Lean Six-Sigma: Treatments for an Ailing NHS?

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Abstract:

Purpose – This paper examines England's Accident and Emergency (A&E) arm of the National Health Service (NHS). It considers the positive impact that Lean has had and Six-Sigma can have in A&E departments to improve the quality and reliability of the service offered, in an area that is facing performance challenges.

Design/methodology/approach – Independent variables average monthly temperature data (degrees Celsius) obtained from the Met Office and weekly A&E data, patient volume is analysed alongside the dependent variable, the percentage of patients seen in four hours or less.

Findings – The model produced a robust positive impact when Lean Six-Sigma is adopted, increasing the likelihood of A&E dependents meeting their performance objective to see and treat patients in four hours or less.

Research limitations/implications – Further variables such as staffing levels, A&E admission type should be considered in future studies. Additionally, it would add further clarity to analyse hospitals and trusts individually, to gauge which are struggling.

Practical implications – Should the NHS further its understanding and adoption of Lean Six-Sigma, it is believed this could have significant improvements in productivity, patient care and cost reduction.

Social implications – Productivity improvements will allow the NHS to do more with an equal amount of funding, therefore improving capacity and patient care.

Originality/value – Through observing A&E and its ability to treat patients in a timely fashion it is clear the NHS is struggling to meet it is performance objectives, the recommendation of Six-Sigma in A&E should improve the reliability and quality of care offered to patients.

Key words: performance, Six-Sigma, NHS, A&E, quality, productivity, efficiency

1. Introduction

Many would argue that the NHS is one of the best services that the UK offers to its citizens. With its philosophy of serving people at large, the NHS represents the standard for a modern health care system funded by public finances. However, the institution and the health care system as a whole has come under severe scrutiny in recent times due to its failure to serve patients at their expected standards. The sustained cuts in financing and staffing are strangling the health services capacity to the ever-increasing health care demands of an ageing population. However, the NHS continuously strives to provide services within the new realities of limited funding, and rising demand due to an ageing population requiring more frequent health care.

The A&E department is perhaps the most critical function within the NHS as it frequently deals with the immediate question of life and death of patients. Critics argue that the department is overcrowded as a result of a limited general practice provision. The A&E function frequently struggles to meet its 95 percent performance objective to see patients within a four-hour period. In order to solve this issue, the debate of funding and staffing for the NHS is on-going. However, this is a discussion outside the boundaries of this paper. The authors believe it is more pertinent to attempt to optimise the performance of the A&E function from an operations perspective.

Waste reduction, efficiency and maximising the use of existing resources have previously been advised to support the functions of the A&E department. Therefore, researchers have already suggested that the adoption of Lean could be a possible solution to solve the NHS issues, through the subsequent removal of non-value added steps. Bancroft and Saha (2016) further argued that the adoption of Lean within the NHS resolved a number of performance related issues that the health service is currently facing. But this is without quantitative empirical justification. In addition, their paper also explored the relationship among time of year, patient volume and the NHS's A&E departmental performance, which provides the original predictability model that this paper can further build on.

Currently, the NHS is scheduled to face a shortfall of £22 to £30 billion by 2020/2021, should the government keep it's spending on the NHS constant (Donnelly, 2016; Leys, 2014). This is down to a multitude of factors such as an ageing and growing population, as well as inflationary pressures. It is therefore clear that as the NHS faces uncertainly around the level of funding available from the government, it must make significant productivity improvements to close this forecasted funding gap and achieve its targeted 95 percent performance objective. Six-Sigma, therefore, has been introduced due to its successful track record in improving productivity through reducing defects in manufacturing processes. Antony et al. (2007) have further justified the possibility of the adoption of Six-Sigma in the service industry.

There is much research to argue that both the Lean philosophy and Six-Sigma methodology are tied to productivity improvements, named as "Lean Six-Sigma". This approach address the issues in a different manner with a more in-depth understanding of the interconnected nature of processes and the variability within these processes, leading to the simplification of procedures, addressing process variability within the NHS's activities, ultimately providing productivity improvements and resulting in the increase of performance for the organisation (Hoerl and Snee, 2012; Antony, 2006).

Most existing empirical studies aim to establish how Lean Six-Sigma can help the A&E department to deal with a sudden unexpected increase in patient numbers, but these studies overlook the impact of Lean Six-sigma after its implementation. Some scholars have extended their research to the impact level of the adoption of Lean and Six-Sigma, however, in the form of consultative papers built upon comparative case studies without empirical evidence (McCann *et al.* 2015; Antony *et al*., 2007). The originality of this study lies in its positivistic analysis and rigour of the econometric analysis following a quantitative scientific approach, to contribute to the adoption of Lean Six-Sigma in the NHS. Another intriguing aspect of this paper is the consideration of the specific temperature variation impacting on performance, which to the authors' best knowledge is a novelty. Therefore, the primary objective of the paper is to scrutinise how Lean Six-Sigma might help to increase the performance of A&E departments in NHS.

2. Literature

2.1 Lean Six-Sigma

Lean Six-Sigma can be looked at from two perspectives: (i) the statistical, and (ii) the business perspective approach. The analytical method aims to have only 3.4 defects per million opportunities (DPMO) and 99.99966% process yield (Linderman et al., 2003; Kwak & Anbari, 2006; Antony & Banuelas, 2001). This approach from an operational stance has proven its suitability within manufacturing processes. However, the narrow focus of this method is somewhat unrealistic for the service industry particularly when considering the NHS A&E department, due to the nature of the services it offers, the inherent complexity of healthcare, and the lack of predictability. Alternatively, the business perspective advocated process improvements and linked to cost savings. The business perspective is a more holistic approach compared to the statistical stance and emphasises on improving the efficiency of all operations to meet the needs of the customer and further improve the performance. Therefore, the business perspective of Lean Six-Sigma fits better within the broad organisational objectives of service industries.

From the business perspective approach of Lean Six-Sigma, Harry and Schroeder (2000) define this as a process that facilitates improvement in the bottom lines of business by designing and monitoring everyday business activities in a way that minimises waste and resources while increasing customer satisfaction. Similarly, Sanders and Hild (2000) describe it as a management approach that fundamentally requires a change in organisational culture, which results in the improvement of service quality. The crux of these narratives is that customer satisfaction improves through enhancements in organisational processes and quality. These improvements are fundamental for any organisation operating in a dynamic environment, whether privately or publicly owned. Due to the ethical obligation of free health care at the point of use, the NHS makes these improvements imperative.

2.2 Lean Six-Sigma adoption in the service industry

The adoption of Lean Six-Sigma in the service industry is a practical and efficient solution, particularly in the healthcare. The anticipated benefits of adopting a Lean Six-Sigma approach in an organisation is, of course, dependent on the sector in which it is applied.

In its native environment, manufacturing, Lean Six-Sigma can yield a number of benefits including the reduction of in-process defect levels, maintenance and inspection time, quality, productivity, time to market, customer satisfaction and financial savings (Kwak and Anbari, 2006; Antony et al., 2007). It persistently aims to reduce process variation and eliminate non-value added activities similar to the Lean approach (Bancroft and Saha, 2016; Antony et al., 2007; Kwak and Anbari, 2004). Antony and Banuelas (2001) and Antony et al. (2007) explain how the perceived benefits cascade and connect, emphasising that it all begins with improved processes, which will ultimately lead to better customer satisfaction, increased efficiencies, greater market share, and improved financial performance.

If process improvement is the key to cascading to further benefits, then it is not difficult to predict that the adoption of Lean Six-Sigma in a service setting could generate similar benefits by improving the service process. Service organisations that have implemented Lean Six-Sigma as a managerial strategy have achieved a variety of benefits including the following (Antony et al., 2007; Antony, 2005; Kwak and Anbari, 2006):

- Reduction of non-value adding processes and activities;
- Shorter lead times;
- Quality improvements, leading to a decrease in costs associated with rework, scrap and returns;
- Increased awareness and knowledge of problem-solving tools and techniques;

- Less variability associated with processes; and
- Greater efficiency and effectiveness generally throughout the organisation due to improved organisation cohesiveness and increased reliance on data and facts.

Therefore, there is little doubt that adopting Lean Six-Sigma at the strategic level, whether within its traditional manufacturing setting from which it was born or the service sector, it has the potential to yield significant benefits even though a complex transformation is required. (Bancroft and Saha, 2016).

However, when considering Lean Six-Sigma in a service setting, there are additional challenges, arguably which may not be encountered in a manufacturing environment. Nakhai and Neves (2009) and Hensley and Dobie (2005) identify some specific problems when implementing Lean Six-Sigma in a service setting, including:

- The difficulty in collecting data;
- It is more complicated to measure, as the consumers and services interacting, adding uncertainty, which would not be evident in a manufacturing process;
- It is problematic to control;
- The reliability of data, due to the human component in services.

When considering the above from a healthcare specific viewpoint, these issues are likely to be exacerbated more so, due to the nature of the 'service' that it provides and the potential for unexpected outcomes and complexities. However, the relentless approach of Lean Six-Sigma can eliminate errors and aim for perfection in healthcare, (Kwak and Anbari, 2006). It is also important to note that the health sector should not be solely measured on the direct interaction with the patient, but also background activities such as processing lab tests and managing the appropriate inventory (Ettinger, 2001). However, this paper hypothesises that the adoption of Lean Six-Sigma in the A&E department will positively impact its performance. The A&E departments across the NHS become overcrowded during variations in temperature due to various ailments and injuries associated with heat waves and unusual cold snaps. The benefits of Lean Six-Sigma will be much more evidenced in the circumstances such as this.

2.3 Lean Six-Sigma and A&E performance

Contemporary literature suggests that the Lean Six-Sigma transformation is a positive direction for the NHS. However, it is essential that the approach is sustained and not viewed as a single journey (Bancroft and Saha, 2016; Bicheno et al., 2009; Gapp et al., 2008). The problematic situation (overcrowding, difficulty in achieving the 95% performance objective) of A&E is believed to be a fundamental quality and process issue upon which this paper is based on. Therefore, the use of Lean Six-Sigma would attempt to improve quality and efficiency from two different perspectives. In detail, Lean management focuses on the removal of waste or non-value added activities (Antony, 2011; Womack and Jones, 1996; Dahlgaard and Dahlgaard-Park, 2006; Slack et al., 2013) through quality improvements. On the contrary, the Six-Sigma approaches to improve organisational processes and output by reducing defects (Hoerl and Snee, 2012; Antony, 2006). Therefore Lean Six-Sigma fits to resolve the issues facing the A&E department well since non-value adding treatments and service defects are widespread across the NHS trusts in England. By identifying non-value adding treatments, we capture those health issues that are not an emergency or caused by any accidents. People with these types of health issues visit the A&E out of desperation because of the severe delays or unavailability of non-A&E services. Whereas service defects are primarily the result of overcrowding, staffing problems and lack of medical resources. Therefore, as shown in figure one below, it can be predicted that the adoption of Lean Six-Sigma will help A&E departments to deal with crowding issues and improve its performance enabling it to achive its 95% objecitve (A&E visitors to be treated within 4 hours), which concludes the first hypothesis of this paper below:

H1: The adoption of Lean Six-Sigma has a positive correlation with the performance of A&E departments.

2.4 Temperature affects the performance of A&E department

Previous reports also suggest that during winter and unseasonably cold periods the A&E department struggles to perform (Donelly, 2015; Campbell, 2015; Triggle, 2014a; Johnson, 2015; Haroon, 2015). It is not difficult to understand, that during colder temperatures those with weaker immune systems such as the elderly and children are more prone to illness. Therefore, increasing the number of visitors to A&E departments, which then result in a decrease of A&E performance. Of course, this is not to suggest that it purely cold weather that impacts A&E's ability to perform well, there is a myriad of other issues such as funding gaps (Pym, 2014; Triggle, 2014b) and greater strain on the system from increasing patient volume (Campbell, 2014). However, it is still reasonable and makes the analysis more accurate to consider the changes of weather temperature as an independent variable affecting A&E department performance. Therefore the second hypothesis flowing the conceptual model of this study in Figure 1 is:

H2: Weather temperature variation has a negtive correlation with the performance of A&E department.

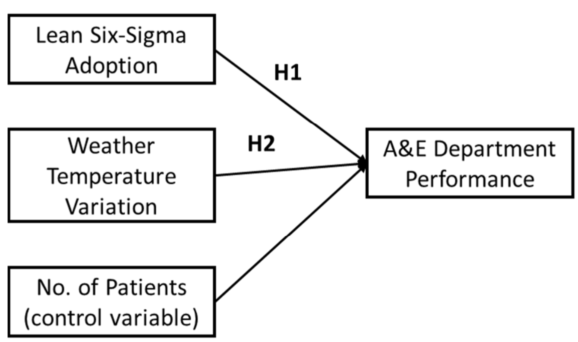

Figure 1 Conceptual Model

3. Research Methods

In order to test H1, an econometric model has been developed as shown in Figure 1 above. Lean Six-Sigma adoption will be measured by using a dummy variable for the full adoption of Lean Six-Sigma, which has been coded as "dummy" in table 1 . Weather Temperature Variation is measured by the average monthly temperature serves as the proxy for indicative overcrowding, which has been coded as "var2"; A&E department performance is measured by the percentage of A&E visitor treated ≤ 4 hours, which has been coded as ''var1''. Also, in order to improve the accuracy of the analysis, a control variable has been introduced and will be measured by the total number of people visited A&E (monthly), which has been coded as ''var 3'' in table 1. The model takes the form as below:

A&E Performance= number of people visiting A&E + temperature + Adoption of Lean Six-Sigma

The mathematical form of the model (i) and the transformed version (ii) are presented as:

$$var1_t = \beta_0 + \beta_1 \, var2_t + \beta_2 \, var3_t + \beta_3 \, dummy_t + e_t \text{--------------(i)}$$

$$lnvar_1 = \beta_0 + \beta_1 \, lnvar2_t + \beta_2 \, lnvar3_t + \beta_3 \, dummy_t + e_t \text{--------------(ii)}$$

The subscript $_t$ captures the time variance of the variable. The log transformation is applied to provide an approximate linear relationship between the dependent variable and the independent variables. The scatterplot matrix 1 in the appendix demonstrates that the data shows non-linear relationships. However, the scatterplot matrix 2 shows that the log transformation provides a roughly linear relationship between the *y* and *x* variables. The transformation also stabilizes the variation to a certain extent and facilitate better interpretation (Montgomery et al., 2012). In order to avoid any bias, we also present the regression outputs applying the square root transformation on the variables in appendix 2 and data in their original form in appendix 3. The results from appendix 2 and 3 correspond closely to the results presented in table 3.

To operationalise the model this paper analyses the weekly Accident and Emergency (A&E) data from January 2011 to June 2015. The weekly data measures the A&E department's efficiency in treating patients. The A&E department aims to treat 95% visitors within 4 hours or less which serves as the indication of its performance. Thus, data for the dependent variable is gathered. Temperature data is obtained from the Met Office, which provides the monthly mean temperature during the examined period. The positive impact of Lean Six-

Sigma in the health care sector is evidenced in the American and the Dutch cases which are the early adopters (Antony et al. ,2007). However, no performance data is available for the NHS concerning its adoption of Lean Six-Sigma. Therefore, inferring a likely impact of Lean Six-Sigma from the full adoption of Lean seems appropriate for this empirical study. We use a binary dummy for full adoption of Lean (McCann *et al.,* 2015). Quantitative data on the full adoption of Lean is not available in the public domain. Therefore, the indicative year when Lean was first adopted provides an intuitive observation of full adoption. A score of 1 indicates full adoption of Lean whereas a score of 0 indicates the opposite. Use of alternative data to resolve unavailability related issues is common in empirical research (Gleditsch, 2002). The total number of A&E visitor serves as the control variable in the model. A regression model based predictive analysis is performed to assess if A&E's ability or inability to meet their 95% performance objective is linked Lean Six-Sigma in relation to variation in temperature. The variables, their measurement, the source of data and the manipulation techniques applied to operationalise the model is presented in table 1.

Table 1. **Data Description[1].**

Variables	Coding	Measurement	Data Source	Manipulation
A&E Department Performance	var1	A measure of A&E efficiency	NHS	Data is derived from percentage of A&E visitor treated ≤ 4 hours, and log naturalised
Weather Temperature Variation	var2	Average monthly temperature serves as the proxy for indicative overcrowding	Met Office	273.15 added to each data point to convert the scale to Kelvin from Celsius, and log naturalised
No. of Patient	var3	Total Number of people visited A&E (monthly)	NHS	Data is derived from a percentage of A&E visitor treated ≤ 4 hours, and log naturalised
Lean Six-Sigma Adoption	dummy	Full adoption of Lean	McCann et al. (2015)	Value of 1 is imputed for years when Lean was fully adopted, otherwise 0

[1] Data transformation and manipulations are explained in Appendix.

4. Discussion

Table 2 **Descriptive Statistics**

	Obs	Mean	Std. Dev.	Min	Max
var1	55	83297.12	31490.56	40519.04	170884.5
var2	55	283.0409	4.605965	273.15	291.55
var3	55	1823679	214976.4	1547196	2246955
dummy	55	0.5636364	0.5005048	0	1

Table 2 **Results:**

lnvar1	OLS	t ratio	ROLS	t ratio
lnvar 2	-9.46	-5.55	-9.11	-5.27
	(1.70)		*(1.73)*	
lnvar3	1.27	5.24	1.34	5.46
	(0.24)		*(0.25)*	
dummy	0.42	7.69	0.41	7.39
	(0.05)		*(0.06)*	
_cons	46.20	4.77	43.21	4.4
	(9.69)		*(9.82)*	
Adj R-squared	0.68		0.67	
R-squared	0.69		0.69	
Obs	55.00		55.00	

Note: Regression results are based on *P< 0.05. The standard errors are in parenthesis. Highest and Mean VIFs are 1.03 and 1.02 respectively.*

The results demonstrate (Table 2) that the model is a good fit as the adjusted R-squared value is 0.68. The variable inflation factor (*VIF*) test is performed to check for multicollinearity, and the result (1.03) shows that the data set does not suffer from the issue of multicollinearity. We have also applied the robust OLS (ROLS) estimator to control for autocorrelation since this estimator efficiently deals with autocorrelation problems. Thus, we have avoided the likely bias in the coefficient provoked by the log-linearisation of the variables. The adjusted R-squared value from the Robust OLS (0.67) is close to the OLS estimation and determines the model's right fit.

The estimation shows that a unit increase/decrease in temperature leads to a performance decrease of 9.46% in A&E. The *t* ratios (OLS 7.69; ROLS 7.39) presented in table 3 suggests the dummy variable is the most important variable in the model. Therefore, the results demonstrate that the full adoption of Lean can have a significant positive impact (42%). Although the NHS is a late adopter of Lean, the benefits are increasingly evidenced. However, the large magnitude of the coefficient for lnvar3 (OLS 1.27; ROLS 1.34) indicates that A&E performance is very much reliant on their optimum capacity of treating people. The unusual increase in patient numbers will almost certainly have a significant impact on how the NHS treats its patients. As we have previously discussed an ageing population, sustained budgetary pressures, coupled with skill shortages will undoubtedly increase the scale of the problem. A Lean strategy can only deliver optimal performance when there are trained personnel and state of the art medical facilities are available. It would be an utter fallacy to assume that by adopting a Lean strategy the NHS can perform at the expected level without sufficient budget.

From the analysis above of the impact of Lean on the NHS as a justification to discuss Six-Sigma as a means to complement the existing Lean approach. Therefore, drawing on the positive results that Lean adoption has produced we infer that Six-Sigma will also benefit the A&E departments. Taner et al. (2007) explain that Six-Sigma focuses on "developing and delivering near-perfect services" and in a healthcare environment could lead to the followed benefits being realised:

- Safer care;
- Quicker care;
- Better coordinated care;
- Fewer mortalities;
- Better responses to patient needs;

- More efficient utilisation of resources.

Antony et al. (2006) suggest that Six-Sigma in a healthcare environment has some potential applications and can be used across a wide-array of processes and activities. Improving accuracies, reducing errors, increasing capacities, improving patient satisfaction, reducing waiting times, reducing inventory levels, improving employee retention and productivity of employees.

With recent reports suggesting that during the 2016 winter period at times almost 25 percent of A&E patients have had to wait more than four hours – far away from the 5 per cent or less, it aims for (Kirkland and Triggle, 2017). It is clear that the NHS continues to struggle during winter months, and Six-Sigma can improve a variety of processes and activities within a healthcare setting, improve patient satisfaction, drive productivity improvements, reduce costs and waiting times.

However, it is important to remember with this statistics, that we are considering human beings and unlike processes, they are not so predictable. More variables could also be added to further our understanding of the influences of the independent variable, such as exploring the type of A&E admission, e.g. major and minor and how this relates to the number of patients seen in four hours or less. Also, use of primary survey data on performance for econometric analysis would surely add to the rigour of future studies.

5. Conclusions

The data analysed builds on previous work (Bancroft and Saha, 2016), this time further investigating the NHS and it is A&E departmental woes. In this paper, the time of year variable (month number), has been exchanged with the average monthly temperature in England, as recorded by the Met Office. The issues the NHS is facing have not changed during the past two years. The A&E arm of the organisation is failing to consistently meet its performance objective to see 95 percent of patients in four hours or less. An ageing and growing population is adding further pressure to an already strained system, coupled with a funding gap, which is forecast to skyrocket over the next five years (Leys, 2014; Donnelly, 2016). Although our analysis is based on robust results, there are limitations as the current estimation model has not captured the impacts of management changes over time, which can considerably impact the outcome of Lean and Six-Sigma adoption. We envisage to counter the limitations in our follow up works. However, it is clear that the NHS must focus on process improvements and continue with their productivity drives in an attempt to lessen the blow of the myriad of factors conspiring against the large health care provider (Bancroft and Saha, 2016).

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Appendices

Appendix 1

Figure 2 Scatterplot matrix before log transformation

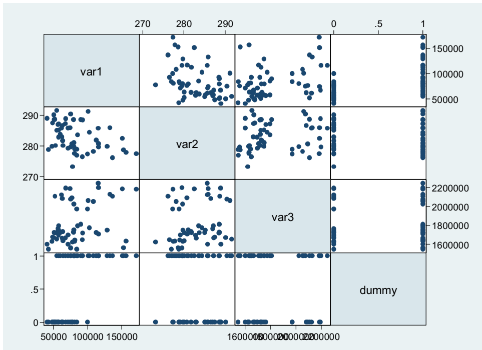
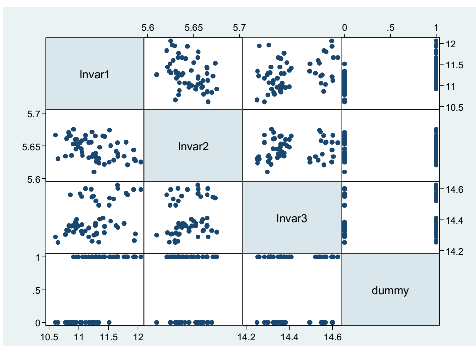


Figure 3 Scatterplot matrix after log transformation

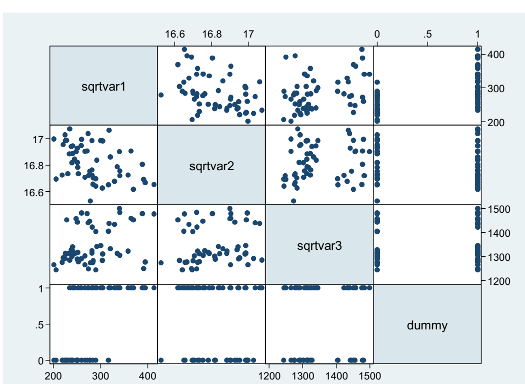


Appendix 2

The mathematical form of the model applying the square root transformation

sqrtvar1 $= \beta_0 + \beta_1$ sqrtvar2 $+ \beta_2$ sqrtvar3 $+ \beta_3$ dummy +e --------------(iii)

Figure 3 Scatterplot matrix after square root transformation



OLS Results:

Source	SS	df	MS	Number of obs	55.00
				F(3, 51)	34.55
Model	97765.02	3.00	32588.34	Prob > F	0.00
Residual	48106.56	51.00	943.27	R-squared	0.67
				Adj R-squared	0.65
Total	145871.58	54.00	2701.33	Root MSE	30.71

sqrtvar1	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
sqrtvar2	-163.61	30.99	-5.28	0.00	-225.83	-101.39
sqrtvar3	0.27	0.05	4.94	0.00	0.16	0.38
dummy	60.08	8.37	7.18	0.00	43.28	76.89
_cons	2642.73	515.03	5.13	0.00	1608.75	3676.70

ROLS Results

Robust	regression	Number of obs.	55.00
		F(3, 51)	37.14
		Prob > F	0.00
		R2	0.67
		adjusted R2	0.65

sqrtvar1	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
sqrtvar2	-151.57	30.34	-5.00	0.00	-212.48	-90.66
sqrtvar3	0.29	0.05	5.45	0.00	0.18	0.39
dummy	57.22	8.20	6.98	0.00	40.77	73.68
_cons	2411.70	504.22	4.78	0.00	1399.44	3423.95

Appendix 3

The mathematical equation of the model with data in their original form

$$\text{var1}_t = \beta_0 + \beta_1 \text{var2}_t + \beta_2 \text{var3}_t + \beta_3 \text{dummy}_t + e_t \text{--------------(i)}$$

OLS Results:

Source	SS	df	MS	Number of obs	55.00
				F(3, 51)	29.49
Model	33970000000.00	3.00	11323000000.00	Prob > F	0.00
Residual	19579000000.00	51.00	383910928.00	R-squared	0.63
				Adj R-squared	0.61
Total	53549000000.00	54.00	991655264.00	Root MSE	19594.00

var1	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
var2	-2898.30	587.10	-4.94	0.00	-4076.94	-1719.65
var3	0.06	0.01	4.59	0.00	0.03	0.08
dummy	35045.43	5340.68	6.56	0.00	24323.58	45767.28
_cons	778717.20	164380.60	4.74	0.00	448709.30	1108725.00

Number of obs	55.00
F(3, 51)	30.40
Prob > F	0.00
R2	0.64
adjusted R2	0.62

var1	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
var2	-2456.94	537.80	-4.57	0.00	-3536.61	-1377.27
var3	0.06	0.01	5.46	0.00	0.04	0.09
dummy	31405.07	4892.21	6.42	0.00	21583.56	41226.59
_cons	644374.10	150577.20	4.28	0.00	342077.80	946670.40