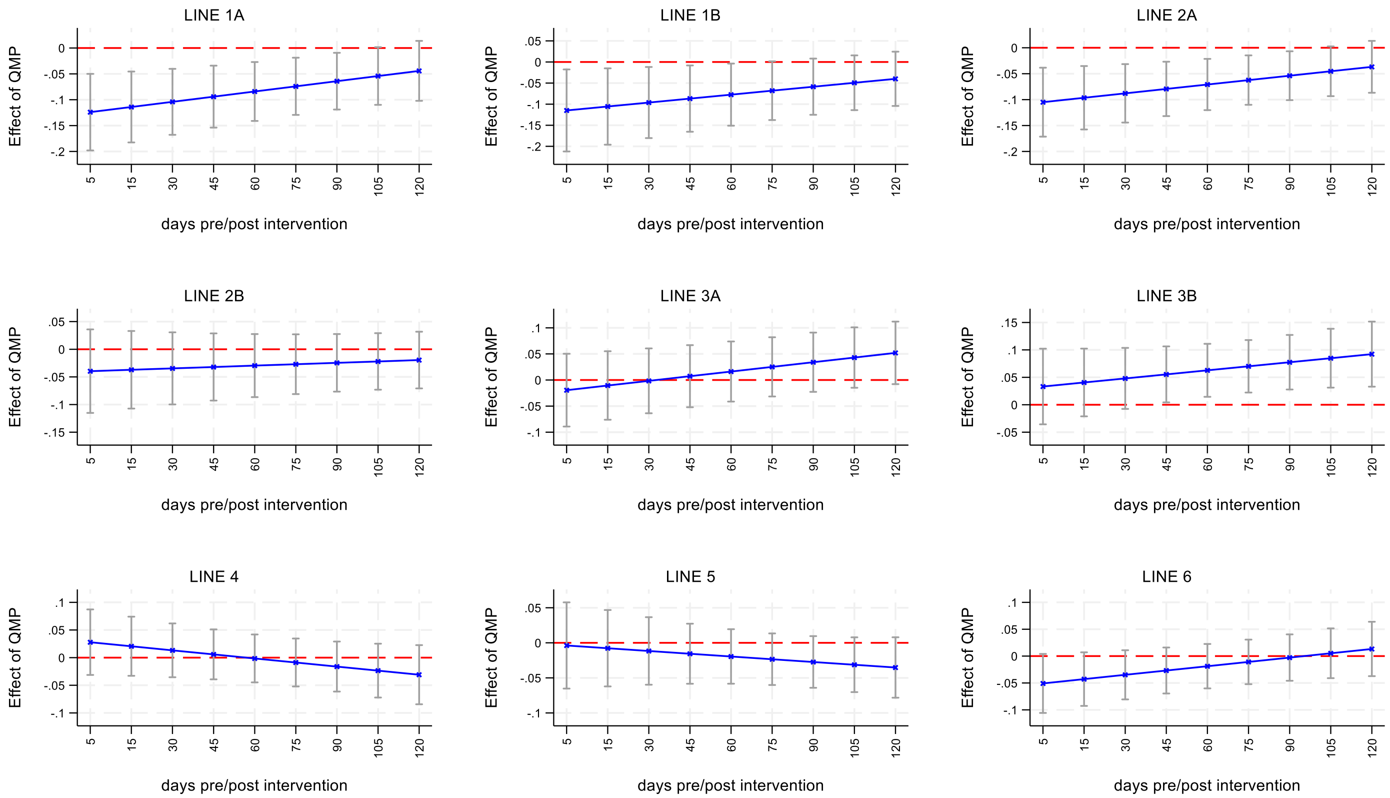
Notes: This figure focuses upon output per worker, providing estimates shown in blue for the effect of the management intervention across different windows around the intervention. There are nine sub-plots each for a different assembly line. A red horizontal reference line from the vertical axis at zero is shown as we are looking for effects that are different to zero and 95% confidence intervals are shown in grey.

FIGURE 1C: The impact of the new quality management practice on target efficiency around window of intervention for each line



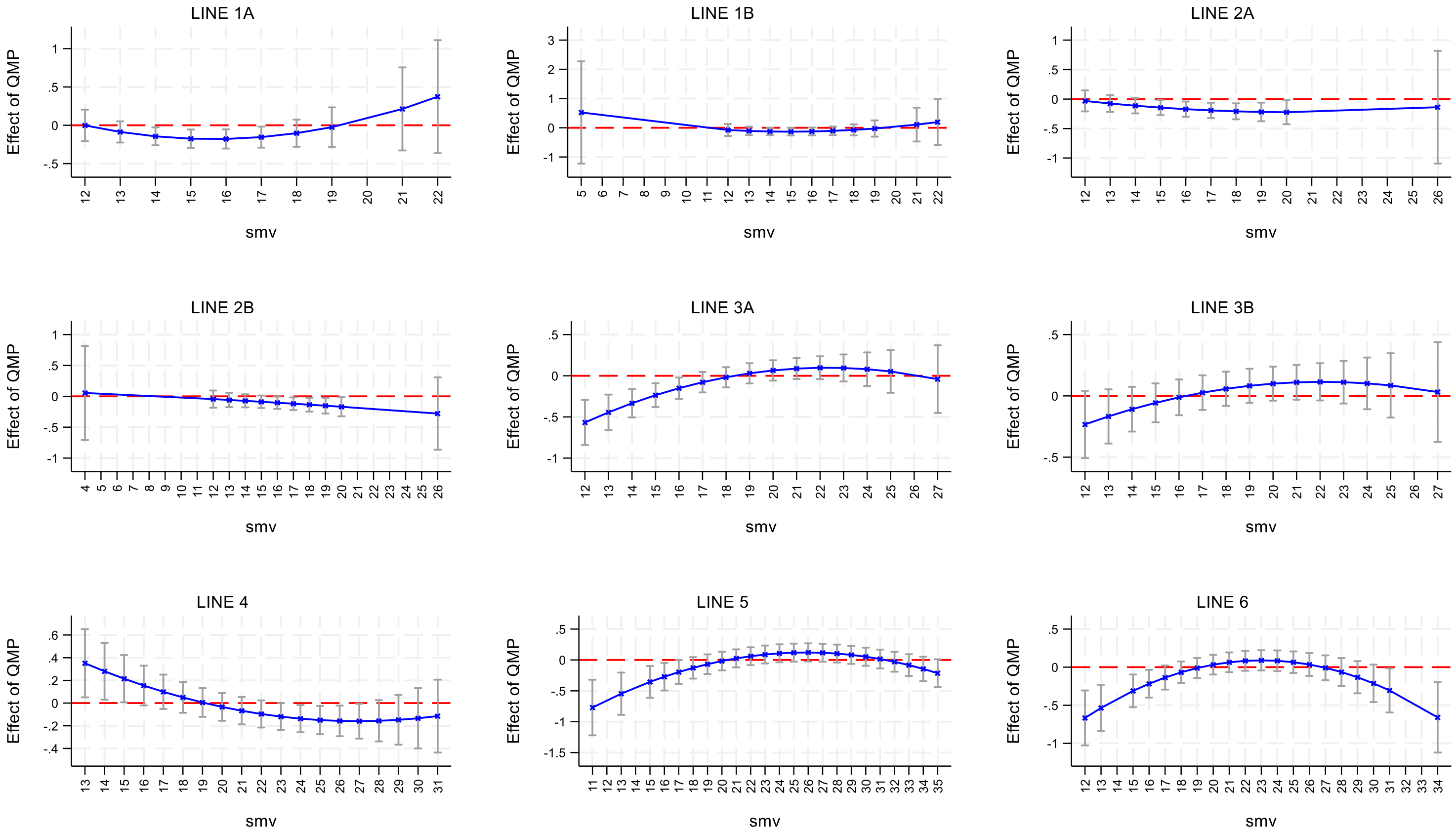
Notes: This figure focuses upon target efficiency, providing estimates shown in blue for the effect of the management intervention across different windows around the intervention. There are nine sub-plots each for a different assembly line. A red horizontal reference line from the vertical axis at zero is shown as we are looking for effects that are different to zero and 95% confidence intervals are shown in grey.

FIGURE 1D: The impact of the new quality management practice on productivity around window of intervention for each line



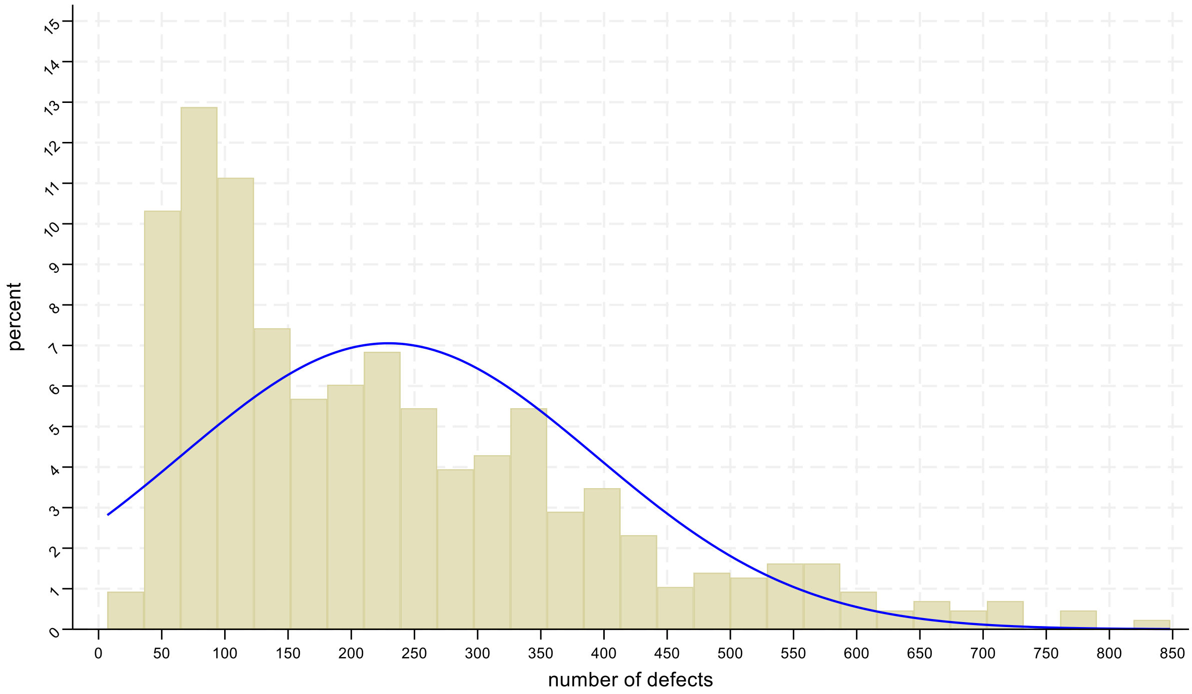
Notes: This figure focuses upon productivity, providing estimates shown in blue for the effect of the management intervention across different windows around the intervention. There are nine sub-plots each for a different assembly line. A red horizontal reference line from the vertical axis at zero is shown as we are looking for effects that are different to zero and 95% confidence intervals are shown in grey.

FIGURE 2: Heterogeneous effect of management intervention on output per worker by standard minute value and across assembly lines



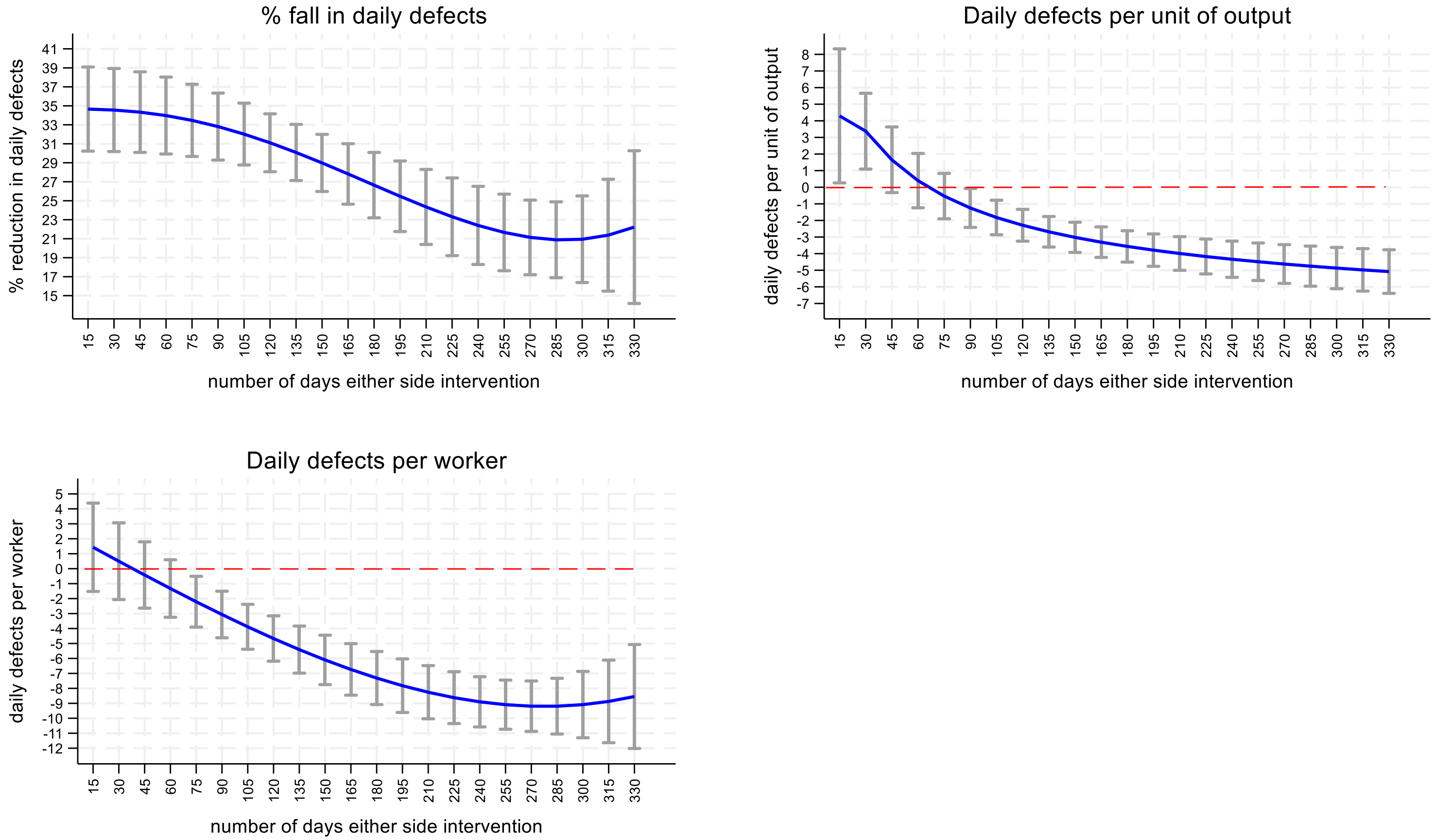
Notes: This figure shows whether the effect of the management intervention differs along average standard minute value (SMV) and across different assembly lines, with estimates shown in blue. There are nine sub-plots each for a different assembly line. A red horizontal reference line from the vertical axis at zero is shown as we are looking for effects that are different to zero and 95% confidence intervals are shown in grey.

FIGURE 3: Number of daily quality defects



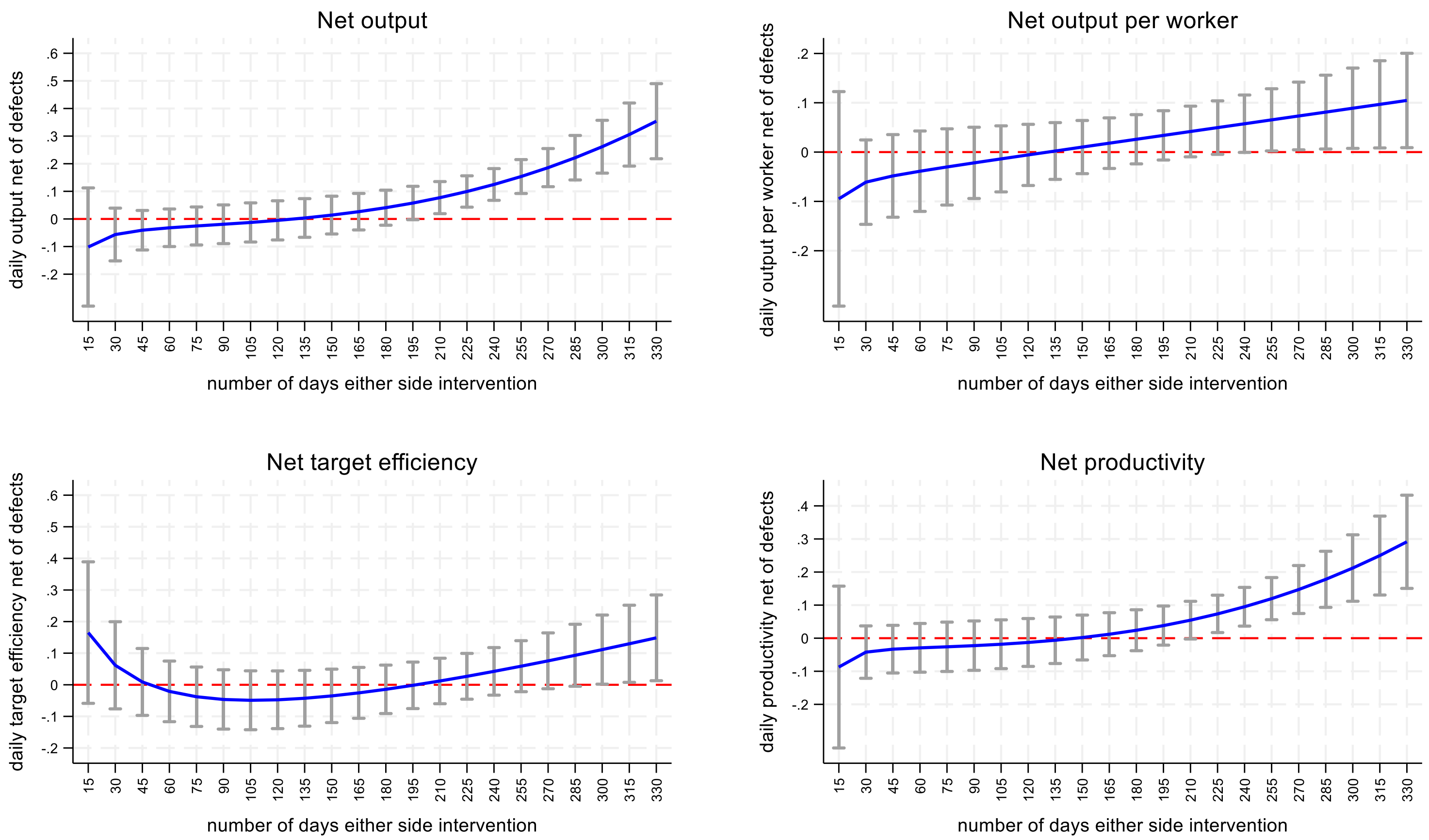
Notes: This figure shows the distribution of total daily defects over the sample period. The blue line imposes the normal distribution.

FIGURE 4: Estimated reduction in daily quality defects around window of intervention



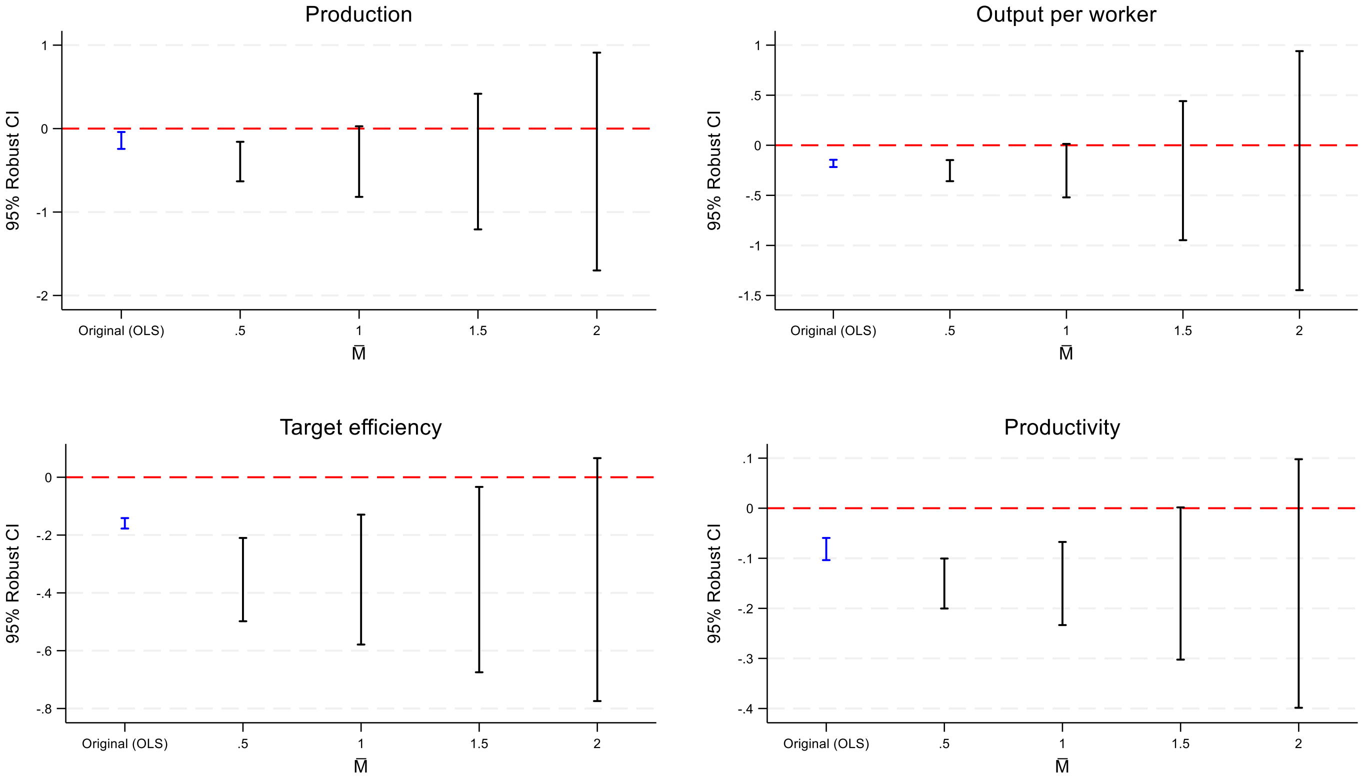
Notes: This figure shows the results of modelling the number of daily defects, daily defects per unit of output and daily defects per worker, across different window lengths around the intervention, with estimates shown in blue. A red horizontal reference line from the vertical axis at zero is shown as we are looking for effects that are different to zero and 95% confidence intervals are shown in grey.

FIGURE 5: Estimated effect of quality management practice on daily net firm performance around window of intervention



Notes: This figure shows the results of modelling net output, net output per worker, net target efficiency and net productivity across different window lengths around the intervention, with estimates shown in blue. A red horizontal reference line from the vertical axis at zero is shown as we are looking for effects that are different to zero and 95% confidence intervals are shown in grey.

FIGURE A1: Robust confidence sets for the treatment effect pre/post trends for alternative relative bounds ($\bar{M}$)



Notes: This figure shows the breakdown of the null effect that parallel trends holds exactly across each firm performance metric. A red horizontal reference line from the vertical axis at zero is shown as we are looking for effects that are different to zero. The blue line shows the 95% confidence interval for the OLS estimate. The black line the 95% confidence interval for the point estimate across different bounds of the relative magnitude of violations of parallel trends in the post-treatment based upon observed violations in the pre-treatment period, i.e. $\bar{M} \in (0.5,1,1.5,2)$. For output and labour productivity the intervention breaks down when the post-treatment violation of parallel trends is 50% as large as the maximal pre-treatment violation. Whilst for target efficiency and productivity the breakdown of the null effect that parallel trends holds exactly only occurs at a value of $\bar{M} = 2$, ruling out a zero effect at the point of intervention.

ENDNOTES

[1] A limitation of the data is that only information on aggregate daily defects is available, i.e. it is not line specific.

[2] Bandiera et al. (2005) consider the introduction of a change in incentives on the trade-off between the quantity and quality of output. They compared the productivity of workers who picked fruit before and after the introduction of piece-rates. Their results showed that productivity was significantly higher under piece-rates, however, interestingly there was no effect on daily quality defects (although they used highly aggregated data with only 67 observations).

[3] 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.

[4] The international standards of SMV were set by a consortium from the German, Swiss and Austrian National Associations. SMV is also known as Standard Allowable Minute (SAM).

[5] Note that information on daily hours worked is not available and so this is assumed to be a constant 8 hours.

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

[7] Tables A1 to A3 in the Appendix provide a detailed description of the operations undertaken on each line for all products produced over the period of 867 days. Table A1 shows common operations across all lines (of which there are 55), Table A2 shows line specific operations (of which there are 140) and Table A3 shows operations that occur across a subset of lines (of which there are 145).

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

[9] Mottaleb and Sonobe (2011) who consider the growth of the garment industry in Bangladesh focus upon the number of workers as a measure of firm performance.

[10] In specifications where firm performance is defined as output per worker labour input is omitted as a control. Similarly, when modelling target efficiency or productivity, co-variates which were used to construct the dependent variable are excluded as controls (note that the results which follow are robust to their inclusion).

[11] 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.

[12] Where $line_i$ $(i = 1, \ldots, 9)$ 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.

[13] 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.

[14] 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 (4). The results which follow are generally robust to alternatively specifying the lag length from $z = 1,2,..,10$ and are available upon request.

[15] Similar results are found in terms of the sign, magnitude and statistical significance of β_1 if line fixed effects ($line_i$) and interactions with the binary indicator for the presence of the management intervention (QMP_t) are excluded, i.e. imposing the constraint that $\theta_i = \gamma_i = 0$.

[16] The minimum SMV at 0.051 is for operation 243 which is a *"gap zipper"* and a common job across all lines (Table A1), and also for operation 217 where the task is *"serge watch mouth pocket"* undertaken on lines 3, 4, 5 & 6 (Table A3). Conversely, the maximum SMV at 1.25 is for operation 659 where the operation is *"attaching a waist band (top seam with close band)"* undertaken on line 2 only (Table A2), and also for task 612 where the job is for a *"top seam waist band top side with close band end"* undertaken on lines 2, 3, 4, 5 & 6 (Table A3).

[17] It should be noted that the production lines at the factory are independent over the 867 days where the workload of each line (output and inputs) is calculated independently. Each line has its own production and quality supervisors as well as a line specific production manager. The industrial engineering department is responsible for balancing all the lines at the factory. However, within the firm's hierarchy, one senior manager oversees the managers and supervisors of two to three assembly lines. Dependencies across lines may occur when some workers on a line are absent or alternatively if a line experiences technical issues. In such cases, the production manager may borrow machinery or workers from other lines to balance the factory, to ensure that bottle necks are not created on any line on the factory floor. In our analysis we assume line balancing to be fixed and not changed throughout the study period and so this is potentially a limitation of our analysis. However, focusing upon short windows either side of the intervention may help to partially address the issue of endogenous line balancing.

[18] Non-linear effects are incorporated interacting QMP with both average SMV and its square, denoted for brevity by the polynomial function $g(SMV)$.

[19] The estimated effect of the quality management practice for lines 1A and 1B is given by $(\beta_1 + \tau)$ and $(\beta_1 + \gamma_2 + \tau + \xi_2)$ respectively, etc.

[20] Similar results are obtained if we control for differential pre-trends using baseline characteristics assuming linear trends.

[21] We have undertaken further sensitivity analysis of the parallel trends assumption by implementing the robust inference methodology recently proposed by Rambachan and Roth (2023). This approach explores the plausibility of the parallel trends assumption by examining pre-treatment differences in trends and does not enforce the constraint that parallel trends assumption is binding. Instead, it imposes restrictions on how different the post-treatment violations of parallel trends can be from the pre-treatment differences in trends, whereby the causal parameter of interest is partially identified under these restrictions. The results of this analysis are shown in Figure A1 in the Appendix where there are sub-plots for each firm performance outcome. The original OLS outcome is only valid if the parallel trend assumption holds precisely and is shown to follow the same sign for each outcome as found in the analysis so far. Robust confidence sets for the treatment effect upon the implementation of the management practice on 15th September 2014 are given for different bounds of the relative magnitude of violations of parallel trends in the post-treatment based upon observed violations in the pre-treatment period, i.e. $\overline{\mathrm{M}} \in (0.5,1,1.5,2)$. A minimum (maximum) value of $\overline{\mathrm{M}}$ denotes the post-treatment violation of parallel trends is no more than half (twice) as large as the maximal pre-treatment violation. The results for output and labour productivity reveal that the significant effect of the intervention breaks down when the post-treatment violation of parallel trends is fifty percent as large as the maximal pre-treatment violation. Focusing upon target efficiency and productivity the analysis of Figure A1 shows that the breakdown of the null effect that parallel trends holds exactly only occurs at a value of $\overline{\mathrm{M}} = 2$, ruling out a zero effect at the point of intervention.

[22] The piece-rate is dependent on the number of defects produced by the worker, where defective pieces are sent back to the employee, however there is no monetary penalisation for this. Table B1 in the Appendix shows the results of using worker-day level data to investigate the impact of the quality management practice and the number of defects on the natural logarithm of the employee's daily wage rate. Using a Mincer earnings function the analysis reveals under both a fixed and random effects estimator, that wages were higher after the intervention (by around 8 percentage points) and decreasing in the number of defects made (one extra defect decreases wages by approximately1 percentage point). Although workers were not directly penalised for defective operations the negative impact plausibly stems from the fact that time is lost when an employee must redo a task (i.e. when defective operations are sent back).

[23] Increasing incentives for all tasks is likely to minimize this problem and incentives should be complementary in nature.

[24] The d-statistic from the OLS results shown in column (1) reveals that autocorrelation is problematic.

[25] The estimate of ψ is statistically significant at the 1% level in the Newey-West estimates for any lag length specified.

[26] The deviance statistic in column (3) reveals that a poisson estimator would be inappropriate due to over-dispersion.

[27] The fall in the number of defects is calculated from $e^{(\hat{\psi})}$, i.e. the incident-rate ratio, and the percentage reduction is given by $\left(e^{(\hat{\psi})} - 1\right) \times 100\%$.

[28] Note that given the frequency of the data is daily and at the firm level (rather than line specific) there are not enough observations to run individual regressions for different window lengths as done in Table 4 for the alternative measures of firm performance.

[29] This is calculated from $\left(e^{(\widehat{\psi+\kappa_w})} - 1\right) \times 100\%$.

[30] This could just be a temporary effect due to various forms of disruptions caused by the new policy, which dissipates once everyone on the line got used to the new policy.

[31] To do this we re-estimate equation (8) with the dependent variable $\log\left(\tilde{Y}_t\right)$, and covariates $\boldsymbol{X}_t$.