Case Study on the Business Performance of Suppliers to the Portuguese Health System During the Period of International Financial Assistance

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Abstract
A multiple linear regression model and corresponding inferential analysis were used to study the business performance (*Y*-sales) and impact of the strategies implemented on suppliers of medical devices to the Portuguese health system during the period of economic crisis and international bailout provided by the International Monetary Fund (IMF) and European Commission EC (2011-2013). Specific measures over commercial investment (X_1) and sales concentration (X_2) were adopted, rendering these as the variables particularly suitable to explain the sales. ANOVA analysis shows that the model is globally significant, and that X_1 is relevant in explaining business performance *Y*, as confirmed by the individual t-test. This is not the case of X_2 as, despite the reasonable economic meaning of its regression coefficient, the individual t-test points to its irrelevance. The validity of model hypothesis, namely on the residuals, were attested by performing the White and Breusch-Godfrey statistical tests. The economic interpretation of the regression coefficients evidences the success of the measures adopted and the small variation observed on X_2 could account for its apparent statistic irrelevance. The general management should adopt one of the following options: either decrease more the level of concentration until the variable becomes, hopefully statistical relevant, or follow the opposite trend and increase even more the concentration level and observe its impact on the sales. The work evidences the application of a mathematical tool to aid decision making in current management of small trading companies being mostly transversal given the specificity of this Portuguese economic sector.

Keywords: Business, Management, Quantitative Analysis, Multiple Linear Regression, Inferential Statistics.

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1. **Introduction**

Portugal has enjoyed significant improvements in its health status over the last three decades, with indicators such as life expectancy and rates of perinatal and infant mortality approaching the European Union average (Barros, Machado & Galdeano, 2008). Despite this, there are still health fragilities, namely between socioeconomic groups and regions along the country that did not reach the level of the EU or OECD averages (OECD 2013, *Health at a Glance*). Moreover, health care expenditure rose from 8.0% of GDP in the nineties to 10% in 2007 raising the question of sustainability of the health system, as mentioned by Thomson *et al.* (2009). This remarkable growth has been possible by strong investment in new procedures and technologies that were made available to the end user by a substantial effort of research institutes in cooperation with small and medium size local suppliers and distributers that developed their skills in order to search modern solutions, namely in the field of medical devices in a difficult period of adjustment to the Euro currency (Blanchard, 2007). This trend was threatened by the recessive economic cycle observed after the global crisis of 2008 (European Commission 2009, *DGEFA European Economy*), and deeply influenced by the strong internal economic crisis that followed the Portuguese bailout provided by the International Monetary Fund (IMF) and European Commission (EC) during the period of 2011 to 2013 (Armingeon & Baccaro, 2012 or Baum & Glatzer, 2014). The Portuguese healthcare sector and particularly the public system suffered many reforms and austerity measures, as mentioned by Karanikolos *et al.* (2013) or Valente and Marques (2014), demanding strict adjustment of all the players, namely the suppliers. The data used in the present study meets this context, since it was obtained from the commercial activity of a medium size company working in the health Portuguese market for more than 30 years, maintained here undisclosed for confidentiality. The dimension of the organization is very typical of the field, as in Portugal and Europe the majority of the medical devices (MD) suppliers to the National Health Systems are small or medium size companies, which contrasts with the pharmaceutical sector, where multinational companies are predominant (Eucomed Medical Technology, 2014).

Regression techniques are widely used in different fields of knowledge, spanning from management, economy, marketing or natural sciences (e.g. Shpresa Syla, 2013; Gujarati, 1992; Hill, Griffiths & Lim, 2008; Dransfield, Fisher & Vogel, 1999). In particular, multiple regression models play a significant role because very few phenomena can be explained by only a single explanatory variable. The use of quantitative and statistic methods that allow to conclude on business performance, namely sales, as a function of variables, such as marketing investment, human resources costs, interest rates and other variables have been firmly recognized to be of great help for a more efficient and solid management activity (Mentzer & Cox, 1984).

The company mentioned was experiencing less satisfactory results in the end of 2010 due to national austerity measures and economic crisis leading the general management to consider that indicators such as high concentration level of the sales and marketing investment should be considered key variables to fight, and hopefully, invert the tendency observed on the business. A plan for decreasing the concentration, investment in marketing activities, human resources, costumer visit plans was implemented in the beginning of 2011 and followed until the end of 2013. The sales were accessed during thirty six months along with the corresponding marketing investment and level of concentration as measured by the Gini (1910) methodology. The present paper aims to get a better knowledge on the business performance and response of the sector under the very specific and difficult mentioned context through the use of a quantitative approach (multiple regression analysis) and corresponding statistical analysis. The use of standard data analysis tools and inferential statistics to tackle real problems is exemplified, hopefully allowing concluding in a broader way over the sector.

2. Methods

To study the relationship between sales concentration and commercial investment on the business performance a multiple regression model was used as follows,

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + U_t \tag{1}$$

where Y_i are the sales of month *i* in the medical devices (MD) department, X_{i1} is the i^{th} investment in the commercial activity and X_{i2} is the corresponding concentration level as measured by the Gini (1910) approach. The term U_t represents the random error, assuming homoscedasticity.

Monthly sales Y_i and corresponding values of the independent variables were considered from January 2011 to December 2013, those of the first year shown in Table 1 (complete data provided in **Appendix 1**, Table A1).

Table 1 Sales ($Y_i/10^5$ Euro), investment in the commercial activity ($X_{i1}/10^5$ Euro) and sales concentration Gini coefficient (X_{i2}) of the medical devices department from January to December 2011 (complete data provided in Table A1-Appendix 1).

Month	Sales ($Y_i/10^5$ Euro)	Investment ($X_{i1}/10^5$ Euro)	G (Gini coefficient) (X_{i2})
1	2.543784	0.275245	0.613258
2	2.532769	0.262479	0.592637
3	2.617796	0.274686	0.544287
4	2.558764	0.275358	0.545412
5	2.514824	0.271212	0.540184
6	2.648487	0.277066	0.530610
7	2.629756	0.284756	0.530678
8	2.632389	0.275894	0.554372
9	2.734390	0.265951	0.558602
10	2.760121	0.266725	0.554891
11	2.564318	0.288388	0.527612
12	2.585316	0.298378	0.539618

The concentration data was obtained from the distribution of the sales among the costumers using a classification in seven categories for each month, as exemplified in Table 2 for the second month. A similar approach was used for the remaining periods.

Table 2. Classification of the sales among costumers in the second month of 2011.

Sales /Euro	AF	RF	ARF	S	RS	ARS
< 500	92	0.597	0.597	20111.232	0.079	0.079
$[500, 1000[$	19	0.123	0.720	13848.463	0.055	0.134
$[1000, 2000[$	18	0.117	0.837	23722.284	0.094	0.227
$[2000, 3000[$	7	0.045	0.883	17227.391	0.068	0.295
$[4000, 10000[$	11	0.071	0.954	62959.489	0.249	0.545
$[10000, 15000[$	4	0.026	0.980	50869.188	0.201	0.745
≥ 15000	3	0.019	1.000	64538.820	0.255	1.000
Total	154			253276.87		

AF-Absolute Frequency; **RF**- Relative Frequency, **ARF**- Accumulated Relative Frequency; **S**-Sales; **RS**- Relative Sales; **ARS**- Accumulated Relative Sales.

The Gini Coefficient was determined by equation 2 (*ARF*- accumulated relative frequency; *ARS*- accumulated relative sales) using the six first groups of the classified sales distribution for each of the thirty six months.

$$G = \frac{\sum_i ARF_i - \sum_i ARS_i}{\sum_i ARF_i} \tag{2}$$

Using matrix notation, the predicted Y values given by the regression described in (1) may be written as:

$$Y = X\beta + U \tag{3}$$

where Y is a T-dimensional column vector containing observations on the dependent variable, X is a $T\times k$ matrix of observations of the independent variables, β is a k-column vector of invariant parameters. T=36 is the number of observations and k =3 is the number of right-hand side regressions in the present situation. The estimate of β is obtained by minimization of the squared error term:

$$\sum_{i=1}^{36} \varepsilon_i^2 = \sum_{i=1}^{36} (Y_i - \hat{Y}_i)^2 = \sum_{i=1}^{36} (Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_{i1} - \hat{\beta}_2 X_{i2})^2 \tag{4}$$

or in matrix notation,

$$\varepsilon^T \varepsilon = \left(Y - X\hat{\beta}\right)^T \left(Y - X\hat{\beta}\right) \tag{5}$$

leading to the usual the standard formula, Gujarati (1992):

$$\hat{\beta} = \left(X^T X\right)^{-1} X^T Y = \begin{bmatrix} \hat{\beta}_0 \\ \hat{\beta}_1 \\ \hat{\beta}_2 \end{bmatrix} \tag{6}$$

where $\hat{\beta}_0$ is the regression intercept and $\hat{\beta}_1$ and $\hat{\beta}_2$ are interpreted as the sensitivity of Y to the independent variables, holding all other factors fixed.

The minimization of Equation (5), involving setting equal to zero the partial derivatives with respect to $\hat{\beta}$, was performed using the data analysis regression tool of software *OriginPro*-9.1. The inferential data, namely the global significance of the model (ANOVA analysis), individual statistic tests on the coefficients and tests on the residuals were performed at a 95% confidence level with the same software package.

3. Results and Discussion

The data was used to predict the values of the regression coefficients of Equation 1, as summarized in Table 3 along with the corresponding values of the global coefficient of determination, R^2, and adjusted $\overline{R}^2$.

Table 3. Regression coefficients, $\hat{\beta}_0$, $\hat{\beta}_1$ and $\hat{\beta}_2$, coefficients of determination (unadjusted and adjusted) and correlation outputs obtained by the OLS method for the sales (Y_i) and corresponding commercial investment (X_1) and sales concentration Gini coefficient (X_2) from January 2011 to December 2013.

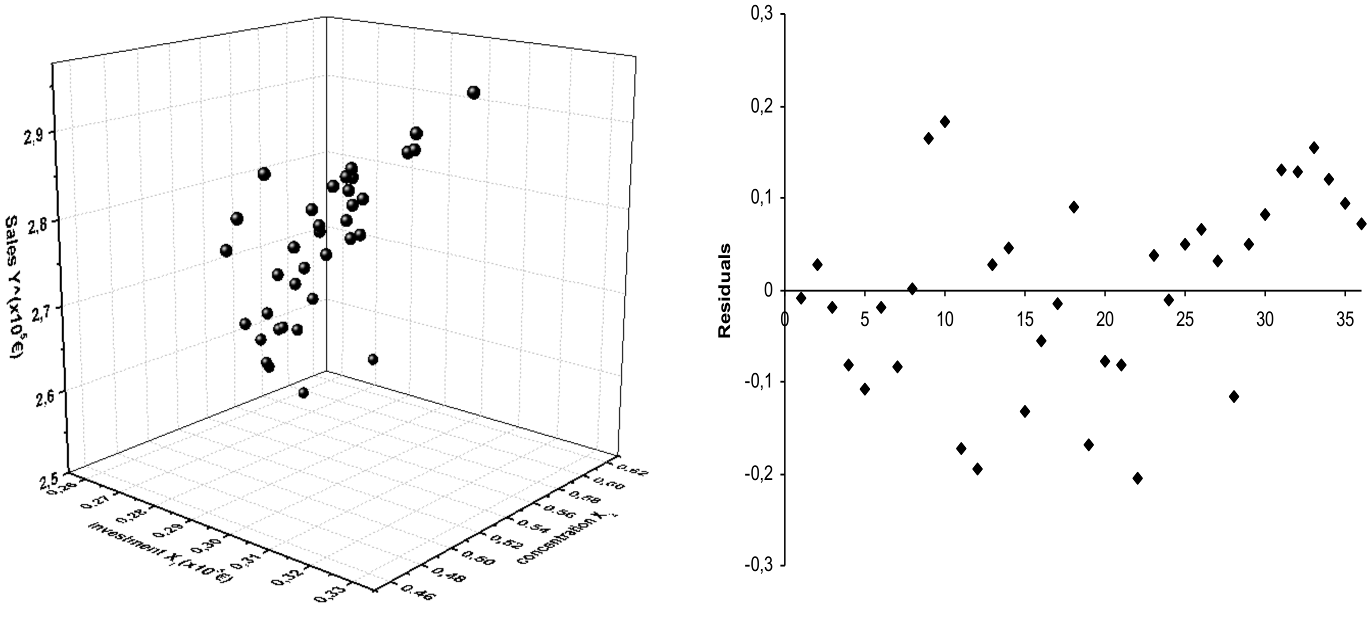
Coefficient		R^2	$\overline{R}^2$
$\hat{\beta}_0$	1.73642	0.54736	0.51992
$\hat{\beta}_1$	5.78049		
$\hat{\beta}_2$	−1.26180		
Correlation	intercept	X_1	X_2
intercept	1	−0.86421	−0.88298
X_1	−0.86421	1	0.52793
X_2	−0.88298	0.52793	1

The fitted model,

$$\hat{Y}_i = 1.73642 + 5.78049 X_{i1} - 1.26180 X_{i2} \tag{7}$$

is represented in Figure 1A as a scatter plot of the predicted sales values of each month $\hat{Y}$ as a function of the commercial investment X_1 and Gini concentration X_2. A plot of the residuals observed for each month is also shown (Figure 1B).

The coefficient of determination obtained indicates that the quality of the regression is acceptable as 54.74% of the variability of the sales is explained by the variability of the commercial investment X_1 and level of concentration X_2, through the multiple linear model adopted. The similar fitting quality given by the corrected coefficient ($\overline{R}^2$ =0.51992) accounts for the fact that the number of observations used is appropriate for the number of variables used in the present study.



(A) **(B)**

Figure 1. (A) Three-dimensional plot of the best-fit multiple regression predicted sales values of each month $\hat{Y}$ as a function of the corresponding commercial investiment X_1 and Gini concentration coefficient X_2. **(B)** Plot of the residuals obtained for each of the thirty six observations.

The global quality of the model used is attested by the ANOVA analysis summarized in Table 4 showing that the explained sum of squares (ESS= 0.47036) is above the residual sum of squares (RSS= 0.38897) leading to an F statistics of 19.95 and P-value of 2.089E−6, which for a significance level of 0.05 is in the critical range for rejection of the null hypothesis ($H_0 : \beta_1 = \beta_2 = 0$), rendering the model globally significant.

Table 4. Analysis of Variance (ANOVA) data obtained on the multiple linear regression (MLR) model used to predict the sales (Y_i) as a function of the corresponding commercial investment (X_1) and sales concentration Gini coefficient (X_2).

	DF	**SS**	**MSS**	**F**	**P-value**
Regression	2	0.47036	0.23518	19.95243	2.08929E−6
Residual	33	0.38897	0.01179		
Total	35	0.85932			

DF-Degree of Freedom, **SS**- Sum of Squares, **MSS-**Mean Sum of Squares, **F**-Statistics, **P-value**- Prob > F.

The residuals plot (Figure 1B) points to random distribution and investigation on homogeneity of their variance, was assessed by performing the White's (1980) test. An auxiliary regression of the square residuals for all possible non redundant cross products of the regression was computed, according to Equation (8):

$$\varepsilon_i^2=\alpha_0+\alpha_1 X_{i1}+\alpha_2 X_{i2}+\alpha_3 X_{i1}^2+\alpha_4 X_{i2}^2+\alpha_5 X_{i1} X_{i2}+U_t \quad (8)$$

The regression calculations performed for Equation (8) are presented in Table 5.

Table 5. Regression results obtained by the OLS method for the square of the residuals as a function of X_{i1}, X_{i2}, X_{i1}^2, X_{i2}^2 and $X_{i1}X_{i2}$ for testing heteroscedasticity (White's Test, 1980).

Coefficient	$\hat{\alpha}_0$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\hat{\alpha}_4$	$\hat{\alpha}_5$
	−1.83928	4.94258	4.10174	−5.61682	−2.97025	−2.91192
R^2	0.11826					
$\bar{R}^2$	−0.02869					

The White's test statistics, calculated as the product of the sample size by R^2 from the test regression (nR^2), is asymptotically distributed as a χ^2 distribution with degrees of freedom (DF) equal to the number of slopes coefficients (excluding the interception) in the test regression, resulting DF= 5. For the present data, NR^2= 4.25736, which is well bellow the critical value of 11.07 needed to reject the null hypothesis at 95% confidence level. We therefore conclude on the constancy of the variance of the residuals. Further model validity, namely the existence of autocorrelation on the residuals was assessed by performing the Breusch-Godfrey or LM test (Breusch, 1978 and Godfrey, 1978). It involves regression of the residuals for all the variables and previous residuals up to order *p*, according to Equation (9):

$$\varepsilon_i=A_0+A_1 X_{i1}+A_2 X_{i2}+\rho_1\varepsilon_{i-1}+\rho_2\varepsilon_{i-2}+\ldots+\rho_p\varepsilon_{i-p}+U_t \quad (9)$$

The regression calculations performed for Equation (9) with p = 2 are presented in Table 6.

Table 6. Regression results obtained by the OLS method for the residuals as a function of X_{i1}, X_{i2}, ε_{i-1}, ε_{i-2} for testing autocorrelation (Breusch-Godfrey´s test, 1978, $H_0:\rho_1=\rho_2=0$).

Coefficient	$\hat{A}_0$	$\hat{A}_1$	$\hat{A}_2$	$\hat{\rho}_1$	$\hat{\rho}_2$
	−0.45738	0.78681	0.43289	0.43922	−0.11287
R^2	0.15746				
$\bar{R}^2$	0.04125				

The test statistics is obtained from the product of the sample size ($T=N-p$) by R^2 and follows a χ^2 distribution with p degrees of freedom. For the present data $T=34$, resulting TR^2= 5.35364, which is bellow the critical value of 5.99 needed to reject the null hypothesis at a 95% confidence level, evidencing the absence of autocorrelation on the residuals. It is therefore reasonable to proceed with an economic interpretation of the implemented regression.

Equation (7) states that when the investment and concentration are equal to 0 the sales in the corresponding month would stabilize in 1.73642×10^5 Euro, which has little economic meaning as these represent limit conditions: no commercial investment and "ideal complete balance" of the sales among the costumers, which are far from the context and values of the independent variables considered in the present study. The positive relation between Y and X_1 is in good agreement with that expected and the model indicates that an increase in the commercial investment of 1×10^5 Euro ($\Delta X_1 = 1$) will cause an increase in the sales of $\sim 5.78 \times 10^5$ Euro, holding all other variables constant. A negative relation is obtained between Y and X_2, telling that an increase in concentration will lead to a decrease in the sales, which seems to be in agreement with that expected as well. Further validation may be obtained by inferential data, namely the individual significance of the coefficients given by the t-Student tests, presented in Table 7.
The t-Student statistics (4.34729) observed for the coefficient regarding X_1 is above the critical value for rejection of the null hypothesis, with a P-value of 0.00012, well below the significance level chosen (0.05). This variable is therefore significant to explain the variation of the sales in the medical devices department, thus providing statistical support to the economic interpretation and shows that the strategy regarding the investment in this area is quantitatively related with the results obtained.

Table 7. Individual statistics significance t-tests on the coefficients of the multiple linear regression model used to predict the monthly sales (Y_i) as a function of the corresponding commercial investment (X_1 Euro) and sales concentration Gini coefficient (X_2) at a significance level of 5% ($H_0 : \beta_i = 0$).

Coefficient	t-Student test	P-Value
β_0	2.46493	0.01908
β_1	4.34729	1.24323E−4
β_2	−1.59741	0.11971

The t-statistics regarding β_2 assumes a value of −1.597 that falls on the region of non rejection of the null hypothesis ($H_0 : \beta_2 = 0$, DF=33) at a 95% confidence level with a P-value of 0.1197, stating the statistical irrelevance of X_2 in explaining the variation of Y in the model. The strategy adopted of making investment in promotion and marketing activities among costumers located in the interior regions of Portugal resulted in the decrease of the concentration as can be seen by the trend of the data in Figure 2. However, there is some dispersion and despite the low values observed in three months (observations 21, 26 and 29 (~0.47)) they seem to stabilize in the range of 0.51 to 0.53, eventually contributing to the statistical irrelevance of X_2.

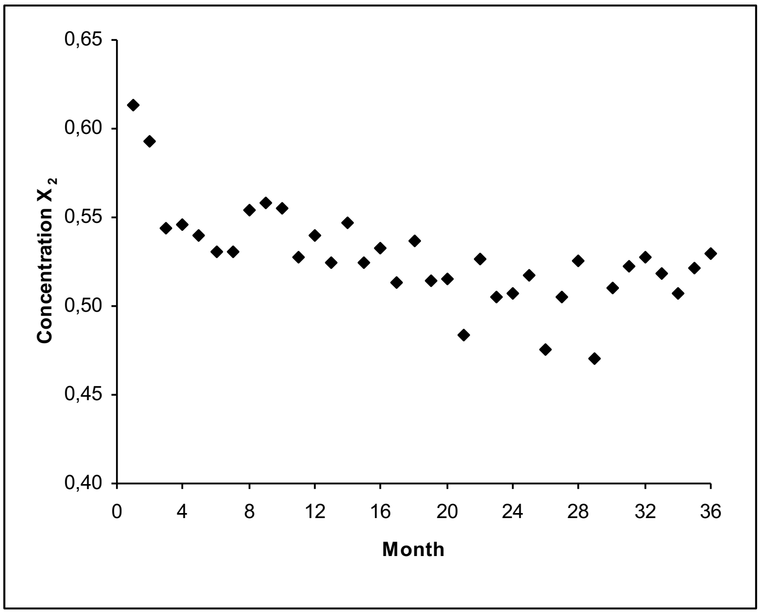


Figure 2- Evolution of the Gini coefficient in the thirty six months analysed (Jan 2011 to Dec 2013).

The observed irrelevance of X_2 could also be due to multicolinearity between the variables X_1 and X_2 but no such possibility seems to be apparent from the scatter plot presented in Figure 3 and corresponding bivariate correlation coefficient of 0.52793 obtained from the multiple regression output (Table 3).

The association of the dependent variable with the independent variables can also be investigated separately by performing simple linear regression as presented in Tables 8 and 9. Global significance is attested by the very low p-values of the ANOVA tests (Table 9) validating further analysis on the relations between the variables. Comparing the simple regression results with those of the multiple regression (Tables 3 and 4), we see that both correlations are now relatively weak (Y and $X_1 : \overline{R}^2$=0.48056; Y and $X_2 : \overline{R}^2$=0.26719) but the sign observed for the slopes align with those of MLR, thus confirming positive correlation with X_1 and negative with X_2 . The dissimilarities observed in the magnitude of the coefficients when performing SLR and MLR are expected as bivariate correlations completely ignore the effect of other variables. The very weak correlation observed with X_2 seems to confirm the lack of statistical relevance found previously turning less clear its impact on the dependent variable of sales. This may be associated with the small variation attained on X_2 during the period analysed, despite the effort to decrease the concentration made by the general management. In fact, one should consider that the model is describing the true relation, telling that further increase in the concentration level should correspond to a sales decrease of medical devices.

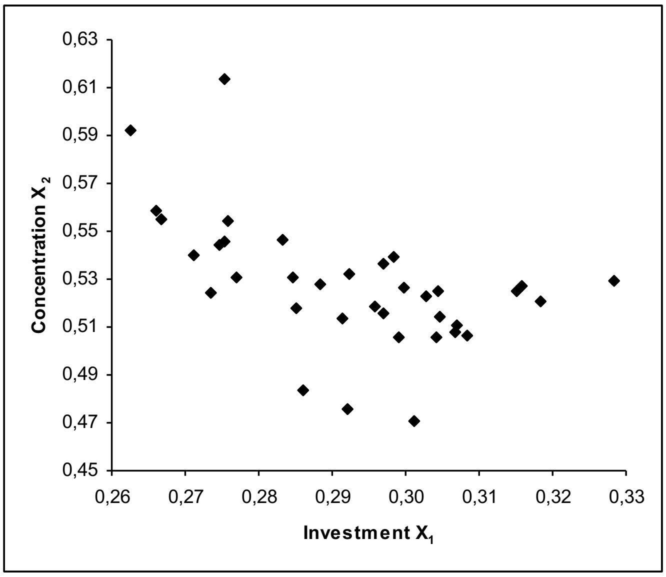


Figure 3- Representation of the concentration-Gini coefficient, X_2 as a function of the commercial investment, $X_1/10^5$ Euro.

Table 8. Regression coefficients $\hat{\beta}_0$ and $\hat{\beta}_1$ and coefficients of determination (unadjusted and adjusted) obtained by performing separately the OLS method to predict monthly sales (Y_i) as a function of commercial investment (X_1) and concentration (X_2) from January 2011 to December 2013.

	$\hat{Y}$ vs X_1		$\hat{Y}$ vs X_2	
Coefficient	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_0$	$\hat{\beta}_1$
	0.80947	6.66813	4.38304	−3.07468
R^2	0.49540		0.28813	
$\overline{R}^2$	0.48056		0.26719	

Table 9. Analysis of Variance (ANOVA) data obtained by performing separately simple linear regression to predict the monthly sales ($Y_i/10^5$ Euro) as a function of the corresponding commercial investment ($X_1/10^5$ Euro) and concentration (X_2).

$\hat{Y}$ vs X_1	**DF**	**SS**	**MSS**	**F**	**P-value**
Regression	1	0.41097	0.41097	33.38013	1.67521E−6
Residual	34	0.41860	0.01231		
Total	35	0.82957			
$\hat{Y}$ vs X_2	**DF**	**SS**	**MSS**	**F**	**P-value**
Regression	1	0.24760	0.24760	13.76138	7.37897E−4
Residual	34	0.61173	0.01799		
Total	35	0.85932			

DF-Degree of Freedom, **SS**- Sum of Squares, **MSS**-Mean Sum of Squares, **F**-Statistics, **P-value**- Prob > F.

The general management of the company should analyse the change in strategy regarding this variable, choosing one of the two options: make further investment in promotion activities among distant clients in order the decrease significantly the concentration and, hopefully, get a good correlation with the final sales until it renders significant, or abandon this strategy with the focus on the traditional costumers and increase even more de concentration. The latter, would lead to a higher dependence on fewer costumers with the corresponding increased risk.

A different conclusion is obtained by analysis of the inferential data on the β_1 coefficient. From this study is it clear that the strategy of the company to fight the recessive economic cycle and financial crisis in terms of increasing the investment on a key variable has clear impact in the sales, although a better reflection has to be done regarding spending in spreading the range of costumers for the interior regions of the Country. However, one should consider that despite the high level of investment in the last six months of 2013 (Table A1-Appendix A) the impact on the sales was not notorious as these tend to stabilize, showing some saturation and lack of response from the market, maybe due to the recessive economic cycle generated by the strong austerity measures taken by the government during the bailout to Portugal from 2011 to 2013. To overcome this tendency of stagnation the general managements should consider the trend followed by many other Portuguese companies, namely of the construction sector, that tried internationalization to preferential markets such as Lusophony African countries. This is in fact of utmost importance to the survival of many companies as stated recently by Sutter, Vasconcellos and Polo (2014) on their study based on the theoretical framework of internationalisation and application to an emerging market company.

4. Conclusions

The present work explores the application of multiple regression and corresponding statistical analysis to better understand the response of small companies supplying medical devices to the Portuguese health sector during a period of strong economic crisis and bailout from the International Monetary Fund and European Commission. The trends and discussion made may be mostly transversal given the similarities of the companies operating in this Portuguese economic sector. The model is successful in explaining the sales as a function of the commercial investment and level of concentration as attested by the ANOVA and residuals statistical tests applied to the data. Economic meaning was withdrawn from the interpretation of the regression coefficients and specific business strategies were appointed as guidelines for the near future, namely internationalization. The percentage of the variability explained by the linear regression here attempted, although acceptable, evidence that other variables may in fact have explanatory power on the sales as expected for such a significant dependent variable. It would be therefore interesting to explore the impact of other variables such as interest rates, and level of the debt to the bank sector on the sales performance over the sector.

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Appendix A

Table A1 Sales (Y_i/10^5 Euro), investment in the commercial activity (X_{i1}/10^5 Euro) and sales concentration Gini coefficient (X_{i2}) of the MD department from January 2011 to December 2013.

Month	**Sales (Y_i/10^5 Euro)**	**Investment (X_{i1}/10^5 Euro)**	**G (Gini coefficient) (X_{i2})**
1	2.543784	0.275245	0.613258
2	2.532769	0.262479	0.592637
3	2.617796	0.274686	0.544287
4	2.558764	0.275358	0.545412
5	2.514824	0.271212	0.540184
6	2.648487	0.277066	0.530610
7	2.629756	0.284756	0.530678
8	2.632389	0.275894	0.554372
9	2.734390	0.265951	0.558602
10	2.760121	0.266725	0.554891
11	2.564318	0.288388	0.527612
12	2.585316	0.298378	0.539618
13	2.682310	0.273389	0.524480
14	2.730113	0.283199	0.546672
15	2.701388	0.304486	0.524677
16	2.698750	0.292388	0.532267
17	2.757120	0.291312	0.513378
18	2.866811	0.297016	0.536689
19	2.679202	0.304756	0.514479
20	2.724511	0.296892	0.515766
21	2.697793	0.285951	0.483351
22	2.598730	0.299725	0.526589
23	2.864291	0.298988	0.505581
24	2.868134	0.308328	0.506670
25	2.782019	0.285220	0.517821
26	2.890215	0.292172	0.475549
27	2.889122	0.304286	0.505581
28	2.779200	0.315028	0.525273
29	2.934491	0.301233	0.470474
30	2.949920	0.307066	0.510610
31	2.956923	0.302726	0.522568
32	3.024559	0.315884	0.527235
33	2.946992	0.295927	0.518601
34	2.989892	0.306725	0.507591
35	3.013790	0.318388	0.521059
36	3.037892	0.328378	0.529618