IS THERE A TRADE-OFF BETWEEN SUPERVISION AND WAGE? EVIDENCE FOR A METAL MECHANICAL INDUSTRY IN BRAZILIAN SOUTH

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RESUMO

O objetivo deste trabalho é testar a existência do *trade-off* entre supervisão e salário em uma indústria do ramo metal mecânico no sul do Brasil. A metodologia utilizada para avaliar os efeitos sobre a produtividade e a eficiência dos trabalhadores foi o modelo de diferenças em diferenças. Avaliando os resultados, constatou-se que com o aumento de supervisão observou-se um aumento na produtividade que variou entre 13,5% a 26,8%. Assim, com o aumento da produtividade, cabe à firma escolher entre aumentar o nível de supervisão ao custo de US$ 624,98 ou praticar salários eficiência ao custo de US$ 2.907,72.

Palavras-chave: Salários eficiência. Supervisão. *Insider Econometrics.*

ABSTRACT

The objective of this work was testing the existence of trade-off between supervision and wages in a metal mechanical industry in Brazilian south. The methodology used to assess the effects on productivity and the workers efficiency was the model of differences in differences. Evaluating the results, it was found that with increased supervision an increase in productivity ranging between 13,5% and 26,8%. So, with increased productivity, the firm having to choose between increasing the level of supervision, at the cost of US$ 624,98 or practice efficiency wages at a cost of US$ 2.907,72.

Keywords: Efficiency wages. Supervision. Insider Econometrics.

JEL Classification: M51, M52, M54

1. INTRODUCTION

The objective of the article is to test the existence of a trade-off between supervision and wages, using the efficiency wages model developed by Shapiro and Stiglitz (1984), for the case of a firm in the metal mechanics field. The basic question to be investigated is regarding what are the effects and implications of the different levels of supervision on the workers performance in a context of asymmetric information.

The logics of the efficiency wages theory (*shirking model*) suggests there is a (*trade-off*) dilemma between supervision and wage (SHAPIRO; STIGLITZ, 1984). In the case this trade-off exists, the firms could make use of such strategy to increase the manpower / workforce productivity, be it practicing efficiency wages (paying a wage above that of the work market), be it increasing supervision and, with this, increasing the possibility of detecting "*shirking behavior"* on the workers side.

The case analysis and the empirical tests were based on the data regarding Bruning, a firm of the metal mechanic field, located in the municipality of Panambi (Rio Grande do Sul – Brazil), in which an alteration in the degree of supervision in the assembly line of the aluminum fuel tanks, between November 2010 and October 2012. The article seeks to increase the body of evidence for the *shirking* model with the use of primary data and a robust econometrics analysis to assess the implications of the change occurred. Case studies such as that of Bruning, as well as those of Ford (RAFF; SUMMER, 1987) and of Safelite (LAZEAR, 2000), help understand what happens at the firm's level.

To test the *trade-off* between supervision and wages, as well as the consequent *moral hazard* reduction and productivity increase, two groups of workers were observed, for a period of two years: Group 1 (daytime shift) and Group 2 (night shift), with different supervision levels. Group 1 had two supervisors and remained this way throughout all the period analyzed (November 2010 to October 2012), while Group 2, between November 2010 and October 2011, had only one supervisor and between November 2011 and October 2012 started counting on two supervisors. The hypothesis to be evaluated is that, during the first period, productivity should be higher in Group 1 than in Group 2 (with different supervision levels and without wage differences) and that the productivity of Group 2 should be near or similar of that of Group 1 during the second period (with the same supervision level).

The article follows the approach called by Shaw (2009) *Insider Econometrics*, that seeks to test the impact of human resources policies and other management practices on production – in the case studied here, supervision or monitoring of a fuel tank production line for trucks. In this article are the three main characteristics (*The Distinctive Characteristics of Insider Econometric Research*) pointed out by Ichniowski and Shaw (2013), that compose an *Insider Econometrics* type of study, since it adds data from within the enterprise, with a robust econometric tool in order to measure the effect of a change in the administrative/managerial practices. Specifically, in relation to the methodological part, the empirical difference strategy is used in differences, once there is data of two different groups in relation to supervision, in two periods of time: before and after the supervision shock, on two impacted variables: productivity and efficiency.

In short, the results point at an increase in average daily productivity of the workers who belong to Group 2 after the supervision increase. The estimated effect is situated between 13,5% and 26,8%, depending of the estimation window. The results are robust to different strategies of distortion. Regarding efficiency, the estimated results are significant in only one of the samples used, which does not allow us to perform a precise analysis of the effect the supervision increase on this variable.

In addition to this introduction, the paper has four more sections. In section two the *shirking* model is developed and discussed, with its theoretical implications for the analyzed case. The third section makes a description of the Bruning Industry, and detailing of the case. The fourth section brings the empirical strategy and the analysis of the results. Finally, in the fifth section, the conclusion with the main results of the case study, based upon what has been seen in the preceding sections.

2. *SHIRKING MODEL* AND THE SUPERVISION LEVEL

In the *shirking* model, Shapiro and Stiglitz (1984), we have that the effort of workers at the job depends of the level of real wages / actual earnings received. Assuming that the utility function (U) for the worker presents a relationship between wage (w) and effort (e) and seeking to maximize this function, it is assumed that:

$$U\ (w, e) \text{ e } \frac{\partial U}{\partial w} > 0\ ; \frac{\partial U}{\partial e} < 0 \qquad \text{Equation (1)}$$

The greater the effort (e) of the worker, the lower will be the utility (U) of the wages (w).

$$U \cong (w - e) \qquad \text{Equation (2)}$$

In the case the worker is unemployed, he will receive an unemployment-benefit ($\overline{w}$) and the effort will be zero ($e = 0$).

For the unemployed worker, there exists a probability (b), per unit of time, in which he will be out of work, due to replacement (frictional unemployment) -$\left(\frac{1}{b}\right)$), this rate is assumed to be exogenous. In addition, each employee has an intertemporal discount rate (r) which maximizes the present value of utility (U). It is assumed that this discount rate will always be higher than zero ($r > 0$). The only choice the worker has is to select the effort level (e). In the case the worker performs his work with his usual effort level (chooses working hard), without shirking (non shirk), he will receive a wage (w) and will keep his job until exogenous factors generate a dismissal. In the case he chooses not to work hard (*shirk*), there is a possibility (q), per unit of time, of him being caught (by the supervision) and being laid off.

It is to be expected that the worker will choose the effort level that maximizes his intertemporal utility. This involves a comparison between the values of the utilities, in the case of working hard (*not shirk)*, in the case of not working hard (*shirk*) and in the case of the worker being unemployed. In this way, the expected utility must be calculated, throughout the life cycle of a worker who opts for “shirking” and match the expected utility throughout the life cycle, for a worker who chooses to "shirk". The worker will choose working hard (*not shirk*), only if, the utility of *not shirking* is higher than the utility on *shirking*. In this way, this becomes the condition for the worker to choose working hard (*no-shirking condition* - NSC). Calculating the critical wage (w) that respects this condition, we have that:

$$w \geq e + \overline{w} + \left(\frac{e}{q}\right) . \left(\frac{b}{u} + r\right) \qquad \text{Equation (3)}$$

Where $u = \frac{(N-L)}{N}$ represents the unemployment rate.

For Stiglitz (2009), when the firms manage to select the monitoring level (q), than can make an exchange (*trade-off*) between monitoring level and wages. Supposing a variation occurs in the supervision level (q) *ceteris paribus*, it is possible to build an inverse relation between the supervision level and the wage which attends the NSC condition, an issue which will be assessed in the article.

In the next section an analysis is made of a case of variation in the level of supervision of a firm in the metal mechanic area, testing the main propositions of the shirking model, developed in this section.

3. CASE STUDY

The objective of this section is to relate the theory of the efficiency wage (*shirking* model) for the case of Bruning Tecnometal[1], using data referring to the productivity of the production line of aluminium made fuel tanks, for a given change in the level of supervision and the resulting implications.

For this analysis the case study methodology will be used, a methodology already used in similar situations by Raff and Summers (1987), and for the case of Ford, and by Lazear (2000), for the case of Safelite. Besides this, for such investigation, a research strategy will be adopted in line with what Bartel, Ichniowski and Shaw (2004) and later Ichniowski and Shaw (2013) called *Insider Econometrics*[2].

One of the advantages of researching with data from within the firm, according to Ichniowski and Shaw (2013), is the possibility of identifying the behavioural mechanisms that explain the connection between the administrative policies and the results, in terms of productivity, before "noises" are incorporated to the data.

Bruning being located in Panambi, a city with 38.058 inhabitants[3] and having 3.400 workers, employs 25,40% of the male population between 19 and 59 years of age and 4,16% of the female population between 19 and 59 years of age (IBGE, 2010). In this way, Bruning is exposed to an enormous shortage of manpower. Therefore, the work to reduce the total number of employees is constant. Among the work developed, we highlight the elimination of a supervisor of the production line of the aluminum fuel tanks. This elimination lasted between November 2010 and October 2011.

The data of the case refer to primary data obtained from two sources (1) through a monitoring system called CODI[4], that supplies the *andon*[5] functions of *takt time*[6] measurer in an aluminium made fuel tanks

[1] Bruning Tecnometal LTD was founded by Mr. Ernesto Rehn on April 1, 1947, in the city of Panambi in Rio Grande do Sul, where, to this day, its production plant is located. Currently, Bruning produces shaped metal parts by means of low temperature processes (room temperature), called metal stamping. Added to this, the firm has the welding and painting processes, which are sometimes necessary to supplement the sets produced for customers. At the end of 2013 Bruning had a US$ 256 million revenue. With such a billing Bruning can be considered among the 1,000 largest companies in Brazil (Best and Biggest Examination, 2013). Nowadays, Bruning represents 48% of the collection of the city of Panambi.

[2] Such a case can be classified as Ichniowski and Shaw (2013) called *Insider Econometrics*, as it meets the five characteristics of Insider Econometric Research, which are: (1) estimate a regression of productivity, where productivity is a function of some administrative practice; (2) identify why administrative practices alter the level of productivity and where they have greater and lesser impact; (3) modeling administrative practices; (4) work with data at the firm's level (micro-level data) related to employees or group of employees with a common production function; and (5) use field research or interviews with managers within firms to formulate testable hypotheses and interpret results, providing additional evidence on the economic mechanisms behind the results.

[3] According to the IBGE, data of the 2010 census.

[4] System manufactured by the CODI enterprise (http://www.codi.com.br).

[5] Visual management tool that shows the state of the operations during production. An andon can indicate the production status (amount produced, amount produced with defects, time machine stopped). For more details see Marchwinski and Shook (2003).

[6] Time available for production divided between the client's demand. For more details see Marchwinski and Shook (2003).

production line; and (2) through the Human Resources department of the enterprise. The data were measured for two groups of workers, in this study identified as Group 1 and Group 2.

The data collected were the following: (1) Performance (productivity); (2) Efficiency; (3) Availability; (4) Salaries. Being: (1) Performance (productivity: is the relationship between the time spent for the production of the item in question and the theoretical time considered to form the cost of the item. It could be said, in a simplified way, that the speed (effort / concentration) with which the operator works; (2) Efficiency: is the relationship between the time the machine is producing by the total time in which it is available for production. It can be said, in a simplified way, that it is the total amount of time in which the operator is effectively working; (3) Availability: time in which the machine was available for producing within the working shifts. It takes into account the total time of the shifts, minus the times for maintenance or unexpected stops[7]; and (4) Wages: nominal net income earned by the workers in each of the functions. These data were arranged confronting the hypotheses (H_0 e H_1).

H_0: Before the increase in the supervision level for Group 2, productivity was higher in Group 2 than in Group 1 ($PM_1 > PM_2$), therefore, the average productivity must be greater in Group 1 than in Group 2 without wage differentiation.

H_1: after the increase of the supervision level in Group 2, the moral hazard of the group submitted to more supervision (Group 2) was reduced, becoming equal to that of Group 1 ($PM_1 = PM_2$), therefore, the average productivity of Group 1 should be equal to that of Group 2

The tested groups were of the semi-closed type, with small alterations of the participants, due to the low rotation of the sector (3,7% per year), maintaining the other conditions constant (*ceteris paribus*), ensuring the lowest possible influence of the work environment, the degree of workers' experience and even turnover. So, this was a real and timely case study where it was possible to work with more data and in a smaller universe than those evaluated by Gatica et al. (1995), Arbache (2001), Esteves (2006 and 2008) and Uhr and Ziero (2011), who used aggregate and sectorial data for the Brazilian economy.

The product. fuel tank in aluminum, is responsible for 15% of the revenue of the firm, where 4.8% of employees working in production, are allocated. This is produced to meet the needs of the truck assemblers installed in Brazil.

Within Bruning, there is a separate area (called line 47), isolated from the rest of the factory, that was built exclusively to hold the production line of the truck fuel tanks. This line does not suffer interference from other production sites at Bruning.

The CODI controls are installed in the operations of welding of partitions and of lids. Those stages are the robotized welding operations of the fuel tanks and constitute the bottleneck operations[8] in the production of aluminium fuel tanks. In this way, these two operations dictate the production rhythm of all the assembly line.

The welding operations, for these two points are done by pre-programmed robots, prepared exclusively for these operations. The operators who work in these two stages receive 40 hours training about soldering and identification of possible defects, besides another 40 hours training in the operation of the robot. The times and movements of those two operations are quantified and analyzed by Bruning's

[7] As unexpected stops we can have: lack of electricity, production meetings, going to the toilet, etc.

[8] Bottleneck operation is one that presents the largest processing time.

production engineering team. Nonetheless, the operator can "not pull his weight" during the preparation and positioning of the tanks for the robotized welding and / or after the performance of the welding, when the tanks need to be moved again, from the robot to the next operation. The preparation, positioning and removal of the tanks are manual operations, where the operator can, simple, take more time than necessary, be it positioning the tank, be it not removing the tank after being soldered by the robot. The choice of when to perform the operations is at the discretion of the operator.

Production line 47 possesses a theoretical manpower distribution, throughout the productive process. Such distribution is called capacity frame. The capacity frame for the line foresees the need for 40 operators and two supervisors per shift, to obtain the maximum production with all the work places filled, respecting the logic of the *takt time*[9]. The *takt time* is measured by the Codi, together with the welding robots. While the robot is performing the welding operation, the Codi system is making the reading and registering the times. Between the welding of one tank and another, the Codi system registers that the robot is not being used, which characterizes waste of time in the process and the reduction of such time represents productivity gain. Performing the change of the tanks, at the end of each welding operation, is the function of the operator. Without a good supervision accompaniment it is very easy for the operator to adopt a *shirking* posture, during the course of these exchanges.

Line 47, according to the data of the Human Resources department at Bruning, presents a low turnover rate. Within the analyzed period for this work (11/01/2010 - 10/31/2012) the turnover rate remained within the historical patterns of 3,7% per year. The mean time at the firm for employees of each shift during the period analyzed in this study was 2 years and 11 months for employees of the first shift and three years and four months for the second shift employees.

The average wage received by machine operators during the assessed period (11/01/2010 to 10/31/2012) was US$ 496,02, while the wage received by supervisors was US$ 624,94. The US$ 496,02 wage results in an average yearly income, for the worker, of US$ 6.448,26 (13 wages throughout the year), which is 57% below the per capita GDP (2010) of the municipality of Panambi[10]. This can be considered a strong piece of evidence the firm does not practice efficiency wages among these workers.

Between November 2010 and October 2011 a modification was made in relation to the degree of supervision in production line 47. During that period, one of the assembly line supervisors of the capacity frame of the second shift (Group 2), was eliminated. This modification did not take place in the first shift (Group 1) which continued having two supervisors.

Such modification was made due to the great difficulty of the firm in finding qualified[11] manpower for this function. This modification led to a change in the ratio supervisors / supervised with a difference of 50% between one working shift and the other. For the first shift (Group 1) this ratio remained at $\frac{2}{40} = 0{,}05$, however, for the second shift (Group 2) this ratio became $\frac{1}{40} = 0{,}025$. In November 2011, the second supervisor for the second shift (Group 2) was replaced. With this, the ratio supervisors / supervised returned to be the same for both shifts (groups). Thus, between November 2011 and October 2012 both shifts (groups) maintained supervisors / supervised ratio of $\frac{2}{40} = 0{,}05$. That way, during the period of one year, the groups of workers operated with different supervision levels, which according to the *shirking* model, such as developed by Shapiro and Stiglitz (1984), represents an opportunity for the

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[9] Time available for production divided by customer demand. For more details seeMarchwinski and Shook (2003).

[10] Data from the Fundaçao de Economia e Estatistica (FEE) (Economics and Statistics Foundation) of Rio Grande do Sul

[11] For this function the minimum qualification for hiring is: mechanics technician - middle level.

arising of the “not pulling your weight” postures, as the chance of an operator being caught practicing this type of posture was reduced.

While Group 1 (first shift) remained during two years (between November 2010 and October 2012) with two supervisors, Group 2 (second shift) had one supervisor during the first year (between November 2010 and October 2011) and two supervisors during the second year (between November 2011 and October 2012). For each variable, in each group, 464 observations were generated regarding performance, efficiency and availability, that will be analyzed in the next section.

4. EMPIRICAL STRATEGY

With the objective of assessing the effect of the increased degree of supervision on Group 2, the present sub-section highlights first the methodology to be implemented in the assessment of this natural experiment[12], after that the results of the estimated models and finally a simulation exercise

4.1 Methodology

To fulfill the objective of this study, we chose to use the method of differences in differences. The choice of this empirical strategy is mainly justified due to having information on performance, efficiency and availability, throughout time, of two different groups, being that the intervention we seek to assess, the monitoring increase in the production lines, focused on only one of these groups.

The central hypothesis for the identification of the impact in the increased supervision of Group 2 resides in assuming that, in the absence of the supervision increase on the second group, the performance, efficiency and availability of both groups would follow parallel trajectories. In other words, any other shocks that might affect the trajectories of the interest variables between the group treated and the control group would exert the same influence. Being thus so, any deviation observed in the trajectories of the interest variables between the two groups, in later periods to the intervention proper, can be attributed to the effect of the monitoring increase on Group 2.

Formally, the following equation will be estimated:

$$Y_{it} = \alpha_0 + \alpha_1 G_i + \alpha_2 P_t + \alpha_3 G_i * P_t \qquad \text{Equation (4)}$$

being: i=1,2 e t=1,...360.

The dependent variable *Y* is both a measure of the production performance as the measure of efficiency and availability. While the variable *G* is a binary variable that takes on value 1 for group 2 and value 0 for group 1. Variable P is also a binary variable that takes on value 1 for all the observations of periods after the 03/11/2011 (date of the beginning of the increased monitoring for group 2), and zero for the periods prior to that date.

The interest coefficient to be estimated is the α_3 that captures the difference of the conditional differences of the dependent variable between the two groups throughout time. In order to visualize what is being said, let us take the four following conditional:

[12] According to Angrist and Pischke (2014) natural experiments take place when some exogenous event occur, generally some policy change (of the enterprise) governmental, generating alterations in the environment in which the individuals, families or workers operate. In order to analyze a natural experiment we must always have a control group which has not been affected by the change and a treatment group that was affected by the eve

$$E[Y_{it}|G_i = 1, P_i = 1] = \alpha_0 + \alpha_1 + \alpha_2 + \alpha_3 + E[\varepsilon_{it}|G_i = 1, P_i = 1] \quad \text{(a)}$$

$$E[Y_{it}|G_i = 1, P_i = 0] = \alpha_0 + \alpha_1 + E[\varepsilon_{it}|G_i = 1, P_i = 0] \quad \text{(b)}$$

$$E[Y_{it}|G_i = 0, P_i = 1] = \alpha_0 + \alpha_2 + E[\varepsilon_{it}|G_i = 0, P_i = 1] \quad \text{(c)}$$

$$E[Y_{it}|G_i = 0, P_i = 0] = \alpha_0 + E[\varepsilon_{it}|G_i = 1, P_i = 1]. \quad \text{(d)}$$

Now, making the difference (a) - (b) and (c) - (d) we obtain:

$$(a) - (b) = \alpha_2 + \alpha_3 + \{E[\varepsilon_{it}|G_i = 1, P_i = 1] - E[\varepsilon_{it}|G_i = 1, P_i = 0]\} \quad \text{(e)}$$

$$(c) - (d) = \alpha_2 + \{E[\varepsilon_{it}|G_i = 1, P_i = 1] - E[\varepsilon_{it}|G_i = 1, P_i = 0]\}. \quad \text{(f)}$$

Finally, with the identification hypothesis of the difference in differences method we have that $\{E[\varepsilon_{it}|G_i = 1, P_i = 1] - E[\varepsilon_{it}|G_i = 1, P_i = 0]\} = \{E[\varepsilon_{it}|G_i = 1, P_i = 1] - E[\varepsilon_{it}|G_i = 1, P_i = 0]\}$, and obtain α_3 from (e) - (f).

Equation (4) was also estimated in other three specifications for checking robustness of the estimated results. The second of the four specifications is included an interaction term between the binary variable that identifies the groups and a trend variable (*t*). With this interaction we allow the trajectories of the dependent variables to possess different tendencies between the two groups. In the third specification we remove the interaction of the second and we include *dummies* of months to control effects related to the seasonal issues that might affect productivity and efficiency. In the fourth and last specification, we include both the interaction as well as the *dummies* of months. The standard errors were estimated by the White correction process for the covariance matrix. Furthermore, three different samples were used to perform the step described above.

In the first sample we used all the available observations. We call this sample “Complete Sample”. The second sample just contains information within the window of the 6 months before and after the 11/03/2011. This sample we call “six months sample”. Finally, the third sample contains observations within the sample of the previous and following months to the 03/11/2011. This sample we call “one month sample”. We adopted this procedure to investigate if the monitoring effect, in case it exists, presents some heterogeneous behavior over time. In the one month sample only two specifications are estimated, those that do not include seasonal *dummies*, that in this case would be perfectly collinear with the variable *P*.

With the purpose of checking the validity of the results we adopted two procedures. The first is what we call “temporal placebo”. It consists in the estimation of all the specifications used with the alteration of the date of treatment for previous periods to the real monitoring change in group 2. The idea behind this procedure is to check the existence of trajectories previously not parallel between the dependent variables of the two groups, which makes invalid the identification impact hypothesis of the differences in differences method in our case. If the results observed in the main estimations were in fact significant and were capturing the monitoring effect on the performance and the efficiency, when we make the estimations for periods previous to the change of monitoring policy what is expected is an absence of statistical significance. In this procedure we do not use the information generated after 11/03/2011 with the purpose of not contaminating the estimates of the temporal placebo with information of periods when the intervention is in force.

We estimated the “temporal placebos” in two periods with different sample. The first is six months before the date of the intervention 05/02/2011, with a sample from 11/01/2010 to 10/30/2011, while the second one is a month before the date of intervention, 10/03/2011, with sample from 09/01/2011 until 10/30/2011. The other checking procedure for robustness we used consists in estimating all the specifications having as a dependent variable the availability degree of the machines for working with, which in principle should not be influenced by the supervision increase, since machines only suffer influence from structural factors such as the supply of electric energy, for instance, which indicates that, if there are no availability variation with the increase of supervision and there are productivity and efficiency variations, we have indications of robust results.

4.2 Results

Before analyzing the results of the models based on the differences in differences method, some median tests were held that indicate different levels of productivity between groups before the supervisory increase occurred in Group 2. From the values calculated in Table A.3.1[13], it can be stated that, from the statistical point of view, the medians for Productivity and Efficiency obtained between Group 1, with two supervisors and Group 2, with one supervisor, are statistically different. For the availability, the averages do not show significant statistical difference.

Productivity and efficiency are related to the performance of the line of production workers. Availability, on the other hand, is related to the unexpected stops (maintenance problems, lack of electric energy, etc.). In this way, it is coherent with the shirking model not to find differences between the averages for availability, given that the difference in the number of supervisors does not have much influence on unexpected stops. In this way, hypothesis Ho is confirmed.

With the insertion of the second supervisor in Group 2, based on table A.3.2, it can be asserted that, statistically, the averages obtained for Performance, Efficiency and Availability among Group 1, with two supervisors, and Group 2, with two supervisors, are not different. The H_1 hypothesis is confirmed this way. In addition to this average difference analysis between groups the analysis of Group 2 itself was also performed, before and after the increase in supervision, in which, according to table A.3.3, it was proved that the group, in relation to itself, obtained a significant increase with the introduction of one more supervisor. However, in order to investigate in more detail the shock effect of supervision occurred in group 2, the results highlight the differences in differences method.

Table A.3.4, presents the estimates of differences in differences of the increased monitoring effect on Group 2, in terms of productivity. In the full sample, in three of the estimated specifications the effect is positive and statistically significant to 1,0%. The estimated coefficients indicate that increased supervision generated, on average, an increase in daily performance in the range between 13.5% to 16.8%. The estimations for the other two samples also corroborate the positive effect observed in the complete sample, being the effect of the increase in monitoring over the second group higher in the short term. In the six-month sample estimates are all significant at 1.0% and range from 16.3% to 19.3%. In the one month sample the estimated effects are also significant and are between 21,9% and 26,8%. In the three samples the greater coefficients are associated with the model with the presence of the possibility of different trajectories of the dependent variables among the groups.

[13] Appendixes 1 and 2 highlight graphic analysis of the series. In appendix 3, are the tables with the estimated results.

Table A.3.5, presents the results of the estimations where the dependent variable is efficiency. The results indicate that the monitoring is significant only in the six-month sample. The estimates are situated between 22,6% and 26,7%. In the models with interaction between tendency and group, the coefficients were merely significant to 10%.

It is in table A.3.6 that the results of the "temporal placebo" estimates for performance can be observed. In the sample with six-month sample, only in one of the four specifications the estimated coefficient was significant. In the one-month sample, no coefficient associated to the "false" intervention effect was significant. These results indicate there were no different previous tendencies in the performance between the two groups. Therefore, the results presented in table A.3.1. are corroborated as an effect of the increased monitoring of Group 2 on the performance of the workers. Table A.3.7. presents the results of the temporal placebos for efficiency. In the six-month sample three coefficients are statistically significant, however there is no robustness in the placebo estimates. We observed positive and negative coefficients. In the one-month sample there are no statistically significant coefficients.

Finally, table A.3.8 presents the estimations of differences in differences over the availability variable. No coefficient, for any of the three samples, indicates effect of the monitoring. As it was previously discussed, there is no reason whatsoever for availability to suffer any change due to monitoring increase. The absence of statistical significance in the estimated coefficients for availability, reinforces the robustness of the results we observed mainly for the workers productivity. In this way, it is assessed that the estimates present in table A.3.4 are not spurious, because if they were, it would reasonable to imagine we would find statistical significance in the estimations where availability is the dependent variable.

From the verification that there was an increase in productivity with the supervision increase in Group 2, the result mentioned by Shapiro and Stiglitz (1984), that is, an inverse relationship between supervision and wages, is reached. Since no differentiation was made at the wage level among the workers allocated to the first and second shift, in spite of the elimination of the supervisor position for the second shift (between November 2010 and October 2011), it was to be expected that the production level of the second shift (Group 2) would present a reduction to the level of the first shift (Group 1) H_0 and a productivity increase in group 2 after the H_1 shock. Such condition was justified, mainly. Due to the modification of the detection probability (q) of the "not pulling your weight" (*shirking model*), that was reduced by half with the elimination of a supervisor ($q_1 \neq q_2$). Supposing that before the detection probability of the "not pulling your weight" condition was ($q_1 = 50\%$), in the second moment we have the reduction in half ($q_2 = 25\%$). Next, we conduct a simulation for the case being analyzed.

4.3 Simulation

Using equation 3 it is possible to perform a simulation exercise and calculate which would be the wage that should be put into practice, in order to maintain the workers effort level, even with the supervision level reduction and consequent reduction of detection probability (q) of shirking behavior (wage efficiency).

$$w_1 \geq e + \bar{w} + \left(\frac{e}{q}\right).\left(\frac{b}{u} + r\right) \qquad \text{Equation (5)}$$

Since there were no modifications in the salaries paid to the production line workers throughout time, in other words, the salaries paid between t_0 and t_1 were the same as between t_1 and t_2 ($w_1 = w_2$).

Effort (e) would also remain the same, as well as unemployment payment ($\overline{w}$). Therefore, it can reasonably be supposed, that employee discount rate (r) also does not suffer alteration, that frictional unemployment (b) remains stable and that unemployment wage ($\overline{w}$) for an employee who earns US$ 496,02 per month is US$ 388,86[14]. Considering frictional unemployment of ($b = 1\%$) and the 2010 rate of unemployment as ($u = 6{,}7\%$), we have that:

$$w_1 \geq e_1 + \overline{w} + \left(\frac{e_1}{q_1}\right).\left(\frac{b}{u} + r\right) \rightarrow 496{,}02 \geq e_1 + 388{,}86 + \left(\frac{e_1}{0{,}5}\right).\left(\frac{0{,}01}{0{,}067} + 1\right) \qquad \text{Equation (6)}$$

$$e_1 \geq 31{,}62$$

Since the effort is the same in both moments, it is possible to calculate which must be the wage paid with the supervision reduction (q) to maintain a constant effort level.

$$w_2 \geq e_1 + \overline{w} + \left(\frac{e_1}{q_2}\right).\left(\frac{b}{u} + r\right) \rightarrow w_2 \geq 31{,}62 + 388{,}86 + \left(\frac{55{,}6615}{0{,}25}\right).\left(\frac{0{,}01}{0{,}067} + 1\right) \qquad \text{Equation (7)}$$

$w_2 \geq US\$\ 568{,}71$, a wage 14,66% higher than the wage actually paid.

Yet, as the wage (w) remains constant, it is to be expected that the effort level would have a significant reduction due to the modification of the detection probability (q) of the “not pulling your weight” (*shirking model*).

$$w_2 \geq e_2 + \overline{w} + \left(\frac{e_2}{q_2}\right).\left(\frac{b}{u} + r\right) \rightarrow 496{,}02 \geq e_2 + 388{,}86 + \left(\frac{e_2}{0{,}25}\right).\left(\frac{0{,}01}{0{,}067} + 1\right) \qquad \text{Equation (8)}$$

$e_2 \geq 18{,}63$, a 41,08% reduction in the effort level.

In order to maintain the effort level, according to the Shapiro and Stiglitz (1984) model, it would be necessary to increase the wage of the 40 workers (machine operators) in 14,66% (from US$ 496,02 to US$ 568,71). This would represent an increase in the production costs (*ceteris paribus*) of US$ 2.907,62 ((US$ 568,71 - US$ 496,02).40). Taking into account the wage of the supervisor is US$ 624,98[15], in the case it is possible to maintain the productivity level by adding one more supervisor, such option shows to be less costly than practicing a wage efficiency policy. In the Bruning case, the economic advantage of working with one more supervisor becomes evident, since the additional costs imposed by the hiring and maintenance of this added worker are much lower than the gains obtained through a higher productivity of the welding line of the fuel tanks, thanks to a reduction of the “shirking behavior”.

5. FINAL CONSIDERATIONS

The objective of this work was to test the existence of a *trade-off* between supervision and wage, using the efficiency wage model, more specifically the *shirking model*, (SHAPIRO; STIGLITZ, 1984) for data obtained from the Bruning Tecnometal Ltda firm in the production line of aluminium fuel tanks, based on the *Insider Econometrics* approach. The relevance of the work is that it shows how productivity can be increased and what are its fundamentals as well as the measurement of results.

The analysis of the series indicated that there was an increase of productivity as soon as the level of supervision increased. Besides, the econometric tests indicate the existence of the positive correlation according to Shapiro and Stiglitz (1984) and confirmed for the Bruning case. The results point to the increased average daily productivity of the workers who belong to Group 2 after the increase in supervision. The estimated effect is situated between 13,5% and 26,8% depending on the the sample

[14] We used the average rate of exchange R$/US$ 1,76 and also the values of unemployment insurance for 2010.
[15] Net wage, without social security charges.

estimation. The results are robust to different distortion strategies. Since the efficiency of the estimated results are significant in only one of the samples used, which does not allow us to accomplish an accurate analysis of the effect of increased supervision on this variable.

The main conclusion of the work is, that after the confirmation that the two working hypothesis show to be significant from the statistical point of view, we have that the firm can choose between the addition of one more supervisor, with a cost of U$ 624,98 instead of practicing an efficiency wage for the 40 workers who operate machines in the production line.

Through the calculation of the theoretical model, the increase over the wage should be 14.66% to maintain the same level of effort, for the 40 assembly line operators. Such increase would represent an additional cost of U$$ 2.907,72[16]. In this way, in case the firm chooses to increase in one supervisor (wage of US$ 624,98) instead of practicing efficiency salaries (U$$ 2.907,72), it would reduce the cost in US$ 2.282,74. Thus, it becomes more advantageous for the firm to increase the number of supervisors instead of increasing wages.

REFERENCES

ANGRIST, J. D.; PISCHKE, J. S. Mastering Metrics: The path from cause to effect. *Princeton University*, 2014.

ARBACHE, J. S. Trade liberalisation and labour market in developing countries: theory and evidence. *University of Kent, Department of Economics Discussion Paper* 01/12, jun. 2001.

BARTEL, Ann; ICHNIOWSKI, Casey; SHAW, Kathryn. Using "Insider Econometrics" to study productivity. *The American Economic Review*. Vol. 94, No. 2, p. 217-223, may 2004.

BOWLES, Samuel. The production process in a competitive economy: Walrasian, neo-hobbesian and Marxian model. *American Economic Review*, 75: 16-36, 1985.

BULOW, Jeremy I., SUMMERS, Lawrence H. A theory of dual labor markets with application to industrial policy, discrimination, and Keynesian unemployment. *Journal of Labor Economics*, 4: 376-414, 1986.

ESTEVES, Luiz Alberto. Salário eficiência e esforço de trabalho: evidências da indústria brasileira de construção. *Revista Economia*, Brasília (DF), 9, n° 2, páginas 327-341, maio/agosto, 2008.

ESTEVES, Luiz Alberto. Uma nota sobre intensidade de supervisão nas indústrias brasileiras. *Revista Brasileira de Economia*, 60: 235-246, 2006.

Fundação de Economia e Estatística do Rio Grande do Sul – FEE. 2011 – PIB per capita no município de Panambi. Disponível em: <http://www.fee.tche.br/sitefee/pt/content/resumo/pg_municipios_detalhe.php?municipio=Panambi>. Acesso em: 19 jan. 2014.

FOGUEL, M. N. et. al. (2012). Avaliação Econômica de Projetos Sociais.. 1° Edição SP: *Dinâmica Gráfica e Editora Ltda*.

GATICA, Jaime; MIZALA, Alejandra; ROMAGUERA, Pilar. Interindustry wage differentials in Brazil. *Economic Development and Cultural Change*, 43(2): 315-331, 1995.

[16] Taking into account only the cost of net wages, without social security charges.

IBGE dados do Censo 2010. Disponível em: <http://www.censo2010.ibge.gov.br/sinopse/webservice/frm_piramide.php?codigo=431390&corhomem=3d4590&cormulher=9cdbfc>. Acesso em: 02 jan. 2014.

ICHNIOWSKI, Casey; SHAW, Kathryn. Insider Econometrics. In: GIBBONS, Robert (Org.); ROBERTS, John (Org.). *The Handbook of Organizational Economics*. 1 ed. Scottdale – AR: Princeton, 2013. Capítulo 7, p. 261-311.

LAZEAR, Edward P. Performance pay and productivity. *American Economic Review*, v. 90, N. 5, December: 1346-1361, 2000.

RAFF, Daniel M.; SUMMERS, Lawrence H. Did Henry Ford pay efficiency wages? *Journal of Labor Economics*, vol. 5, no. 4, 1987.

SHAPIRO, Carl; STIGLITZ, Joseph E. Equilibrium unemployment as a worker discipline device. *American Economic Review*, 74: 433-444, 1984.

SHAW, Kathryn. Insider econometrics: a roadmap with stops along the way. *Labour Economics*, 16: 607-617, 2009.

STIGLITZ, Joseph E. *Selected Works of Joseph E. Stiglitz volume I*. 1 ed. Oxford – Oxford: Oxford University Press, 2009. Páginas 287-303.

UHR, Daniel de Abreu Pereira; ZIERO, Júlia Gallego. Existe trade off entre supervisão e salários? Evidencias para a indústria da construção civil brasileira. *Anpec Sul*, 2011.

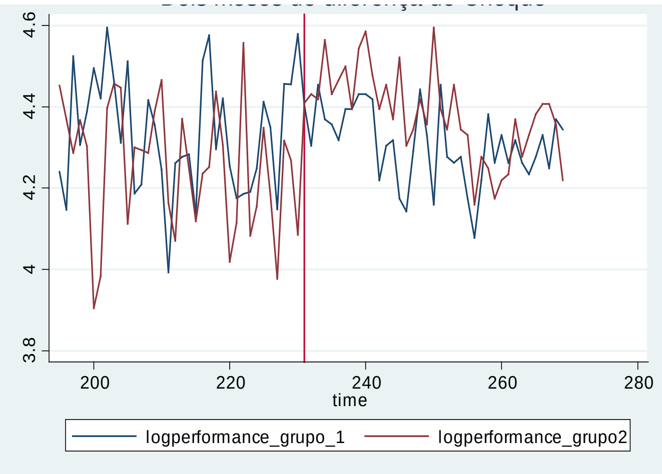
UHR, Daniel de Abreu Pereira; ZIERO, Júlia Gallego. Uma nota sobre a rotatividade da mão-de-obra do setor privado brasileiro. *Revista de Economia e Administração*, v.12, n.1, 132-148p, jan./mar. 2013.

WOOLDRIDGE, J. M. (2003). Econometric Analysis of Cross Section and Panel data. *The MIT Press*.

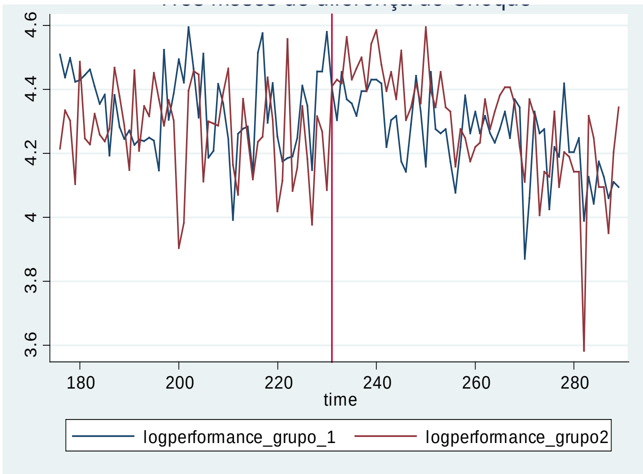
APPENDIX 1

Graphic Analysis of the series before and after the supervision shock

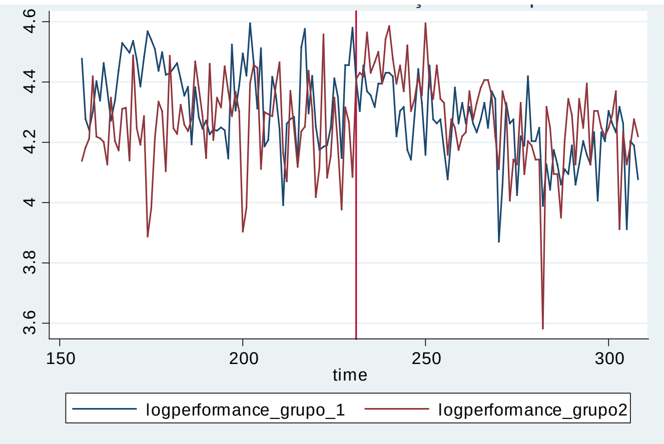
2 Month



3 Month

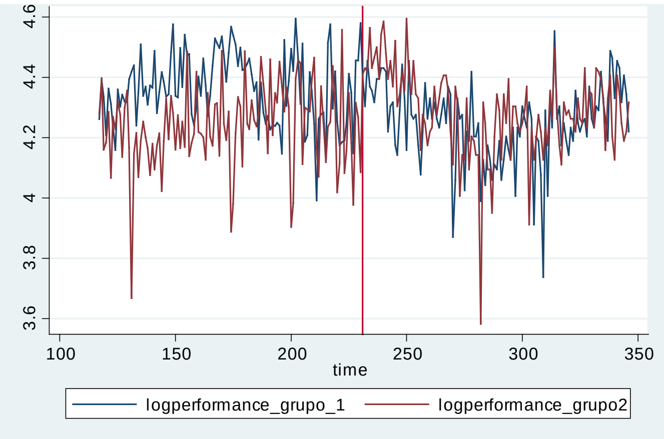


4 Month



5 Month

6 Month



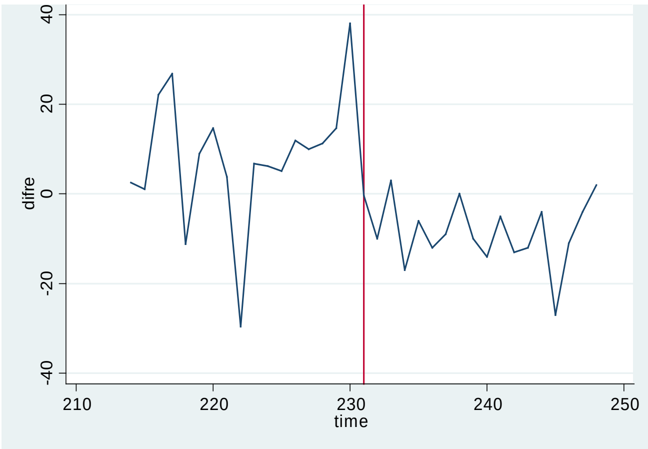
7 Month

Source: Own elaboration parting from the results.

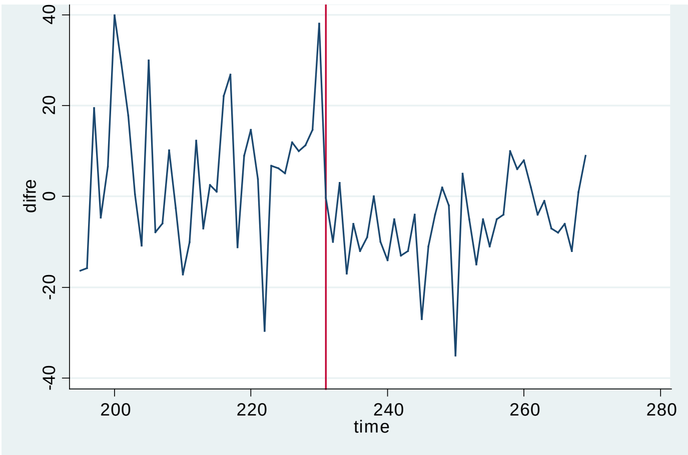
APPENDIX 2

Graphic Analysis of the productivity gap between groups

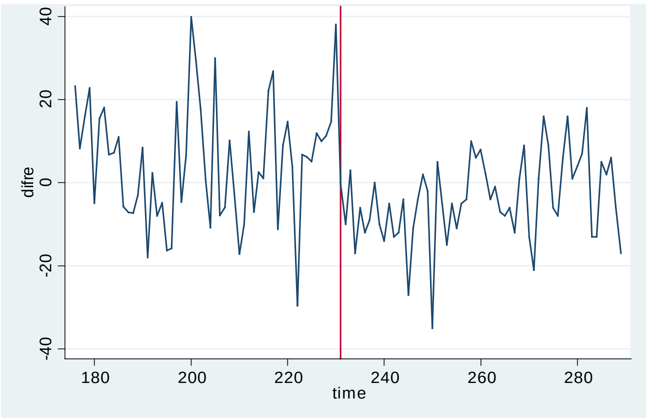
1 Month



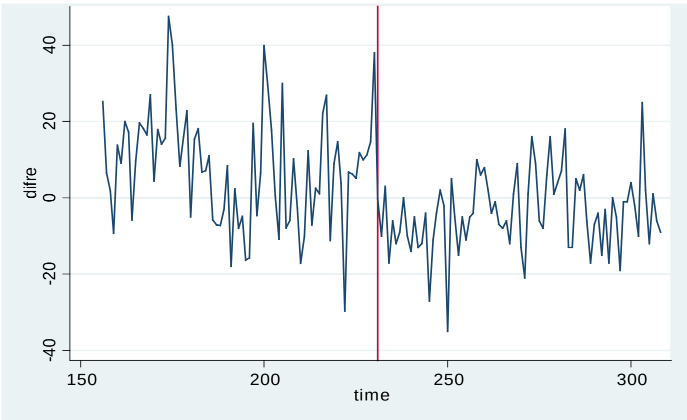
2 Month



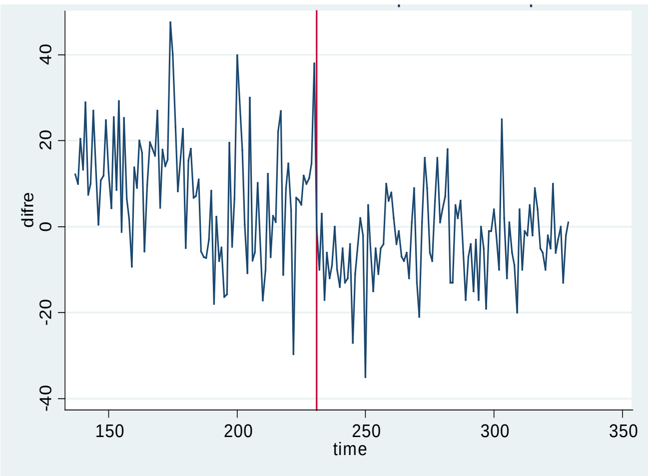
3 Month



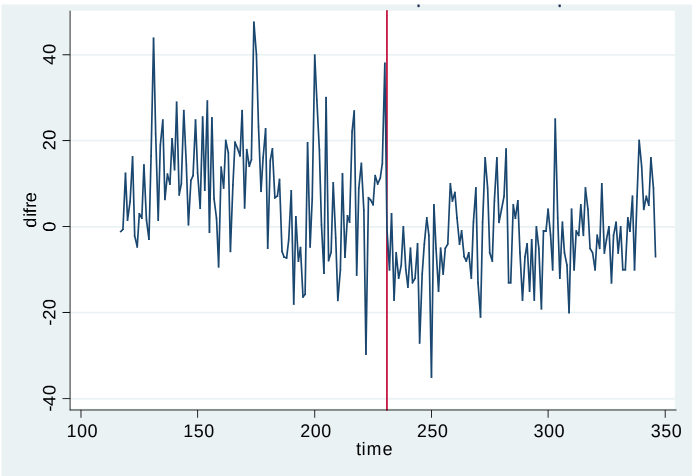
4 Month



5 Month



6 Month



Source: Own elaboration parting from the results.

APPENDIX 3

Table A.3.1 – Test of mean differences Group 1 (with 2 supervisors) against Group 2 (with 1 supervisor)

Performance		Efficiency		Availability	
$\bar{d}$	8,224761	$\bar{d}$	5,106076	$\bar{d}$	1,291695
S_d	12,78741	S_d	13,7883	S_d	16,4757
$S_{\bar{d}}$	0,815296	$S_{\bar{d}}$	0,87911	$S_{\bar{d}}$	1,050452
t	10,08807	t	5,808234	t	1,229657

Source: Elaborated by the author (2014)* Graphic analysis in annex 1.

Table A.3.2 – Test of mean differences - Group 1 (with 2 supervisors) against Group 2 (with 2 supervisors)

Performance		Efficiency		Availability	
$\bar{d}$	-1,24905	$\bar{d}$	0,397409	$\bar{d}$	0,759959
S_d	9,270631	S_d	12,96114	S_d	15,29118
$S_{\bar{d}}$	0,591074	$S_{\bar{d}}$	0,826372	$S_{\bar{d}}$	0,97493
t	-2,11319	t	0,480908	t	0,779501

Source: Elaborated by the author (2014)

Table A.3.3 – Difference between means test based on pairs of observations - Group 2 (with 1 supervisor) against Group 2 (with 2 supervisors)

Performance		Efficiency		Availability	
$\bar{d}$	-7,85312	$\bar{d}$	5,451354	$\bar{d}$	13,75273
S_d	12,16165	S_d	17,26995	S_d	23,01062
$S_{\bar{d}}$	0,775398	$S_{\bar{d}}$	1,101092	$S_{\bar{d}}$	1,467104
t	-10,1279	t	4,950861	t	9,374065

Source: Elaborated by the author (2014)

Table A.3.4 – Estimates of the Monitoring Effect on Performance

	Full Sample (01/11/2010 - 30/10/2012)				Six month sample (02/05/2011 - 30/04/2012)				One month sample (03/10/2011 - 30/11/2011)	
	coef/se	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**
Monitoring effect	0,135***	0,047	0,135***	0,168***	0,163***	0,193***	0,163***	0,168***	0,219***	0,268***
	(0,018)	(0,031)	(0,016)	(0,033)	(0,025)	(0,043)	(0,023)	(0,046)	(0,058)	(0,089)
Group 2	-0,121***	-0,165***	-0,121***	-0,104***	-0,125***	-0,080	-0,125***	-0,117**	-0,110**	0,512
	(0,014)	(0,019)	(0,012)	(0,018)	(0,017)	(0,050)	(0,017)	(0,056)	(0,050)	(0,797)
Post 01/11/2011	-0,019	-0,019	-0,020*	-0,020*	-0,115***	-0,115***	-0,062**	-0,063*	0,001	0,001
	(0,012)	(0,012)	(0,011)	(0,011)	(0,016)	(0,016)	(0,030)	(0,033)	(0,041)	(0,041)
Constant	4,308***	4,308***	4,321***	4,314***	4,364***	4,364***	4,346***	4,347***	4,338***	4,338***
	(0,009)	(0,009)	(0,015)	(0,016)	(0,011)	(0,011)	(0,026)	(0,027)	(0,034)	(0,035)
R2	0,112	0,126	0,325	0,326	0,122	0,123	0,283	0,283	0,298	0,303
R2 Adjusted	0,109	0,122	0,314	0,315	0,116	0,116	0,262	0,260	0,266	0,260
Observations	928	928	928	928	460	460	460	460	70	70
Tendency	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Seasonality	No	No	Yes	Yes	No	No	Yes	Yes	-	-

note: *** p<0.01, ** p<0.05, * p<0.1

Source: Own Elaboration parting from the results.

Table A.3.5 – Estimates of Monitoring effect on Efficiency

	Full sample (01/11/2010 - 30/10/2012)				Six month sample (02/05/2011 - 30/04/2012)				One month window (03/10/2011 - 30/11/2011)	
	coef/se	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**
Monitoring effect	0,070	-0,024	0,071	0,283***	0,260***	0,267*	0,260***	0,226*	0,204	0,267
	(0,062)	(0,110)	(0,053)	(0,104)	(0,092)	(0,145)	(0,067)	(0,127)	(0,145)	(0,202)
Group 2	-0,134***	-0,181***	-0,134***	-0,028	-0,170***	-0,159	-0,170***	-0,221	-0,082	0,719
	(0,032)	(0,056)	(0,033)	(0,054)	(0,041)	(0,141)	(0,041)	(0,153)	(0,085)	(1,627)
Post 01/11/2011	-0,309***	-0,309***	-0,311***	-0,312***	-0,519***	-0,519***	-0,256***	-0,298***	-0,084	-0,084
	(0,038)	(0,038)	(0,031)	(0,031)	(0,058)	(0,058)	(0,080)	(0,086)	(0,109)	(0,109)
Constant	3,773***	3,773***	3,941***	3,901***	3,848***	3,848***	3,811***	3,856***	3,819***	3,819***
	(0,020)	(0,020)	(0,042)	(0,043)	(0,024)	(0,024)	(0,053)	(0,053)	(0,062)	(0,062)
R2	0,088	0,089	0,348	0,352	0,151	0,151	0,550	0,550	0,031	0,033
R2 Adjusted	0,085	0,085	0,338	0,341	0,145	0,143	0,537	0,536	-0,013	-0,026
Observations	927	927	927	927	459	459	459	459	70	70
Tendency	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Seasonality	No	No	Yes	Yes	No	No	Yes	Yes	-	-

note: *** p<0.01, ** p<0.05, * p<0.1

Source: Own Elaboration parting from the results.

Table A.3.6 -"Temporal Placebo" Performance

	Six month sample (01/11/2010 - 31/10/2011)				One month window (01/09/2011 - 31/10/2011	
	coef/se	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**
Monitoring effect	-0,009	0,054	-0,009	-0,097**	-0,061	-0,039
	(0,027)	(0,044)	(0,024)	(0,047)	(0,071)	(0,099)
Group 2	-0,116***	-0,084***	-0,116***	-0,161***	-0,049	0,187
	(0,020)	(0,026)	(0,017)	(0,026)	(0,051)	(0,878)
Post 02/05/2011 or 3/10/2011	0,111***	0,111***	0,045	0,044	0,004	0,004
	(0,017)	(0,017)	(0,030)	(0,030)	(0,049)	(0,049)
Constant	4,252***	4,252***	4,323***	4,335***	4,334***	4,334***
	(0,013)	(0,013)	(0,024)	(0,025)	(0,035)	(0,035)
R2	0,244	0,250	0,380	0,386	0,080	0,081
R2 Adjusted	0,239	0,243	0,362	0,366	0,040	0,027
Observation	462	462	462	462	74	74
Tendency	No	Yes	No	Yes	No	Yes
Seasonality	No	No	Yes	Yes	-	-

note: *** p<0.01, ** p<0.05, * p<0.1

Source: Own Elaboration parting from the results.

Table A.3.7 - "Temporal Placebo" Efficiency

	Six month sample (01/11/2010 - 31/10/2011)				One month window (01/09/2011 - 31/10/2011	
	coef/se	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**
Monitoring effect	-0,071	0,170**	-0,071	-0,172*	0,075	-0,087
	(0,063)	(0,081)	(0,057)	(0,091)	(0,133)	(0,189)
Group 2	-0,099**	0,024	-0,099**	-0,150***	-0,157	-1,939
	(0,048)	(0,063)	(0,039)	(0,055)	(0,102)	(1,712)
Post 02/05/2011 or 3/10/2011	0,149***	0,149***	0,001	0,000	0,016	0,016
	(0,038)	(0,038)	(0,069)	(0,069)	(0,091)	(0,092)
Constant	3,699***	3,699***	3,923***	3,936***	3,804***	3,804***
	(0,029)	(0,029)	(0,054)	(0,054)	(0,067)	(0,068)
R2	0,066	0,086	0,264	0,265	0,056	0,069
R2 Adjusted	0,060	0,078	0,242	0,242	0,016	0,016
Observations	462	462	462	462	74	74
Tendency	No	Yes	No	Yes	No	Yes
Seasonality	No	No	Yes	Yes	-	-

note: *** p<0.01, ** p<0.05, * p<0.1

Source: Own Elaboration parting from the results.

Table A.3.8 Effect on Availability (Placebo)

	Full Sample (01/11/2010 - 30/10/2012)				Six month sample (02/05/2011 - 30/04/2012)				One month window (03/10/2011 - 30/11/2011)	
	coef/se	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**
Monitoring effect	-0,031	-0,053	-0,031	0,099	0,085	0,071	0,084	0,038	0,008	0,030
	(0,053)	(0,093)	(0,047)	(0,090)	(0,076)	(0,124)	(0,055)	(0,110)	(0,127)	(0,157)
Group 2	-0,039	-0,050	-0,039	0,026	-0,037	-0,059	-0,037	-0,107	-0,004	0,264
	(0,025)	(0,047)	(0,028)	(0,049)	(0,030)	(0,118)	(0,030)	(0,129)	(0,067)	(1,367)
Post 01/11/2011	-0,311***	-0,311***	-0,313***	-0,313***	-0,400***	-0,400***	-0,173***	-0,213***	-0,083	-0,083
	(0,030)	(0,030)	(0,026)	(0,026)	(0,046)	(0,046)	(0,067)	(0,073)	(0,081)	(0,082)
Constant	4,089***	4,089***	4,243***	4,219***	4,101***	4,101***	4,055***	4,101***	4,095***	4,095***
	(0,015)	(0,015)	(0,037)	(0,038)	(0,017)	(0,017)	(0,036)	(0,038)	(0,039)	(0,039)
R2	0,146	0,146	0,339	0,341	0,165	0,165	0,567	0,567	0,024	0,024
R2 Adjusted	0,143	0,142	0,329	0,330	0,160	0,158	0,554	0,553	-0,021	-0,036
Observations	927	927	927	927	459	459	459	459	70	70
Tendency	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Seasonality	No	No	Yes	Yes	No	No	Yes	Yes	-	-

note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: Own Elaboration parting from the results.