Measuring Carbon Efficiency

Environment 180C—Chen, C.M.

May, 2011

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Table of Contents **Page Number**

Abstract

There is currently no standardized system of comparing production companies on their business and environmental practices. In an effort to fill this gap, this research project creates a standard called the eco-efficiency frontier on which to compare company's progress towards creating more goods and services while using fewer resources and creating less waste – in other words, being eco-efficient. We examine ten food manufacturing companies over the time span of three years to gauge their level of efficiency in comparison to each other. We then examine other financial information from all the companies to draw potential relationships between company operation processes and eco-efficiency scores. Our project yields interesting results and suggests that beverage companies may be more eco-efficient than other types of food manufacturing companies. Our eco-efficiency model has the potential to be applied to many different industries using different financial variables and can bring to light many interesting relationships and information that can be used to help all companies reach eco-efficiency.

Introduction

Since the Industrial Revolution, there have been new breakthroughs in understanding the impact of human pollution on the environment. This has led to a greater understanding of environmental sustainability within our society, as well as a greater emphasis on implementing sustainable practices in industries that have been heavy sources of pollution in the past. Increased public awareness and concern over the effects of pollution have led many businesses to consider ways to improve their image by incorporating environmentally friendly practices that are also economically viable. An environmentally friendly change can be economically viable if it is more efficient than the practice that was previously in place (Andrews 2006). Defining eco-efficiency and finding a way to measure it has proven to be difficult. There have been several different approaches and methods proposed to define what is considered "efficient."

Generally, efficiency means producing the maximum number of benefits with the least consequences. Eco-efficiency has a slightly different meaning illustrated throughout this text. Many industries produce different types of products that generate carbon emissions. These carbon emissions generated by various facilities are measured into their efficiency scores to further develop solutions necessary. Furthermore, it is significant to have all the industrialized companies with measured eco-efficiency score to make sustainable progress in optimizing the notion of being environmentally friendly. We collect the input and output data used in the analysis of eco-efficiency from two databases : Carbon Disclosure Project (CDP) and Standard & Poor's Compustat. We focus on companies in the food and beverage sector according the 3 digits NAICS (North America Industry Classification System: code: 311 and 312). The samples chosen for the given databases were Campbell Soup Company, Coca Cola Company, Dean Foods, General Mills Inc., H. J. Heinz Company, Kellogg Company, Kirin Holding Company

Ltd., Kraft Foods Inc., PepsiCo Inc., and Sara Lee Corporation. The resultant data from these companies are then transferred to the efficiency model to calculate the eco-efficiency frontier, which indicates the maximum economic outputs and minimal pollution levels associated with each firm's current resource consumption level.

This research project investigates the relationship between different production company's carbon emissions and their economic productivity. Using several indicators of these two variables, our goal is to generate eco-inefficiency/efficiency scores (eco-score) using the optimization model discussed later in this report. Specifically, we try to find a correlation between a company's gross profits, cost of goods sold, number of employees and Scope 1 and 2 carbon emissions (definitions of emission scopes will be provided later in this report). We have chosen to limit our research project to only focus on food and beverage companies in North America as previously stated, but our methodology can theoretically be applied to different industries in different regions of the world.

Literature Review

There have been several attempts to define eco-efficiency and what it entails. According to one source, it can be thought of "as the economic value a company creates relative to the waste it generates" (Derwall et al. 2005). Another source states the definition as "a general goal of creating value while decreasing environmental impact" (Huppes and Ishikawa 2005). The source further breaks down eco-efficiency into four categories; environmental productivity, environmental intensity, environmental improvement cost, and environmental cost-effectiveness. Environmental productivity is the production value per unit of environmental impact, environmental intensity of production is the environmental impact per unit of production value, environmental improvement cost is the cost per unit of environmental improvement, and environmental cost-effectiveness is the environmental improvement per unit of cost (Huppes and Ishikawa 2005).

Another definition provided by the World Business Council for Sustainable Development (WBCSD) is "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity" (Verfaillie and Bidwell 2000). These definitions are very similar and revolve around the basic idea that being eco-efficient means benefitting the environment while still being productive. Eco-efficiency cannot always be represented by hard data so many difficulties arise when attempting to measure it. Defining "efficiency" is very subjective and often left up to the beliefs and interests of the researchers.

Different representations of defining eco-efficiency are seen in the creation of various models. For instance, one type of model can be based on defining eco-efficiency as minimizing negative outputs. This can be portrayed through the pricing of variables. All outputs are defined in terms of monetary value, and if no market prices exist for an output, a shadow price can be used. This reduction approach can also be correlated with a quantity based model, which seeks to define outputs by the quantity produced from a given level of input. Undesirable outputs, such as pollution and greenhouse gas emissions, can be measured by the quantity that was generated, rather than attempting to monetize these factors (Färe et al. 1989). These are just a few examples of the different ways eco-efficiency can be represented and measured. Models have the ability to visually represent eco-efficiency and can be an important monitoring tool for companies to manage their eco-practices.

Real life application of these approaches can be seen in analyzing the production process of a business, such as a paper manufacturing plant (Färe et al. 1989). In Färe et al. (1989), production components, including the amount of paper, energy, capital, and chemical resources, are measured as inputs. The amount of paper produced and the amount of different types of pollution generated from this production are considered as outputs. These factors are incorporated into a mathematical model in order to calculate environmental efficiency scores. These quantities can also be translated into monetary value in order to determine revenue loss for the firm that produced them. The goal of the firm is to maximize profits and minimize pollution. This maximization is translated into eco-efficiency through modeling. It shows that minimizing the quantity of pollution outputs produced will maximize profits because pollution directly translates into revenue loss (Färe et al. 2007). The model assumes that the disposability for these undesirable outputs is weak, meaning they are difficult to get rid of.

This incorporation of pollution abatement factors has been implemented in mathematical models of eco-efficiency. In order to directly measure the difference that is caused by implementing environmental regulations, these models must also take into account the production that would occur in an unregulated environment. This is needed in order to determine how these regulations influence desirable outputs. It is possible for regulations to cause a shift in an industry's behavior so that less undesirable outputs are generated, but a loss in desirable output production can occur as well. According to Färe et al. 2007, if this loss of production is greater than the reduction of undesirable outputs, then the effects of regulation are not eco-efficient.

Research that seeks to define some sort of standard for measuring eco-efficiency has all revolved around creating a mathematical model. These models take input variables, such as the resources used and production levels of goods, and generate values that attempt to define the outputs generated from these inputs. For example, Charnes et al. (1978) developed the Data Envelopment Analysis (DEA) model. The DEA model has been widely used to measure efficiency. After the publication of Carnes et al. in 1978, there was research done to extend the idea and develop the DEA model to satisfy market conditions. The researchers helped to apply DEA to several industries includes emission analysis, operation analysis including banks, schools, and retailers, and funds' portfolio management analysis.

Data Envelopment Analysis is another general performance evaluation method that can be applied to measure eco-efficiency. It focuses more on production units than specific industrial firms. DEA emphasizes a social point of view as opposed to a managerial point of view. Its general formula is $\frac{Economic\ Value\ Added}{Environmental\ Damage}$ (Kuosmanen and Kortelainen 2005). Eco-efficiency is expressed as $EE_n = \frac{V_n}{D(Z_n)}$, where n represents the production unit, EE_n is the eco-efficiency, V_n is the economic value added, and D (Z_n) is the environmental damage index. The maximum eco-efficiency score is 100% or one (on a scale of zero to one).

The efficient frontier is mapped against two different environmental pressures. A production unit is eco-efficient if it is impossible to decrease any environmental pressure it generates without simultaneously increasing another environmental pressure or decreasing the economic value added (Koopman 1951). One of the advantages of the DEA model is its ability to take into account substitution possibilities between environmental pressures. The frontier does not have an assigned value because it treats all environmental pressures according to the evaluated firm's strength and weakness in environmental performance. Production units that land above the curve are eco-inefficient and can still reduce their environmental by-products without stifling economic activity. Their radial distance from the curve is an indication of how much the production unit can achieve with the best practicing technology. See Figure 2 for an illustration for the co-efficiency frontier.

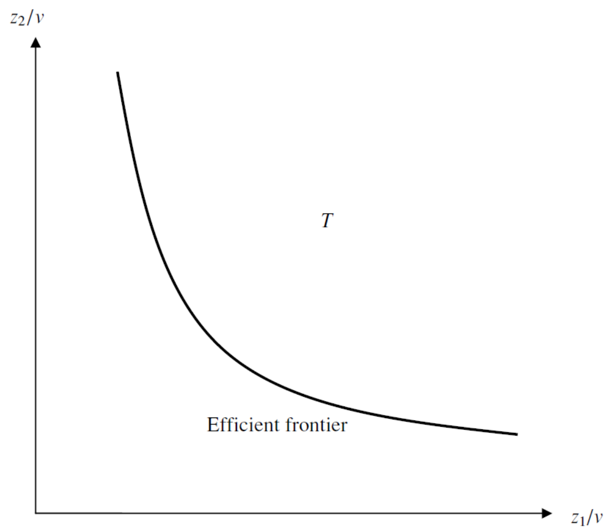


Figure 2: The DEA model efficient frontier. *T* represents the efficient technology set. $\frac{Z_1}{v}$ and $\frac{Z_2}{v}$ represent different environmental pressures (Kuosmanen and Kortelainen 2005).

In the models previously discussed, the eco-efficiency concept was defined as a relative concept. Firms would be eco-efficient if their undesirable outputs and resource utilization was low *relative* to the amount of goods that they were producing. Under this definition, eco-efficient firms can still produce a significant amount of undesirable outputs in the form of pollution if their scale of operation is high. If they still manage to produce a significantly greater amount of goods in comparison to the pollution they generate, a firm can fall under the category of being eco-efficient. But when it comes to the environment, things like natural ecosystems cannot be looked at in the same manner. Ecosystems and natural habitats have a definitive and finite amount of pollution they can endure before they are irreparably damaged or destroyed. Firms that produce pollution levels higher than these thresholds therefore are not being sustainable. Their production processes are still destructive and unsustainable of the natural environment surrounding them (Kuosmanen et al, 2005). The natural environment that is being destroyed can be a source of resources as well; its destruction could then negatively impact the needed inputs of another firm or industry. This is something that must be considered when it comes to defining eco-efficiency: whether it should be expanded to include ecological impacts and environmental sustainability, or left primarily as a means to compare direct inputs and outputs for productivity.

Eco-efficiency has also been analyzed in terms of government regulations that attempt to push firms into more environmentally friendly practices. The actions of the government can be seen as external factors that will impact the behavior of firms by influencing the costs of certain inputs and outputs. A notable factor that has been impacted by the government is carbon dioxide. Carbon dioxide emissions are viewed as negative pollution outputs because they are greenhouse gases that contribute to global warming. Various local government agencies have imposed regulations that seek to limit the output of carbon dioxide by firms. In light of this, several models have been proposed that incorporate the economic impact these regulations have on production. These impacts can then be used to determine whether regulations are effectively pushing firms towards being more eco-efficient. Regulations can have a significant impact on the economy in terms of pollution taxes and permits. Thus, they can influence the value of inputs and outputs that become costs for the firm. If the firms' responses to these regulation-influenced values forces them to adopt more environmentally friendly practices in order to optimize their profits, then the regulations can be deemed as eco-efficient. Policymakers and industry leaders must be able to assess and interpret these relationships in order to make informed decisions that will optimize their productivity. These models are made under the assumption that leaders will act in a manner that is best for their interests, and this is why their representation is essential to defining eco-efficiency (Cleveland 1984).

Based on current literature pertaining to the topic of eco-efficiency models, it can be concluded that significant headway has been made in terms of relating environmentally friendly practices with economic production and profitability (Huppes et al., 2005). The fundamental concept of eco-efficiency based on these models can be portrayed in three aspects: reducing the amount of resources that we use from the Earth (reducing inputs), reducing the amount of pollution that we emit onto the Earth (reducing undesirable outputs), and increasing the amount of products that can be made through our industries (increasing desirable outputs, which are goods.)

Yet a deeper analysis of this portrayal reveals that attempts to define this concept on a broad, inclusive scale has proven to be very challenging. One of the biggest issues has been the lack of clarity when it comes to defining the variables that influence eco-efficiency. Variables such as non-disposable negative outputs are able to be further differentiated into more specific categories, and these have yet to be incorporated and accounted for in eco-efficiency models. Other challenges include the inability of these models to create performance benchmarks that can stand on their own (without using industry leaders as a standard) and the necessity to expand upon how eco-efficiency defines sustainability from an ecological perspective. The goal for future developments in measuring eco-efficiency should focus on frameworks that can be applied to a broad range of companies and are relatively simple in calculations. They should place a greater effort on showcasing companies that provide a balanced set of environmental performance indicators, instead of ones that excel in a specific area. Measuring eco-efficiency is a widely debated topic in today's growing environmentally conscious society and will continue to be a work in progress.

Methodology

In order to better focus on the different approaches that this project requires, we decided to divide our project group into two teams (Data Team and Tech Team). These two teams allow us to concentrate on taking different approaches in order to reach our objectives for this project.

<u>Data Team</u>

The data team is the larger of the two teams, and it consists of 6 of the 8 members of the group. This team requires more manpower in order to effectively acquire and analyze the large databases we are using for this project.

<u>Role of data and teach teams</u>

The data team's primary role is to search for and analyze corporate data found on two databases, the Carbon Disclosure Project (www.cdproject.net) and Compustat. Each database contains information on companies within different industries. This information varies, as some companies choose to disclose more facts than others. Tech team is responsible of calculating the eco-efficiency scores, as well as producing the 3-d graphics.

<u>Database Background</u>

1) Carbon Disclosure Project (CDP)

The CDP is a database that began in 2000 with the intent of publicizing corporate information which would encourage environmental responsibility and climate change solution development. As of today, there are roughly 3,000 organizations in 60 countries around that world that have agreed to measure and make public (disclose) data such as greenhouse gas emission totals and business strategies for counteracting climate change. The CDP is run by a non-profit independent organization, and is the largest database in the world of its kind (Carbon Disclosure Project 2009).

The CDP receives several types of response from companies that wish to disclose their information. The two types of reports we focused on were the Supply Chain Response and the Investor Response, described below. It is important to note, however, that there are limitations in the data that has been collected from these companies. CDP data are self-reported emissions that are estimated values, and therefore there is no guarantee about the quality of the reported figures.

A. Supply Chain Response

Companies that have already or are beginning to incorporate carbon management strategies into their supply chains join the CDP Supply Chain Program and release information via a Supply Chain Response questionnaire. For this project, the data team will be utilizing Supply Chain Responses from the companies that it selects.

B. Investor Response

Companies that wish to release financial and emissions data in order to provide information for potential investors respond via a CDP Investor Response questionnaire. This information is then compiled into a yearly report and presented throughout the global market, as well as to a large group of investor companies who are signatories to CDP's information request for that year. In 2010, there were 534 investing institutions that signed and requested CDP Investor Responses, and their total assets were estimated at $64 trillion (Carbon Disclosure Project 2009).

2) Standard & Poor's Compustat

Compustat is a standardized database that is maintained by Standard & Poor's Investment Services. Data is first collected from a diverse set of undisclosed sources in a wide variety of formats. This information is then standardized and checked for validity in accordance to stringent conditions outlined by the Financial Accounting Standards Board (FASB) and the Securities and Exchange Commission (SEC). This standardized data is guaranteed to be accurate and comparable across different companies, industries, and time periods. Compustat North America is a database consisting of information procured from U.S. and Canadian market businesses. It currently holds more than 24,000 publicly held companies with information on financial aspects such annual/quarterly income, cash flows, and balance sheets (Capital IQ Compustat 2011).

Selecting Companies and Industry

Companies are listed in these databases according to their industry. For our project we have selected companies within the food and beverage industry. Companies within specific industries are grouped together based on their North American Industry Classification System (NAICS) code. Food and beverage companies are listed as 311 and 312, respectively.

The data team is responsible for searching both databases within the food and beverage industry and selecting companies that have filed reports for the years 2007-2010 in *both* databases. For the purposes of this project we will be selecting 20 companies with the most complete reports on file for each of these four years.

Input, Output, and Contextual Variables

The data found on both the CDP database and Compustat database vary, and together they provide a number of input and output variables that we can select for use within our eco-efficiency model. For this project the data team will be looking for complete data on companies that pertain to the following variables:

Input Variables: number of employees, cost of goods sold

Output Variables: Gross profits, Scope 1 and 2 CO_2 emissions per year

Scope 1 emission is direct emission from producing products. Scope 2 emission is indirect emission from consumption of electricity, heat and steam by firms.

Contextual variables: research and development expenses, operating profits, index of foreign operations, value-added ratio

The Compustat North America database contains a wide variety of financial contextual variables which may pertain to eco-efficiency. The data team is also responsible for analyzing these variables within the Compustat data.

1) Examples of Contextual Variables within Compustat found by the Data Team

a. *R&D Expense* - How many resources a company is investing into R&D for more efficient production.
b. *Gross Profit* – This value is what remains of the company's total revenue once all operating expenses have been subtracted.
c. *Index of Foreign Operations* – a calculated measure that indicates the internationalization of the firm. This value is defined as the ratio of foreign income over total sales.
d. *Value-Added Ratio* - measures the level of vertical integration (or outsourcing). A low value indicates the firm itself adds little economic value to its commodities, so the firm is not highly integrated and potentially has lots of suppliers. This ratio is calculated as follows:

$$\text{Value-added ratio} = \frac{(\text{interest expense} + \text{depreciation expense} + \text{rental expense})}{(\text{Sales} - \text{gross profit} - \text{total income tax})}$$

Interest expense: The total value of all periodic expenses related to a company's short- and long- term debt

Depreciation Expense – The value that a company deducts from its assets as a result of depreciation every year. If an asset worth $50.00 were to depreciate at 10% a year, the depreciation expense after the first year would be 10% of $50.00 or $5.00 – this expense is subtracted from the asset's value of $50.00 before the next year's depreciation rate is applied.

Rental Expense – All of a company's expenses related to the costs of renting, leasing, or hiring of space and/or equipment.

Sales – the total amount that has been billed to customers reduced by discounts given to customers, returned sales, and customer credit

Total Income Tax – represents the total amount of taxes imposed on a company by federal, state, and foreign governments.

<u>Data Analysis and Frontier Calculation</u>

Once companies with the adequate amount of reported information are found and selected, the data team will extract and compile the data that pertains to the input and output variables we will be using for our eco-efficiency model. The data is turned over to the tech team which will enter the information into the eco-efficiency model and generate eco-efficiency scores.

The tech team will use Lingo, an optimization modeling software that solves linear, nonlinear, quadratic, quadratically constrained, second order cone, stochastic, and integer optimization models, to determine the most optimal input and output combination and generate the eco-efficiency frontier. The eco-efficiency mathematical formula has already been determined from previous studies (Chen et al. 2010). The eco-efficiency model is shown below:

$$E(x, d, u) := \max \frac{1}{N + P}\left(\sum_{n=1}^{N} \frac{\tilde{g}_n^d}{d_{1n}} + \sum_{p=1}^{P} \frac{\tilde{g}_p^u}{u_{1p}}\right)$$

$$\text{s.t.} \quad \sum_{k=1}^{K} Z_k x_{km} \le x_{1m},\ m = 1, \ldots, M$$

$$\sum_{k=1}^{K} Z_k d_{kn} = d_{1n} + \tilde{g}_n^d,\ n = 1, \ldots, N$$

$$\sum_{k=1}^{K} Z_k u_{kp} = u_{1n} - \tilde{g}_p^d,\ p = 1, \ldots, P$$

$$Z_k \ge 0, \tilde{g}_n^d \ge 0, \tilde{g}_p^d \ge 0, \text{for all k, n, and p}$$

Where k: number of firms

x_{km}: input used to produce desirable output

d_{kn}: desirable output

u_{kp}: undesirable output

$\tilde{g}_n^d$: correction value to reach maximum efficiency in terms of desirable output

$\tilde{g}_p^u$: correction value to reach maximum efficiency in terms of undesirable output

M: number of input used to produce desirable output

N: number of desirable output

P: number of undesirable output

Companies "on" the frontier have the highest gross profit relative to cost of goods sold, with the lowest Scope 1 and 2 emissions. The frontier will in turn be used to calculate the relative eco-efficiency of all the other firms. Scores of 0 indicate the most efficiency. The value of all other scores indicates the distance from the eco-efficiency frontier and thus how *inefficient* a company's operations are. For example, if two firms (Company B and C) have maximum efficiency in a group of three firms (Company A, B, and C), the relationship of each company is shown in Figure 2. Company B and C forms an efficiency frontier in this case. Company A will be on the efficiency frontier if the firm decreases its CO_2 emissions and increases its gross profit.

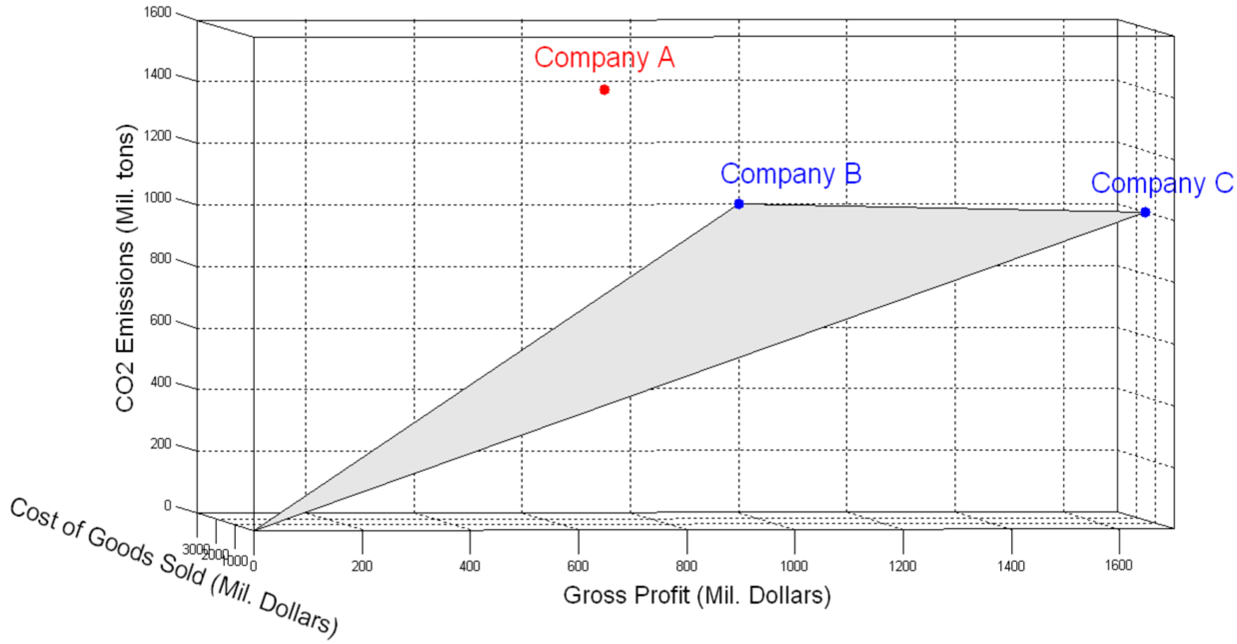


Figure 1. Example of eco-efficiency model in 3D plot.

In this example, Company B and Company C are most efficient in the group. Those two companies form an efficiency frontier. Company A is not relatively efficient.

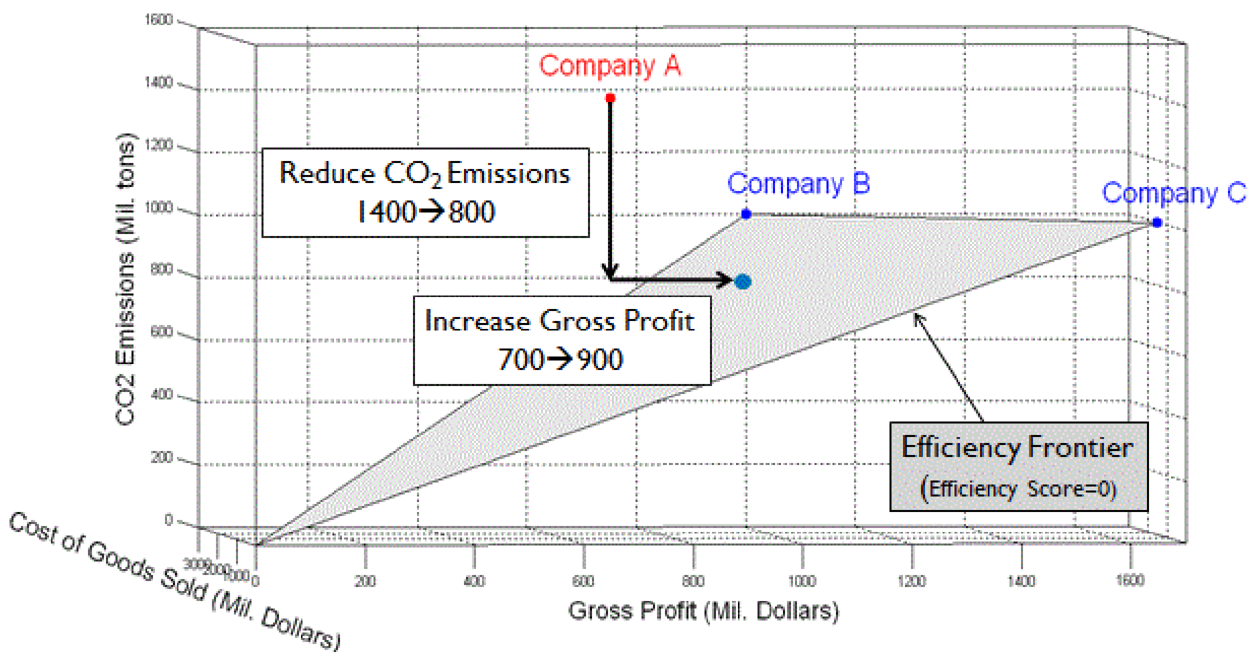


Figure 2. Example of how much Company A would have to reduce CO2 emissions and increase their gross profit in order to be on the efficiency frontier

After computing the scores, the tech team will use MATLAB, is a programming language which will help data visualization in 2D and 3D, to graphically represent the eco-efficiency frontier and all company's positions in relation to this benchmark target. The above graphs are examples that were generated using the MATLAB program and similar graphs will be produced with the data used in our project.

Results

In order to maintain consistency, we could only use data of companies for which we had complete emissions and financial data from 2008 to 2010. This narrowed our sample size to ten companies:

- Campbell Soup Company
- Coca Cola Company
- Dean Foods
- General Mills, Inc.
- H. J. Heinz Company
- Kellogg Company
- Kirin Holdings
- Kraft Foods Inc.
- PepsiCo, Incorporated
- Sara Lee Corporation

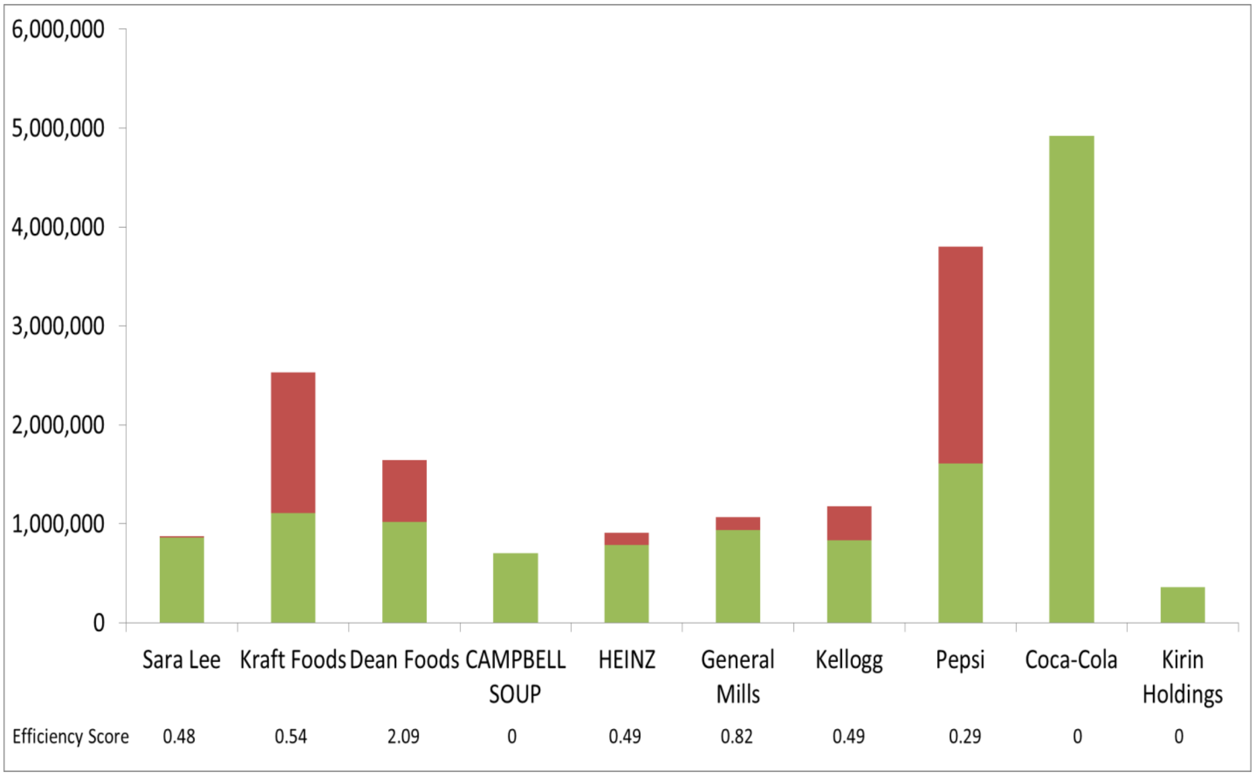
We chose to use gross profits, cost of goods sold, and CO_2 emissions as our variables. We ran the two through to separate models. The first model was run using only one year of company data, and was run for every year. The second model was run using all three years of data. This was done so that we could compare the results to see if companies that were efficient in 2008 were still efficient when compared to companies in 2009 and 2010. After the models were run, the data from the combined model was used to check for correlation between R&D expense/sales, eco-score, and gross profit.

Eco-Efficiency Scores	2008 Score	2009 Score	2010 Score	Average Score
Campbell Soup Company	0	0	0	0
Coca-Cola	0	0	0	0
Dean Foods	2.089	1.447	2.155	1.897
General Mills, Inc.	0.821	0.589	0.76	0.723
H. J. Heinz Company	0.486	0.538	0.515	0.513
Kellogg Company	0.486	0.429	0.59	0.502
Kirin Holdings	0	0.309	0.749	0.353
Kraft Foods Inc.	0.536	0.516	0.425	0.492
Pepsi	0.288	0.303	0	0.197
Sara Lee Corporation	0.483	0.569	0.48	0.511
Average	***0.5189***	***0.47***	***0.5674***	***0.519***

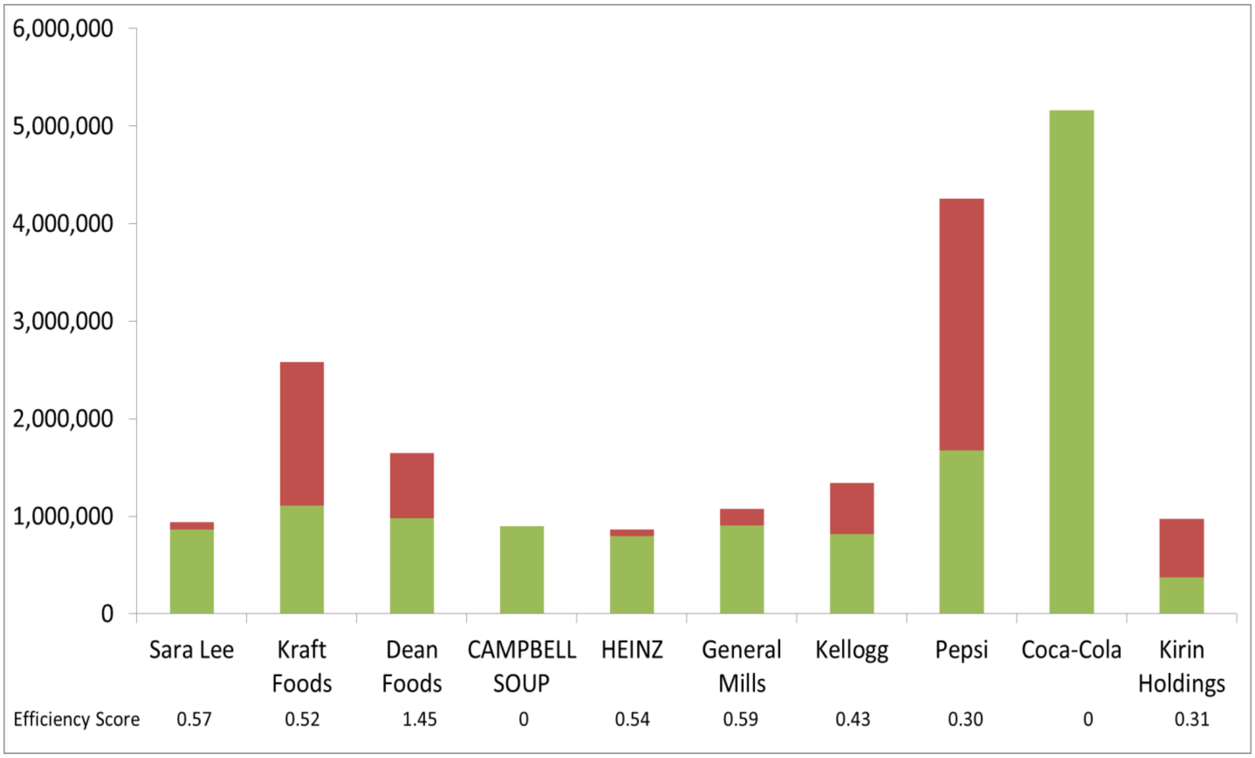
Figure 3. Eco-efficiency scores across all three years (based on the single year model).

The single year model yielded four efficient companies in 2008, five companies in 2009, and four companies in 2010. Coca-cola, Pepsi, and Campbell were efficient across all three years. In the single year model, the average eco-score for the year does not decrease with time as was expected. The score jumps from 0.34 to 0.16 and then up to 0.56. In the single year model of those five companies, only Pepsi, Coca-cola, and Campbell increased their efficiency or remained efficient. Kraft and General Mills were very inefficient in the single year model.

2008 Eco-efficiency Scores



2009 Eco-efficiency Scores



2010 Eco-efficiency Scores

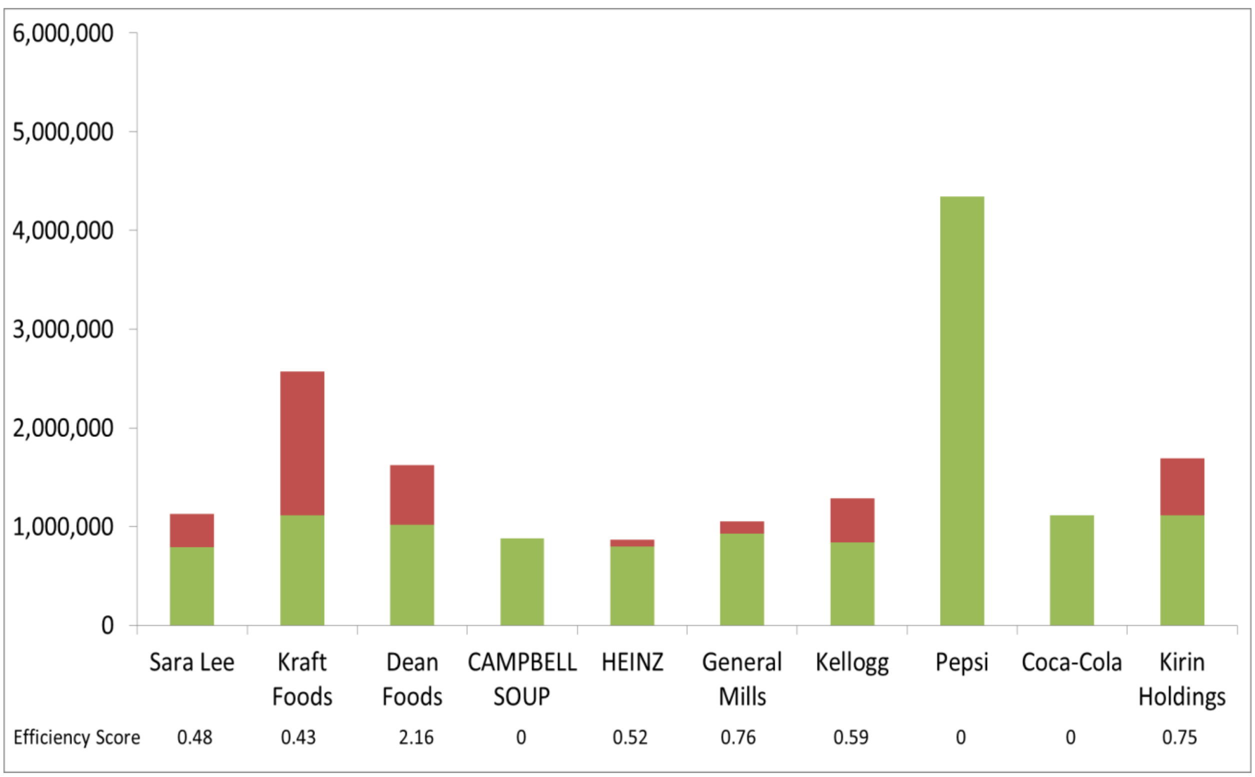


Figure: Eco-efficiency score bar charts for 2008, 2009, 2010.

The combined model yielded three efficient companies in 2008, two companies in 2009, and two companies in 2010. In the combined model Coca-cola and Campbell were the only companies that were efficient across all three years. For the combined model the average yearly scores range from 0.52 to 0.47 and then back up to 0.57 with the total average for all of the years being 0.52. In the combined model Coca-cola, Campbell, Kraft, General Mills, and Pepsi all increased their efficiency or remained efficient across the three year period.

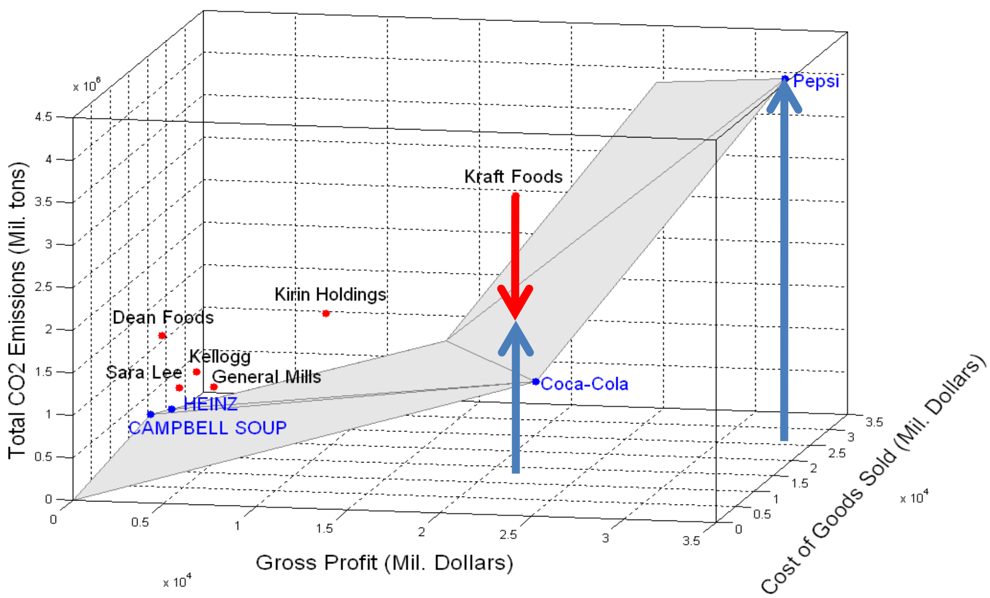


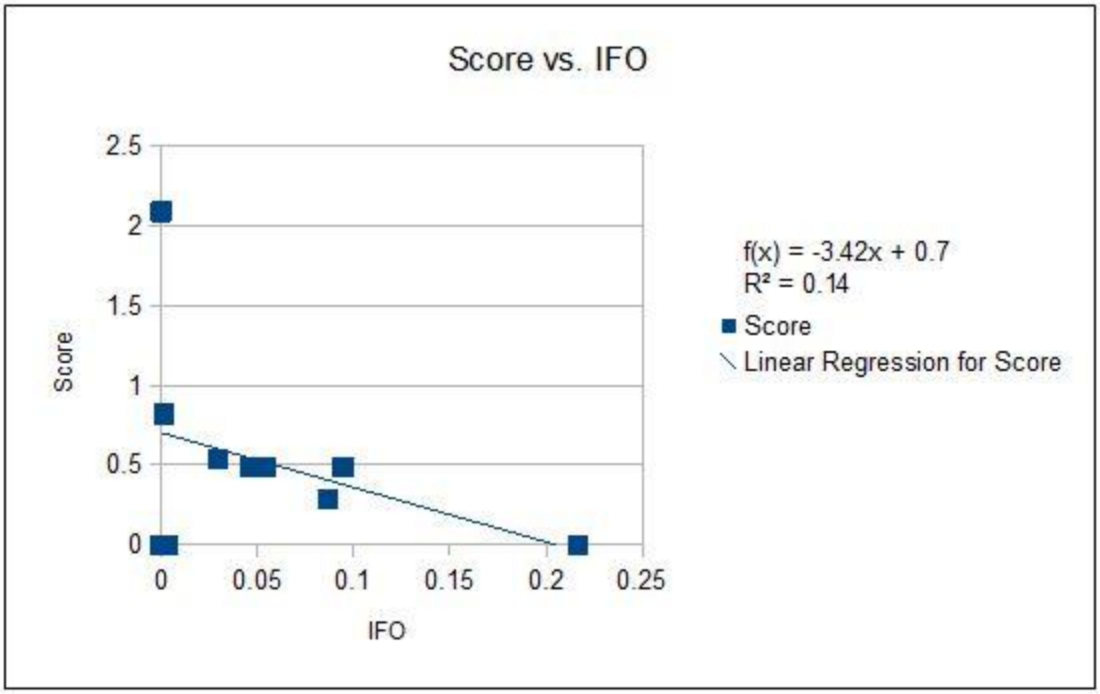
Figure 4. Eco-efficiency frontier of year 2010. Blue companies are on the eco-efficiency frontier. Red companies are in-efficient.

When the scores from the combined model were used to plot the linear regression graphs, there was found to be a correlation between R&D expense/sales and eco-score and between eco-score and gross profit.

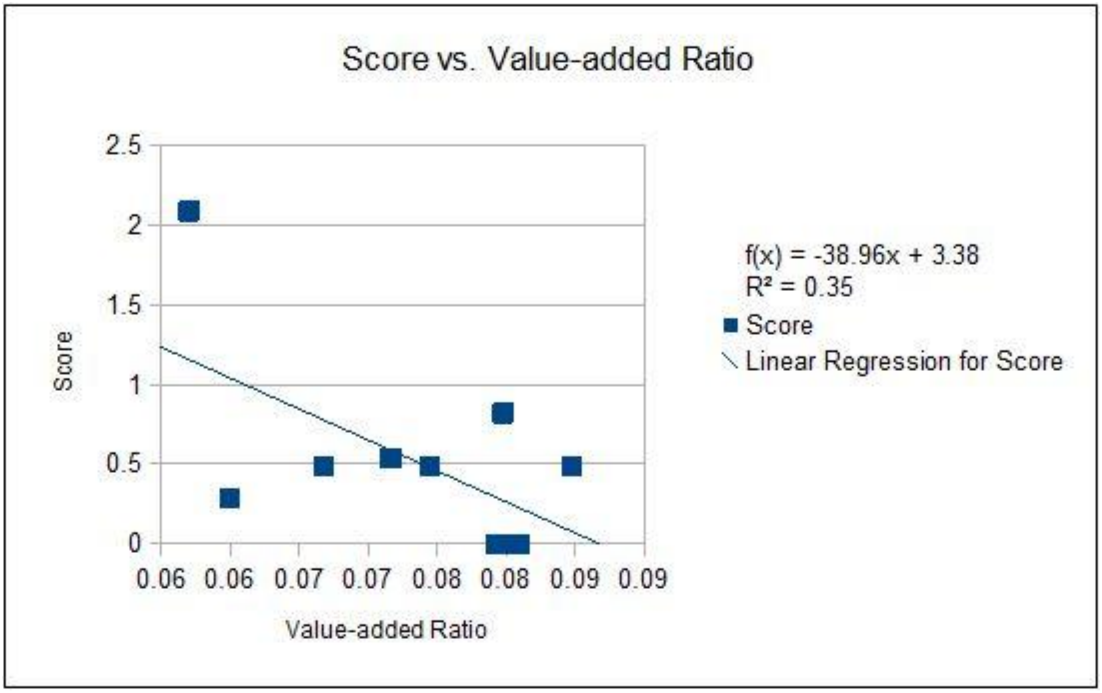
Discussion

We looked at several contextual variables: index of foreign operations, value-added ratio, and research and development expenses to see if there are discernable relationships between how companies operate and their eco-efficiency scores. The following relationships and their explanations are purely hypothetical and require more research to be confirmed. In addition, most relationships between eco-efficiency scores and contextual variables are very weak because our sample size is very small.

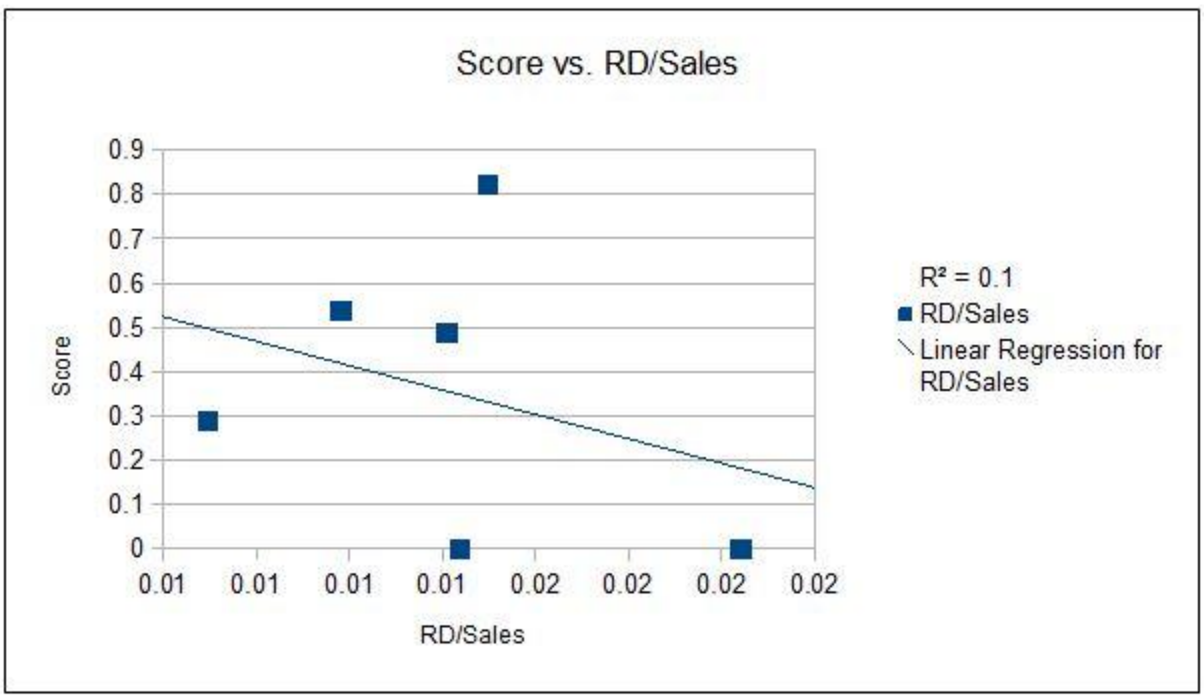
The following contextual variable relationships are drawn from 2008 data.



As index of operations increases, eco-efficiency scores decrease indicating that companies are becoming more efficient. This may be because having local facilities eliminates the need to transport goods to their local stores. A related reason may also be the reduced cost of goods sold. Less transportation of raw materials and decreased transportation of goods translate to less carbon emissions.



As value-added ratio increases (meaning higher amounts of vertical integration and less outsourcing), eco-efficiency score decreases. This maybe because companies that have higher control over their production process can keep it leaner and more eco-efficient in comparison to outsourcing the manufacturing needs and not having control over the operations.



As research and development expenses increase, so do eco-efficiency scores. This makes sense because companies with newer technology are generally “greener”. Our project will make this possible and with its success, will make it more difficult for companies to avoid reporting their carbon emissions. The companies that currently willingly report all their emissions data, along with public and private pressures, will eventually push all firms to acquire an eco-score.

Conclusion

According to our results, Campbell Soup Company, Coca Cola Company, and Pepsi Company were on average the three most efficient companies. One possible correlation that could be drawn is that Coca Cola and Pepsi are both beverage companies. The environmental impacts of beverage production are less than food-based production because they do not have to deal with the impacts of agriculture. In terms of packaging, aluminum beverage cans have a small environmental impact because they can be infinitely recycled. Plastic is a different story, but Coca Cola has made efforts to reduce their plastic use by coming up with a bottle that is made out of 30 percent plant-based materials (The Coca Cola Company 2009). Other companies that use copious amounts of plastic packaging should follow suit and develop more sustainable packaging. Campbell Soup Company does have some similarities with Coca Cola and Pepsi and these parallels could be used to explain why they are an efficient company. Campbell Soup’s primary product is soup, which contains mostly liquid and is packaged in an aluminum can. They have also redesigned certain aspects of their company in order to be more efficient. For example, Campbell moved one of their processing plants to Canada, which saved them lots of carbon emissions from truck transportation (see Appendix A for more detail). Investigating the environmental policies of these three companies has given insight as to possible reasons why these companies are more efficient than the others chosen in our study.

Dean Foods and General Mills were the two least efficient companies on average. These companies make different products, but delving into their production processes could lend insight as to why these companies are inefficient. General Mills' main product is cereal manufacturing. The major environmental concern with this is the energy and heating used to bake the cereal (see Appendix A for further detail). High amounts of heat and energy can lead to increased greenhouse gas emissions. One way the General Mills could aim to reduce their energy usage would be to install solar panels or use another renewable energy source. As for Dean Foods, the main products of this company are milk and cheese. The main environmental concern with dairy production is the methane that is emitted from cows (see Appendix A for further detail). Dean Foods could increase their efficiency by adopting a similar possibility to the Sara Lee Company. Sara Lee is producing energy by processing their by-products through anaerobic digestion using methane (Carbon Disclosure Product 2010). Dean Foods and General Mills could be inefficient for a variety of different reasons and these are just a couple possibilities as to why.

For further analysis of our data and why some companies are more efficient or inefficient, there needs to be more research conducted. There are several factors that could contribute to why a certain company is more efficient over another one. Due to time constraints, we were unable to research every possible contributing factor. One area of analysis that would be interesting to look at would be the source of energy each company uses and how much. Other factors that could contribute to a difference in eco-efficiency score would be if the company has merged or acquired new products and the company's Scope 3 emissions. We were unable to include Scope 3 emissions into our project because there was a significant lack of data. Many companies do not disclose their carbon emissions in general, let alone Scope 3 data. Hopefully as the regulations surrounding carbon emissions become more stringent, there will be more readily available data provided by the companies.

The need to come up with a better way to measure eco-efficiency is important for two reasons: “improvement of eco-efficiency is often the most cost-effective way of reducing environmental pressures” and “policies targeted at efficiency improvements tend to be easier to adopt than policies that restrict the level of economic activity” (Kuosmanen and Kortelainen 2005). The original goal of the project was to use the proposed model to determine a uniform way of measuring eco-efficiency using carbon emissions and financial data from companies. . Our project will make this possible and with its success, will make it more difficult for companies to avoid reporting their carbon emissions. After working through a few obstacles, we determined the best variables to use for the calculations. While there is lots of missing data within this industry, we were able to see trends in the data we were able to use. The companies that currently willingly report all their emissions data, along with public and private pressures, will eventually push all firms to acquire an eco-score.

Appendix A: Product Backgrounds

<u>Meats, Cheeses, and Dairy Products: Jennifer Lu</u>

Commodities derived from animals such as meats, cheeses, and dairy products generate environmental waste. Companies included in this study such as Kraft Foods, Sara Lee Corporation, and Dean Foods that sell these products are making efforts to measure their operation's carbon emissions and take action to mitigate these emissions. The following is a description of the production process of one type of meat – chicken – and an overview of the cheese and milk-making processes. In this report, I will explore the production process of livestock (focusing mainly on chicken), cheese, and dairy products (mainly milk) and describe the environmental impacts and best management practices of that product. Then I will examine the eco-efficiency scores of the aforementioned companies to see how their environmental practices correlate with their scores.

A certain breed of chicken called the Broiler chicken is favored for its meatiness and ability to grow and gain weight quickly. The chickens live in large open spaces until they are ready to lay eggs, at which they go to the coop. Eggs are collected and put into large incubators where they will hatch in 20 days. The breeder hens live about 45 weeks before they are slaughtered and processed for pet food or meat in soups. Chicks are not fed steroids or hormones, but sick chicken are treated with antibiotics. The medication is allowed time to be flushed from the chicken's system before it can be slaughtered (Made How 2006).

Milk is collected from dairy cows twice a day by stainless steel vacuum-milking machines. The milk is stored in a large, refrigerated holding tank until a refrigerated bulk tank truck arrives to pick up the milk. Cheese can be made from several types of milk: cow, sheep, goats, horses, camels, water buffalo, and reindeer. First, milk will be allowed to sit until it curdles and separates from the whey, the watery, gray-ish fluid that contains lactose, vitamins, minerals, and traces of fat. Substances such as rennet, lactic acid, or plant extracts can be added to the milk to induce curdling. The whey is drained away and the solid curd is cut into cylinders or blocks. The curd is pressed into molds and wrapped in brine or cloth and stored so it can properly age. Cheese are aged anywhere from a month to a few years and then sold (Made How 2006).

With the production of chicken and all other livestock – cattle, hogs, sheep, lamb, and turkeys – comes the various environmental impacts of raising a vast number of animals in small spaces and such short spans of time. A major issue is the amount of feces generated by the livestock; what it should be used for, how it should be stored, and how to prevent it from leaching into the water table. Runoff adds nutrients, toxins, and pathogens into ground water that can affect humans and animals alike. Antibiotic resistant strains of pathogens such as *E. coli*, *Salmonella*, and *Campylobacter* develop in the high-density quarters of livestock and can make the consumers of these products sick (Tilman 2002). Air, ground, and surface water pathogens in the water can wipe out a sizable number of livestock and lead to greater drug resistance from the pathogens and humans who ingest the meat.

According to the United States General Accounting Office in its 1995 “Animal Agriculture” report, the best management practices to combat feces runoff include using treatment lagoons, retention ponds, and other storage structures to hold the waste until it can be used as fertilizer. Some irrigation pumps apply liquid animals waste (free of pathogens) onto agricultural land to be used as fertilizer and some farms compost the waste. Dead or injured animals that cannot be sold to stores are also composted to reduce the total weight and volume of the waste instead of being sent to landfills (Made How 2006). Other solutions include vegetated filter strips and constructed wetlands that will absorb the waste and suspended solids from the ground before the runoff reaches the water body.

The methane cows produce is considered a problem because it is a potent greenhouse gas. Landfills capture the methane produced by buried waste and use it to generate energy. Some companies such as Sara Lee Corporation are processing their by-products in anaerobic digestion units that produce methane and combust it to produce energy. In addition, Sara Lee Corporation modified their products to require less refrigeration and redesigned their deli meat packaging bowl and associated shipping materials to leave less waste. Dean Foods is the largest supplier of milk and dairy products and they have committed to reducing packaging and less refrigeration of products. They also compost their manure and use it to fertilize their cropland.

The other main environmental impact of livestock production is caused by the great amount of feed necessary to raise the animals. According to Tilman (2002), the production of 1 kg of meat can require between 3 and 10 kg of grain. The mass growing of crops has its own host of environmental problems including pests, the high use of water, and the use of pesticides and manure which leads to nutrient accumulation and depletion in soil. Nitrogen loading near water bodies leads to the eutrophication (low-oxygen conditions) which leads to the death of most diverse wildlife in the lake.

General solutions to agriculture-related environmental issues include policies and incentives that encourage farmers to take more actions to reduce their footprint on the land. The Sara Lee Corporation is a purchaser of many agriculture and meat commodities such as beef, pork, wheat, corn, and butter so they recognize the potential negative impacts of rising raw materials cost and more complex supply chain issues if raw materials have to travel greater distances to their factories (Sara Lee Corporation Carbon Disclosure Project, 2010). Kraft Foods makes a similar assessment in their 2010 Carbon Disclosure Project (CDP) report and acknowledges the potential for water scarcity and changes in production regions due to climate change. The United States Conservation Reserve Program pays farmers to leave certain sections of their land unused for specified time periods. Other countries use taxes, reward payments, or remove subsidies (Tilman 2002). Eco-labeling and certification of products may also create powerful incentives for farmers to reduce their environmental impact if they are shown to be a top polluter in the industry.

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Chocolate and Confectionary Products: Jae Suh

Introduction

Chocolate and confectionery food companies obtain quite a large portion by globally in industrial sites. The companies sampled within this product category are Hershey's, Cadbury, and Nestle. In the following are the efficiency scores for the sampled companies. Hershey's received a score of 3.3, (Good Guide 2011) due to receiving one of the lowest score for their water management. They have also received violations of Clean Water Act and Clean Air Act. In 2008, they have received a violation for failing to Risk Management Program (RMP) as required by Clean Air Act. (US EPA 2008). The company had failed to develop the mitigation regarding their storage and its use of anhydrous ammonia as one of the toxic chemical substance to be regulated. Cadbury received a score of 6.6, scoring above average for their resources management. Cadbury has score high score due to reducing their water consumption by 17 %. (Environmental Leader 2009). For Nestle, their efficiency score was 5.0, their overall score is above an average, but they have violated the Clean Water Act by emitting excessive pollution to the air from their factories near the springs. These companies manufacture their food products in various ways, such as in candy bars, cocoa, milk shakes, and cakes. It turns out, chocolate confectionary types of food products tends to capture the most attention from our people. Furthermore, by examining closer to the procedures in chocolate products, there can be several indications generated, to use for mitigating the contamination to the environment from these types of food products. There are three production processes to make chocolate; Harvesting and processing the cocoa, and cocoa manufacturing.

Process of manufacturing Chocolate/confectionery products

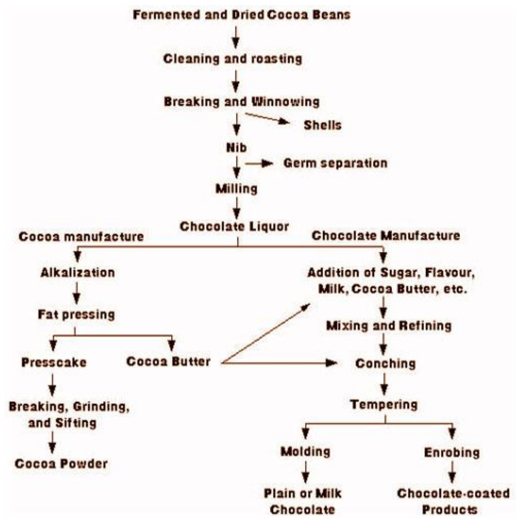

Fig A. showing the general process for cocoa beans to be produced to chocolate.

Harvesting cocoa starts from the forest. Most of the cocoa (i.e., 2/3 of the entire world's cocoa is produced in Western Africa) comes from tropical evergreen Cocoa trees. First, the seed pods of coca will first be collected, and then the beans will be in selection to be shipped for its mass production (Fig A shows the general process for producing cocoa). In general, cocoa beans are grown in pods that branches off of cocoa trees. The pods are then harvested when it turns to look ripe. Machines can possibly damage the cocoa tree or the cluster of pods that grows from the trunk, so the harvesting workers have to pick out the pods by hand. (Beckett 2000) This process seems to be the most sustainable in producing the chocolate due to having nearly 0 percent of carbon emission Further more these cocoa pods are collected into baskets, which are ready to go through the fermentation processing. When the beans undergo through fermentation processing, they are either placed in large, shallow heated trays. If the climate is suitable, the cocoa seeds can be heated by the sun. Periodically, these seeds, in process of getting heated, are stirred to have all beans come out equally fermented. During fermentation is when the beans turn brown. Proper fermentation and drying removes all unpleasant flavors and starts the chemical changes necessary to produce the true cocoa. After comes drying the cocoa seeds. After fermentation, the cocoa seeds must be dried before they can be scooped into sacks and shipped to chocolate manufacturers. (Beckett 2000) Farmers simply spread the fermented seeds on trays and leave them in the sun to dry. The drying process usually takes about a week and results in seeds that are about half of their original weight. Once the cocoa beans have reached the machinery of chocolate factories, they are ready to be refined into chocolate. Generally, manufacturing processes differ slightly due to the different species of cocoa trees, but most factories use similar machines to break down the cocoa beans into cocoa butter and chocolate. Firstly, fermented and dried cocoa beans will be refined to a roasted nib by winnowing and roasting. Then, they will be heated and will melt into chocolate liquor. Lastly, manufacturers blend chocolate liquor with sugar and milk to add flavor. After the blending process, the liquid chocolate will be stored or delivered to the molding factory in tanks and will be poured into moulds for sale. Finally, wrapping and packaging machines will pack the chocolates and then they will be ready to transport. (Beckett 2000) The first thing that chocolate manufacturers do with cocoa beans is to roast them. This develops the color and flavor of the beans into what our modern palates expect from fine chocolate. The outer shell of the beans is removed, and the inner cocoa bean meat is broken into small pieces called cocoa nibs. The roasting process makes the shells of the cocoa brittle, and cocoa nibs pass through a series of sieves, which strain and sort the nibs according to size in a process called "winnowing". Following after this procedure is the grinding process. Grinding is the process by which cocoa nibs are ground into “cocoa liquor", which is also known as unsweetened chocolate or cocoa mass. The grinding process generates heat and the dry granular consistency of the cocoa nib is then turned into a liquid as the high amount of fat contained in the nib melts. The cocoa liquor is mixed with cocoa butter and sugar.

In the case of milk chocolate, fresh, sweetened condensed or roller-dry low-heat powdered whole milk is added, depending on the individual manufacturer's formula and manufacturing methods. After the mixing process, the blend is further refined to bring the particle size of the added milk and sugar down to the desired fineness. The Cocoa powder is blended back with the butter and liquor in varying quantities to make different types of chocolate. After blending is complete, molding is the final procedure for chocolate processing. This step allows cocoa liquor to cool and harden into different shapes depending on the mold. Finally the chocolate is packaged and distributed around the world.

Environmental impact from the manufacturing processes and its mitigation

There are various environmental impacts through the process of making cocoas. Firstly, the harvesting and fermenting the cocoa can cause an effect on environmental microbiologic quality. Pathogens and microorganisms are found in fertilizers. Pathogens tend to cause disease for humans such as skin problems, memory loss, and confusion. There is a major toxigenic fungi found in cocoa beans called Ochratoxin A “OTA” (Tafuri 2004). These toxic microorganisms grow on raw material of the cocoa pods. Furthermore, there has been an analysis on how to generate treatments for OTA. Results show, that there can be significant reduction in the contamination of the toxic chemicals from the raw material through industrial processing. Industrial processing of cocoa significantly reduced the level of OTA contamination through roasting and shelling steps (Muller 1995). In the process of manufacturing the cocoa products, the particulate emission tends to be increasing dramatically. This process is known to contain the most occurrences in emitting pollutions from emissions to land, water, and air. For example, The Blommer chocolate company was violated by the EPA for releasing too much pollution during the grinding process of cocoas (US EPA 2005). During the manufacturing process for the confectionery facilities, there are likely to be emissions emitted from the combustion processes from burning fuel oil, natural gas, liquefied petroleum gas [LPG]. These emissions caused by combustion can be analyzed by fuel analysis and Continuous Emission Monitoring System (CEMS). Fuel analysis is used to predict the amount of sulfur dioxide, metals, and other emissions generated from confectionery facilities by applying the conservation laws. Similarly, Continuous Emission Monitoring System provides periodically recorded emissions in consistency. This helps to determine the rate of emission by simple calculations of pollutant concentration and volumetric gas of that pollutant. (Beckett 2000). There should also be a precaution for these emissions to be leaked or spilled as to be known as fugitive emissions (NPI 1999). In addition, there are routed sewer lines for these confectionery manufacturing facilities. Releases of the wastewater from these confectionery facilities can be an issue from many toxic-contained discharges such as carbon monoxide, fluoride compounds, hydrochloric acid, particulate matter, sulfur dioxide, and much more. These can be implemented by off-site sewage treatment plant. Applicable measurement for the treatment plant includes mass balance analysis. Chemical can remain in specific location, can be carried elsewhere by a transport process, or can be eliminated through transformation into another chemical. This simple observation is known to be the mass balance analysis, where the input and output streams can be characterized to observe the behavior of the chemicals. Moreover, the emissions of the substances to the land on-site include solid waste, slurries, sediments, spills and leaks, storage and distribution of liquids. These emissions is also transported by the sewer, which is sent off-site for treatment (i.e., it is sent to landfill for disposal of waste materials by burial.) Typically, it is best to design the landfill in confined small area, compacted, and covered with layers of soil (Beckett 2000).

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Cereal Products: Andrew Hwang

Introduction

This report seeks to summarize the cereal manufacturing process of three companies within our sample, Kellogg's, General Mills, and PepsiCo. Kellogg's is currently the world leading producer of cereal and one of the top producers of grain-based convenience foods (i.e. cookies, pastries, waffles.) As of 2010, Kellogg's total assets were valued at $11.867 billion, while receiving a net income of $1.24 billion during this year. On its website, Kellogg's currently has listed 56 different brands of cereals that are currently produced in the U.S. General Mills is a food manufacturing corporation that produces a wide variety of food products. Unlike Kellogg's, General Mills is much more diversified in its products, which range from baking mixes to ice cream and vegetable/soy products on top of its cereal production. It is a current Fortune 500 company, boasting a net income of $1.53 billion in 2010, with a total assets value of $17.679 billion. Although the company has only 12 listed main brands of cereal on its website, many of these (such as Cheerios) come in a wide variety of flavors and assortments. PepsiCo has owned the Quaker Oats Company since 2001. Quaker Oats is most famous for its popular oatmeal products, which come in different varieties and flavors. The company also produces grain-based snacks (i.e. Chewy Granola Bars) and 15 different brands of cereals (i.e. Cap'n Crunch Cereal), many of which come in different varieties as well.

Production Process

The cereal manufacturing processes that these companies utilize can be generally categorized into two distinct types: traditional (hot) cereals that require additional heating/cooking for consumption, and ready to eat (cold) cereals that are consumed straight from the box with milk. These two categories are further broken down to more specific types of cereal products.

Traditional Cereals

These cereals require cooking or heating at home and are generally made from oats, wheat, rice, and corn. 99% of the traditional cereal market is oat products (81%) and wheat products (18%), with the other grain types making up less than 1% of cereal products.

Oat Cereals

Oat cereal products consist of old-fashioned oatmeal, quick oatmeal, and instant oatmeal. Old-fashioned oatmeal is made of rolled oat groats (dehulled oat kernels) and cooked by boiling in water (roughly 30 min.) Quick oatmeal is made of thinner flakes of rolled cut groats and requires much less cooking time (1 to 15 min.) Instant oatmeal is similar to quick oatmeal, but additional modifications are made (i.e. incorporating gum to improve hydration); preparation consists of only adding hot water.

Oat Cereal Manufacturing Process

- Grain Receiving
- Oats are delivered to mill via railcar or truck
- Once sampled for quality, they are fed into a receiving separator and stored
- Cleaning
- Oats are then cleaned via several devices; this process removes dust, stems, weeds, seeds, and unsuitable oats.
- Devices include screens designed to fit grain size, aspirators and gravity tables that utilize oat density, and indented disks/cylinders that match oat size
- Hulling

- Most facilities utilize an impact huller which separates the oat hull from groat
- Oats are fed into a rotating disk, which flings the oats against a cylindrical housing that separates the hull

Groat Processing

- Largest groats are separated from the average sized groats – these are used to make old-fashioned oats, while the others are steel cut to make quick oats
- Steaming
- Both cut and whole groats are passed through an atmospheric steamer
- Must remain in contact with the live steam long enough to achieve a moisture content increase from 8-10% up to 10-12%; this is so that flakes can be produced when the groats are rolled
- Flaking
- Oats are rolled between two cast iron equal-speed rolls, with quick-oat products rolled thinner than old fashioned oats.
- Packaging
- After rolling, oats are cooled and directed to packaging bins, which generally consist of spirally wound two-ply fiber tubes with a paper label and individual single-serve pouches for instant oatmeal

Process	Emissions Type
GRAIN RECEIVING	PM (Particulate matter)
CLEANING	PM
HULLING	PM
GROAT PROCESSING	PM
STEAMING	VOC (volatile organic compound)
FLAKING	PM
PACKAGING	PM

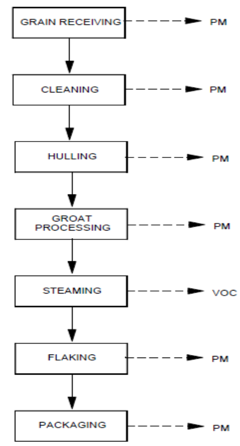


Figure 1. Oat Cereal Manufacturing Process and Emissions Types

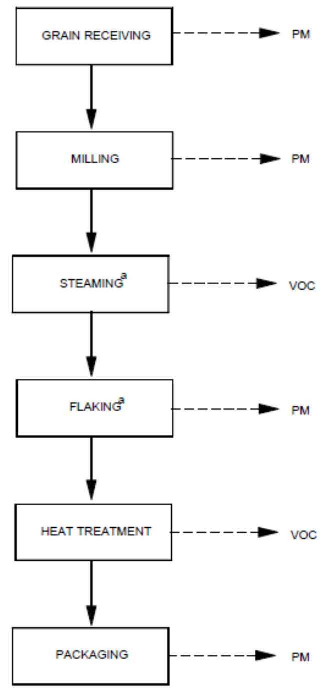
Farina Cereals

Farina can be defined as granular wheat endosperm, and farina based cereals consist of wheat, rice, and corn traditional cereals. These cereals collectively make up the remaining 19% of hot cereal products that are sold in the U.S. today.

Production Process

- Grain receiving (same as oat production)
- Milling of grains such as wheat within a flour mill (farina is packaged after this step)
- Steaming (same as oat production, not required for farina)
- Flaking (same as oat production, not required for farina)
- Heat treatment in order to dry the cereal
- Packaging (same as oat production)

Process	Emissions Type
GRAIN RECEIVING	PM
MILLING	PM
STEAMING	VOC
FLAKING	PM
HEAT TREATMENT	VOC
PACKAGING	PM



<u>Figure 2. Farina Cereal Manufacturing Process and Emissions Types</u>

Ready-to-Eat Cereals

Ready-to-eat cereals are those which are ready to eat right out of the box. They are eaten cold with the addition of milk, and these cereal products are typically the most popular brands sold. Ready-to-eat cereals are grouped by cereal form and shape rather than grain type, as many are a mixture of different grains. Listed below are the various types of ready-to-eat cereals produced.

Types of Ready-to-Eat Cereals:

<u>Flaked Cereals</u>

Flaked cereals are made directly from whole grain kernels or parts of corn, wheat or rice that have been preprocessed and form one flake each.

-Corn preprocess: dry milled to remove the germ and bran from the kernel, leaving the endosperm.

-Wheat preprocess: lightly steaming the kernels and rolling them to break them open.

-Rice does not require any special preprocessing.

Flaked Cereal Manufacturing Process:

- Grains are preprocessed (as mentioned above)
- Mixer: grits are mixed with flavor solution to receive an even coating of syrup, which includes sugar, malt, salt, and water
- Cooker: coated grits are poured into rotating batch cookers, which cook via steam. Cooker is then vented to cool the contents and dumped on conveyor belts.
- Delumper: cook grits are passed through delumping equipment to separate and size the grits into single particles. Air drying is also done during this stage.
- Dryer: grits enter dryer under controlled temp and humidity to achieve desired moisture level.
- Cooling and Tempering: grits are further cooled to ambient temperature and place in large bins so that moisture levels can balance.
- Flaker: grits are passed through large metal rolls that press them into very thin flakes.
- Dryer/Toaster: the flakes are suspended in a hot air stream to be dried and toasted.
- Packaging: flakes are then cooled and packaged in boxes for shipping

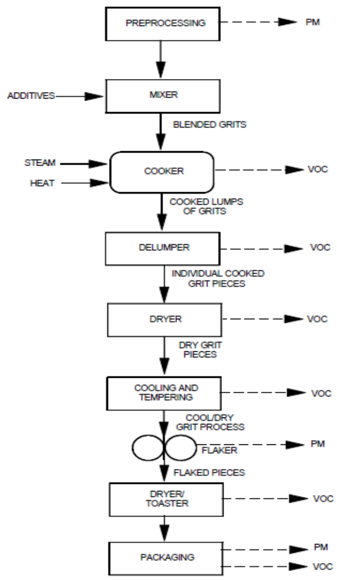


Figure 3. Flaked Cereal Manufacturing Process

Extruded Flaked Cereals

Extruded flaked cereals are formed by mixing ingredients into dough and cut it into pellet sizes, rather than producing cereal flakes from a single grain piece.

Manufacturing Process:

In producing extruded flaked cereals, the cooking and delumping steps in flaked cereal manufacturing are replaced with an extruding step. The extruder consists of a long barrel in which ingredients are mixed and cooked; the dough comes out of the end and is sliced into proper pellet sizes.

Gun puffed whole grain cereals

Gun puffed cereals are cereals which are puffed by the use of “guns”, which create a vacuum that causes the grain to expand rapidly. Grains for this cereal type are limited to rice and wheat.

<u>Puffing Process</u>

- Grains are loaded into sealed guns: manual single-shot, automatic single-shot, automatic multiple-shot, or continuous guns
- Once the gun is sealed, it begins to rotate as gas burners heat the sides of the gun body, causing water in the grain to produce steam
- When the lid is opened, the sudden pressure change causes the grain to puff
- Gun types
    - Manual guns: gun is sealed, steam generated from grain itself
    - Automatic guns: steam is directly injected into gun body
    - Multi-shot/continuous: guns have several barrels mounted on a wheel, all of which are simultaneously loaded and fired at the same time

Extruded gun-puffed cereals

These gun puffed cereals use a meal or flour as the starting ingredient instead of whole grains. The dough is cooked in an extruder then formed into the desired shape before being loaded into the guns.

Oven-puffed cereals

Oven-puffed cereals are made using whole grain rice or corn, or a mixture of the two due to the fact that corn and rice inherently puff when treated to high heat and proper moisture. The grains are cooked with ingredients, cooled, sized, rolled into flakes, dried, and then oven baked to create puffed form.

Whole-grain shredded cereals

Shredded cereals are cereals that do not produce a flake or puff shape; instead, they are made in the form of biscuits, with what appears to be woven strands of grain. White wheat is primarily used to produce shredded whole grain cereals. The wheat is first placed within giant cooking vessels that can contain up to 50 bushels of raw wheat. Steam is then injected directly into the water to heat the grain and commence the cooking process. Once cooked enough, the grain is then surface dried and cooled in bins to temper.

Shredding process: wheat kernels are squeezed between two rolls, one with a smooth surface and the other with a grooved surface. A comb is then placed against the grooved roll and picks the wheat shred from the groove. These layers of shred are placed onto a conveyer belt, where they are fed into a dull cutting device that compresses and creates biscuits. The biscuits are baked and dried, ready for packaging.

Extruded shredded cereals

Extruded shredded cereals are produced in the same way as whole-grain shredded cereals except that a meal or flour from wheat, corn, rice, and oats is used as raw material instead of whole grain white wheat.

Emissions from Production Process

- Particulate Matter (PM)
- Generated from solids handling and mixing
- Occur during milling and processing of grain, dumping of raw ingredients and hulling/cleaning of grain
- Volatile Organic Compounds (VOCs)
- May potentially occur at almost any stage
- Commonly associated with thermal processes such as steaming, cooking, extruding, puffing, and baking
- Package adhesives may be VOC emissions source as well

Product Aspect for Research

Upon reviewing the production aspects of the various kinds of cereals, one major component that they all have in common is that they all require some sort of heat/energy intensive processing in order to be cooked. Some cereals are cooked in order to be malleable and shaped and then baked to its dry form later, while others require only one treatment process of cooking. Nevertheless, it appears that this is the most energy intensive part of the cereal manufacturing process when compared to the other components. These components require energy as well, but most are focused on mechanical operations that can be done by machines powered via electricity. The cooking and heating of cereals via steam, natural gas, etc. has the potential to be more costly in terms of power, and as a result they may have a bigger and more significant impact on CO_2 emissions. Not only do these cooking processes require more energy, but they also must be implemented for a longer time: it takes longer to cook and heat the grains than it does to separate or hull them, and this is even more significant in production processes that require cooking the cereal more than once.

In order to address this aspect of the production process with the goal of making it more eco-efficient, there are several approaches that can be pursued. One approach would be to utilize genetically modified grains that have traits favorable to the production process. For instance, these grains can be modified to have thinner hulls that fall off more easily, reducing the time and energy needed to process them. Grains can also be modified so that the endosperm being used can be more easily cooked with less heat. The purpose of heating the grains in many of the processes mentioned above is to put the grains in a malleable state so that they can be rolled and shaped into flakes. If we are able to utilize grains which are inherently more malleable without (or with much less) heating, then there can be significant reductions in energy consumption and

CO_2 emissions in the production process. This would both reduce emissions directly caused by the grain and increase profits by reducing energy costs. Thus, apart from depending on growers to practice more sustainable agriculture, utilizing new grain types could prove to be even more beneficial in terms of eco-efficiency.

Another approach would be to design and utilize more energy efficient cooking machinery (i.e. steamers and ovens, more efficient gas operated puffing guns.) If new designs are able to be implemented which reduce the amount of fuel needed to heat these machines to a needed temperature, then the production process would be more eco-efficient. These designs could also incorporate better heat retention as well; if heat is more effectively trapped within the machinery, then less fuel and energy would be needed to replace escaping heat. This type of thermodynamic engineering can reduce the energy consumption of these machines, allowing them to cook the grains with much less energy. And this in turn can reduce the carbon footprint of the cereal manufacturing process.

Additionally, the process of cooking cereals tends to utilize a significant amount of water in order to soften the grain via steam. Combining the aspects of genetically modified grain with better technology (better heat retention in steaming units) would reduce the amount of water needed in order to run these production lines. Although strides have been taken by both companies to conduct water risk assessments and transparency in regards to water usage, these efforts do little to actually reduce the amount of water being used. Implementing new technology and research in the aforementioned areas could assist both companies in both becoming greener and reducing their resource expenses (thus increasing their eco-efficiency.)

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Alcohol Product Background: Mitchell Howard

Introduction

For the alcohol and tobacco product category we have only one company but this company is already very efficient by our analysis. Other companies that produce this type of product will most likely have similar sources of carbon pollution from their bottling, manufacturing, packaging, and distributions. The company we investigated is Kirin Holdings co. who is based in Tokyo, Japan but is a global alcohol distribution company that also does business in pharmaceuticals, and other beverages. When the group put the input variables; cost of goods sold, gross profit, and total scope 1 & 2 emissions, into our Data Efficiency Analysis (DEA) model, we saw that Kirin received perfect score in 2008. So for 2008 we see that Kirin was very efficient, but then in 2009 and 2010 their scores were not perfect. We see that in 2009 and 2010 they received a score of 0.309 and 0.749 respectively. There must have been some reason as to why this change occurred. We now want to see what changes could have accounted for this and what Kirin and other companies alike, to get back to a more efficient level. We also want to see how the operations of Kirin play into their efficiency scores and what can be done by them to improve their carbon efficiency scores in our model.

Current Practices and Score

Let's first see how the operations of Kirin play into the three input variables that were investigated and how these variables affect their efficiency score. Looking at the input variables for Kirin we see that they did not change much in the gross profit and costs of goods sold categories, but their scope 1 & 2 emissions did change drastically. They increased from 2008 to 2010 from 357,000 tonnes to 976,000 to 1,691,557. This probably has a big influence on why the efficiency score for Kirin also went up each year. In Kirin's 2010 sustainability report they admit to trying to build a low-carbon society. But their main source of business is distribution of beverage products. They also have a prospective business plan that was implemented in 2007-2008 called Group Vision 2015 in which they state that they want to expand their company to new regions and gain more business. With them being a distribution company and wanting to expand, they will most likely release more carbon dioxide from trucks, trains, and boats transporting their products to new locations and increasing the amount of products distributed. Dieselnet.com reported from the US EPA emissions averages for many years of diesel truck engines. From 1987-1994 the Carbon output of diesel trucks did not change being 15.5 grams/break horse power per hour (g/bhp·hr). But in 2004 the EPA regulation changed to reduce this number 2.0 g/bhp·hr (Dieselnet.com). This is where the emissions requirements stand right now. This shows that Kirin could not be using older trucks that give off more emissions than other companies, because the regulation is pretty stringent for everyone. But that does not mean that there are things they could do to still decrease their emissions from their trucks.

Alternative Transportation Practices

There are other types of trucks that are much more efficient called low emission vehicles (LEV), inherently low emission vehicles (ILEV), ultra low emission vehicles (ULEV), and zero emission vehicles (ZEV). These types of trucks have very low emissions and if Kirin switched to using these types of trucks they would be reducing their emissions output greatly. If they did lower their emissions then they could reach the efficiency frontier we have created in our 3-D graph. But this does pose a problem, if they buy all new trucks, they would be increasing their cost of goods sold and decreasing their gross profit moving them further away from the efficiency frontier. But this cost could be something that only impacts one-year making then the following years better.

Another option for Kirin is to switch to biodiesel fuel type in their trucks. Biodiesel actually reduces carbon emissions by 78% from conventional petrodiesel (biodiesel.org). They could also try to do a program where they share trucking space with other companies so as to increase truckloads that are going to the same locations. By having less number of trucks but still getting products to their required locations, they would be reducing their carbon emissions while still keeping gross profits up and cost of goods sold down, putting Kirin closer to the efficiency frontier. This is something that Kirin already has started and they claim that it has reduced their transportation emissions by 12% (Sustainability report pg 39). They are also using more eco-efficient rail lines, which have reduced the number of trucks as well as emissions. Kirin has an emission goal, for its transportation sector, of 540 tones and it can be achieved if they stick with these alternative options.

Alternative Manufacturing Practices

Kirin also has beverage bottling factories, some located in the Northeastern United States. These factories produce carbon emissions and the electricity that they consume does as well. Of the total electricity that Kirin uses, 74% is purchased electricity, 17% is electricity produced by utility gas, and 8% is produced from biogas (Sustainability report pg 39). The utility gas and biogas productions are new additive technologies that help to reduce emissions and Kirin's dependency on purchased electricity from non-eco-friendly sources. If they could increase the use of these better types of electricity production, they will reduce their emissions, but the cost/benefit weigh out is unknown. Kirin does promise to reduce their emissions from manufacturing, distributions, and office operations by 35% compared to 1990 levels (Sustainability report pg 38). It seems as Kirin is taking their emissions levels upon themselves as a major priority and have many plans on how to do so. Because of this I have confidence that they will be successful in their quest.

Conclusion

We still have to explore why Kirin had worse scores in 2009 and 2010 compared to 2008 if they were trying to reduce their emissions already. What it seems to be was that Kirin is very adamant on expanding their company and they must have built new factories and expanded their distribution lines. They did increase their cost of goods sold in 2010 by about 7,000 (in million US dollars).   This could be the costs of expanding their corporation and lead to the increase of emissions. Both of those inputs factored into the DEA model must be the reason for their increased scores. Kirin looks to be on the right track on paper but the actual facts from our investigations and models show that they are actually moving in the wrong direction. If what they say they plan to do is implemented and does make the impact that is expected, Kirin could be a very efficient company.

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Canned Products: Carly Lyons

Introduction

As the world becomes more aware of the impacts of anthropogenic sources on the environment, companies are evaluating the performance and sustainability of their products. Many companies are now making it a priority to provide information about the sustainable practices to their customers and investors. When examining food companies, the most common forms of best practices are concerning packaging and agriculture because those are the two aspects of the industry that are most environmentally damaging. This is especially true for the canning industry and companies like H.J. Heinz and Campbell Soup.

The canning of food items has been around since the early 1800s. It came about to preserve food and give it a longer shelf life. The most common food items that are canned are fruits and vegetables. The cans themselves are made out of aluminum or steel and have a protective coating (United States EPA 1998). The coating is usually made of tin and used to protect the can from rust and corrosion. The most concerning factor of the packaging is the energy intensity of the metal. Aluminum is very energy intensive and that is why it is more expensive than steel (Golden Recycling 2011). This could be a possible reason for why a company would choose to use steel cans versus aluminum ones. Both metals are infinitely recyclable so that is not a large factor when considering the environmental impacts of cans.

Environmental Concerns of Can Manufacturing

The two harmful concerns of can manufacturing have to deal with energy usage and the coating that is put on the can. Large amounts of heat and energy are used to melt the metal and form it into the shape of a can. Also, once the cans are formed, they pass through a drying oven to cool off (United States EPA 1998). Exhaust from the drying ovens and the solvents used to make the coating are another concern. In terms of greenhouse gases and carbon emissions, the exhaust does not have an enormous impact. The volatile air compounds (VOCs) and hazardous air pollutants (HAPs) are of greater concern because they occur as a result of the high concentration of solvents used in the coating (Foster et al 2006). Greenhouses gases are more of a concern for other forms of food processing and manufacturing. For example, there was a study done on the carbon impact of frozen versus canned foods. The study used life cycle assessment techniques to determine the global warming potential of each product. It was determined that each ton of steel that goes into making a can and displaces a frozen product will save 6.5 tons of greenhouse gas emissions (World Steel Association 2009). A possible reason for this could be that it takes more energy to keep frozen foods in stock. The refrigeration needed to keep frozen foods uses lots of energy whereas canned foods already have the necessary preservatives to keep them from spoiling. As seen here, the main concern with canned foods is the energy needed to produce the can and possible emissions from the coating used to protect the can.

The other major environmental concern when it comes to the food industry is agriculture. Companies are becoming more sustainably aware of where the food comes from and how it is grown. Many are implementing best practices that aim at water conservation and pesticide-free growing methods. With rising global temperatures and depletion of water sources, it is important to minimize water use while still maximizing growth. As for pesticides, it is important to minimize their use because they can emit harmful chemicals into the air and soil. Agriculture runoff that contains these chemicals from pesticides can enter the water supply and potentially cause human harm. Another factor to consider is the transportation of the produce from the farm to the manufacturer. This could be a major potential source of carbon emissions. If there is a long distance between where the product is grown to where it is canned, the company could consider ways to be more energy efficient. Companies are taking all of these factors into consideration and figuring out the best ways they can still produce their products while having less of an environmental impact.

H.J. Heinz Company Environmental Policy

H.J. Heinz Company is a well known producer of canned and frozen foods. They are most notably known for their tomato products. The company's mission statement is "as the trusted leader in nutrition and wellness, Heinz is dedicated to the sustainable health of people, the planet and our company" (H.J. Heinz Company 2009). In response to growing environmental concerns, the company has developed an environmental policy to execute their mission statement. This policy has eight sections: energy consumption, packaging, transportation, renewable energy, agriculture, water, solid waste and employees. Heinz's main sustainability goal is to reduce their greenhouse gas emissions by 20% over a ten year span of time (H.J. Heinz Company 2009). To reach this goal, they have laid out specific smaller goals and implemented best practices.

For packaging, Heinz has converted some of their frozen food lines, such as Smart Ones, to cartons that do not contain chemical bleach. At one of their production facilities in Ohio, metal waste was reduced by 625,000 pounds in 2009 (H.J. Heinz Company 2009). Recycling and waste reduction are keys to sustainability in canned goods manufacturing. The metal used to make cans is infinitely recyclable and it only makes sense to continually recycle it to make more cans. Renewable energy and greenhouse gas reductions are of concern to the company when it comes to packaging. The most notable energy-efficient practice that Heinz uses is that they use continuous cooking equipment that allows for the product to be cooked in the can during production. Other efficiency measures they have taken include compressor system upgrades, installation of steam optimization technology, and lighting improvements (H.J. Heinz Company

2009). Finally, to reduce the amount of material that goes into packaging, Heinz has started to use thinner tinplate for their cans and use recycled steel for 60% of the ends used to make the cans (H.J. Heinz Company 2009). These are a few of the practices that the company is using to reach their sustainability goals.

Another major focus of Heinz's environmental plan is water conservation. One of the ways in which Heinz is conserving water is through the agricultural practice of drip irrigation. This is when a fixed supply of water is fed to the plants close to the ground. The result is slower evaporation and less water usage (H.J. Heinz Company 2009). According to the company's sustainability report, global manufacturing has saved over three million cubic meters of water in the past two years of implementing drip irrigation. In the United States, the manufacturing facilities are capturing, treating and reusing water up to ten times to help conserve water use. Other water conserving practices Heinz uses are "designing systems that eliminate water runoff and minimize evaporation, testing irrigation systems for water application uniformity and variations in flow and pressure, and analyzing water absorption rates, plant needs at each stage of growth and results of water testing tools" (H.J. Heinz Company 2009). In addition to conserving water, Heinz puts a large emphasis on other ways to sustainably grow produce, in particular tomatoes.

The company started a program in the 1970s called HeinzSeed. The goal of the program is to provide farmers with the correct tools and information to best grow tomatoes in a sustainable fashion. HeinzSeed developed a nongentically modified, hybrid tomato seed that the company has been using to produce more tomatoes per plant (H.J. Heinz Company 2009). They used safe environmental procedures to come up with a product that produces a greater yield than the previous variety. In California, the tomato yield has increased 65% in the past 25 years (H.J.

Heinz Company 2009). This is significant because the company is able to have a greater yield while using the same amount of water, land and fertilizer. HeinzSeed also provides information on how to prevent soil erosion through proper tillage techniques.

The final highlight of Heinz's environmental impact report and policy is from a factory in Escalon, California. This particular factory is home to an innovative technique that reduces natural gas consumption. Heinz developed a process that uses catalytic reduction technology to treat exhaust from the boilers. The nitrogen oxide released from the boilers is converted into nitrogen and water vapor. Not only did this new technology reduce nitrogen oxide emissions, it reduced carbon emissions by 2.5 tons per year (H.J. Heinz Company 2009). Future plans of the company should include this technology in all of their manufacturing facilities, as it could be an easy and cost-efficient way to reduce greenhouse gas emissions. The Heinz Company has made a significant start towards being a sustainable company and has high goals to becoming even more sustainable.

Campbell Soup Company Environmental Policy

Campbell Soup Company primarily manufactures soups and stocks. However, they are also the owners of Pepperidge Farm products, which include breads and baked goods. Like Heinz Company, Campbell Soup has a specific environmental plan and policy in place. To give some background on their current environmental success, here are some of the main accomplishments of 2010: reduced water use by more than 150 million gallons, met the U.S. EPA Climate Leaders goal to reduce carbon dioxide emissions per unit of production by 12% between 2005 and 2010, recycled 83% of all waste generated in production, and removed more than 4.5 million pounds of steel, plastic and paper packaging materials (Campbell Soup Company 2011). This progress shows the consumers and investors that Campbell Soup

Company is serious about mitigating their environmental impact. The company believes that this is a start towards their potential as a sustainable company and they have outlined specific goals they would like to reach by 2020. These five goals are to increase recycled waste to 95%, eliminate 100 million pounds of packaging, cut their water use and greenhouse gas emissions per ton of product produced by half, reduce energy use by 35% and make 40% of energy sources from renewable or alternative ones, and reduce water use by 20% and energy use by 30% per ton for their top five agricultural products (Campbell Soup Company 2011). In order to achieve these goals, Campbell Soup Company has implemented the following sustainable practices.

One of the first steps the company took in becoming more sustainable was to join the U.S. EPA Climate Leaders Program and the Carbon Disclosure Project. Both of these are programs that have goals to make companies more aware of greenhouse gas emissions and to help mitigate these emissions. Since joining the Climate Leaders Program in 2006 and tracking their greenhouse gas emissions, Campbell Soup has reduced the tons of carbon dioxide emissions per 1000 cases of product from 4.78 to 4.38 (Campbell Soup Company 2011). Disclosing carbon emissions data voluntarily and on the company website is uncommon so this goes to show that Campbell Soup is proud of the progress they have made towards becoming more environmentally friendly.

As previously mentioned, the two major concerns of food production companies are energy and water usage. Water is an important component in the production of food because it is used for cleaning, cooking and growing. Campbell Soup Company has implemented water conservation policies that have reduced the amount of water use by more than half a million cubic meters from 2009 to 2010 (Campbell Soup Company 2011). In addition to conserving water, the company makes sure that any wastewater is appropriately treated before it is released back into the environment. Even though water conservation is an important part of the company's environmental policy, the main focus is on sustainable packaging.

Reduce, reuse, and recycle are the three driving components of Campbell's sustainable packaging efforts. The definition of eco-efficiency is to increase the number of positive outputs using the same or decreased number of inputs while decreasing the negative inputs. One example of how Campbell Soup has implemented this concept into their packaging production process is by transporting one of their bottle suppliers from the United States to Canada. In doing so, it eliminated the use of 750 trucks and their associated greenhouse gas emissions (Campbell Soup Company 2011). It is redesigning efforts like this that will continue to help Campbell Soup reduce their environmental impacts.

Like Heinz, Campbell Soup Company also places a high regard on sustainable agriculture. With agriculture, the main concern is water usage. To conserve water, the company has started using drip irrigation and retention basins to catch and reduce runoff (Campbell Soup Company 2011). Other best practices they have implemented include conservation tillage and development of disease-resistant crop varieties. Conservation tillage has proved successful in reducing fuel consumption and greenhouse gas emissions. Developing disease-resistant varieties is important because it reduces pesticide usage (Campbell Soup Company 2011). These highlight a few of the efforts Campbell Soup is making in the area of sustainable agriculture.

The final area that Campbell Soup Company prides itself on being environmentally conscious is transportation. They claim that a huge advantage to their company is that many of their container manufacturing facilities are near their food production facilities. This eliminates a great deal of energy, time and emissions used to transport empty food containers before they are filled with the food product. In the United States, the company has started using lighter weighted equipment. The result of this new practice has eliminated the use of 1,700 trucks, saved 230,000 gallons of diesel fuel, and erased over 1 million miles in the distribution network (Campbell Soup Company 2011).

Conclusion

Other companies in the food industry can take a look at Campbell Soup Company and H.J. Heinz Company and compare their environmental policy with their own. Evaluating a company's areas of weakness and seeing what other companies do to help mitigate the environmental impacts of those weaknesses can be a resource for becoming more sustainable. The goal of this project is find a way to determine what makes one company more eco-efficient over another one. Investigating the environmental policy and production processes of a company can divulge information as to why their greenhouse gas emissions may be lower than another.

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Soft Drink Industry: Akhtar Masood

In this report, an overview of the production process of soft drinks will be discussed to point out the most impactful process to the environment and the measures taken by the two soft drink manufacturers in our study, Coca-Cola and Pepsi Co, to mitigate these impacts will be reviewed.

General Production Process

The production process of a soft drink has three components: water treatment, mixing of ingredients and carbonation, and packaging.

Water treatment

Water constitutes 90% of a typical soft drink (Steen 2006.) The quality of the water is an integral factor to its taste. There are three main processes performed to treat the water: coagulation, filtration and de-chlorination.

All water contains small suspended particles such as bacteria and viruses. The method used to take them out starts with coagulation. Coagulation is the process by which an electrolyte is mixed into the water, attracts the particles and clumps them together to make larger particles to be more easily trapped by filters.

After that, the water undergoes a filtration process. During the filtration process, the water is poured through a filter of sand and gravel to remove the clumped up particles. Furthermore, to prevent bacterial growth, sterilization is necessary to destroy anything that might spoil the water's taste or color. The water is pumped into a storage tank and a small amount of free chlorine is added. Factories often use 8ppm for two hours contact time or until the reaction is complete (Steen 2006).

After chlorination, it is necessary to remove the chlorine and residual organic matter using carbon filters. They are very similar to sand filters except activated carbon is used.

Activated carbon is produced by the controlled burning of 1000 degrees Celsius of carbon rich materials such as coal, wood and nut shells (Steen 2006).

Ingredients and Carbonation

Once the water is treated, the ingredients are mixed in with the water. The components of a typical soft drink are as follows: sugars, fruit juice, high-intensity sweeteners, carbon dioxide, acids, flavors, emulsion, colors, preservatives, antioxidants, quillaia extract, hydrocolloids and vitamins/minerals (Steen 2006).

Sugars, fruit juice and high intensity sweeteners contribute to the sweetness, body, flavor, and mouth-feel effects to drink. Carbon dioxide adds sparkle, acids contribute sharpness, sourness and background flavor and emulsion gives the cloudy effect. Preservatives restrict microbial attacks, antioxidants limit flavor and color deterioration, quillaia extract provides heading foam, and hydrocolloids provide shelf life stability and viscosity. Lastly, vitamins and minerals provide nutritional requirements.

These ingredients constitute the syrup of the drink. This syrup is mixed in with the water in what are called “syrup rooms”. The syrup rooms have machines made up of valves, pipeline and stainless steel tanks that mix all the ingredients together. After the ingredients are mixed together, it undergoes a carbonation process then is ready to be packaged.

Packaging

Once all of the ingredients are mixed together, the soft drink is ready to be packaged. The goal of packaging, as stated in David P. Steen’s <u>Carbonated Soft Drinks: Formulation and Manufacture</u>, is to “contain, protect, market, identify, and sell a product to bottler’s customers, retailers, and their consumers, whilst ensuring that it has been developed and made with consideration for the environment and all at a minimum cost” (Steen 2006). Packaging has a great impact on the environment because soft drink manufacturers must design their packaging to be suitable enough to be disposed, recycled, or reused. Attempts to mitigate these impacts are discussed in the next section of the report.

Packaging Practices and Goals

In this section, we will examine the packaging practices and goals of the two soft drink manufacturers in our study, Coca-Cola and Pepsi Co. Coca-Cola is one of the largest soft drink manufacturers in the world. One of the major contributing factors in their environmental impact is packaging waste. They have implemented a recycling program to lower packaging waste. Coca-Cola Recycling was created in 2007 to support their goal of recycling the equivalent of a bottle and can for every one sold in North America. They have placed more than 100,000 recycle bins in the market since 2008, making it easier for people to recycle used beverage containers (Coca-Cola 2009).

Coca-Cola also makes sure materials are recovered and reused. In 2010, Coca-Cola Recycling recovered more than 160,000 metric tons of aluminum and PET (Coca-Cola 2009). These materials were reused to produce new bottles and cans, apparel, carpeting furniture, etc. In addition, Coca-Cola has developed an in-house program to recycle and recover waste material in their production facilities. Participating facilities now recycle more than 96% of their waste, and diverted more than 140 million pounds of material out of landfills and into the recycle stream in 2010 (Coca-Cola 2009).

Pepsi-Co also has taken strides in reducing their environmental impact in terms of packaging waste. From their 2009 environmental report, Pepsi Co revealed their plans to reduce their environmental impact. Some of their promises include increasing the U.S. beverage container recycling rates to 50 percent by 2018 by working together with Waste Management, Greenopolis and Keep America Beautiful in implementing a program called the Dream Machine recycling initiative which encourages beverage container collection at public locations with a rewards points system. (Pepsi Co 2009) Another promise they have made is to continue to use 10 percent recycled polyethylene terephthalate (rPET) in their carbonated soft drink containers in the U.S. (Pepsi Co 2009).

Conclusion

Based on our report, we found that in the combined model Coca-Cola was one of two companies that remained efficient across all three years. In the single year model, both Pepsi Co and Coca-Cola remained efficient or even become more efficient each year. This shows that the environmental practices discussed in this report are strong and effective and that these companies are leaders in their industry in terms of eco-efficiency.

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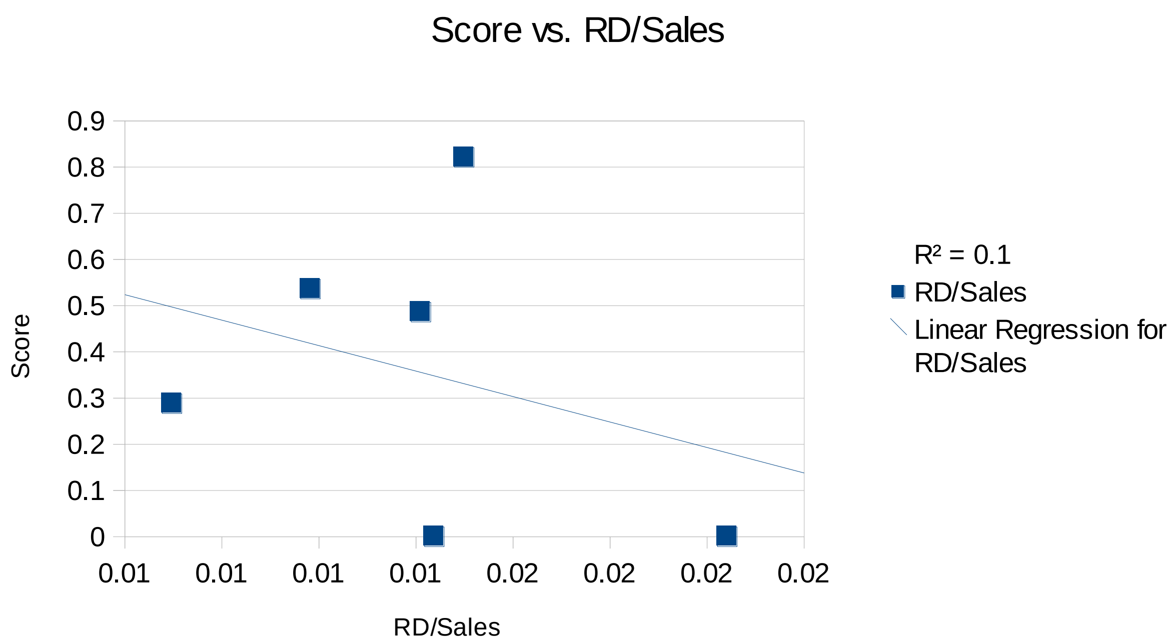
Appendix B: Graphs



Figures 1-4 are the correlation data using the contextual variables from 2008

Figure 1: Graph of correlation between RD/Sales and Score.

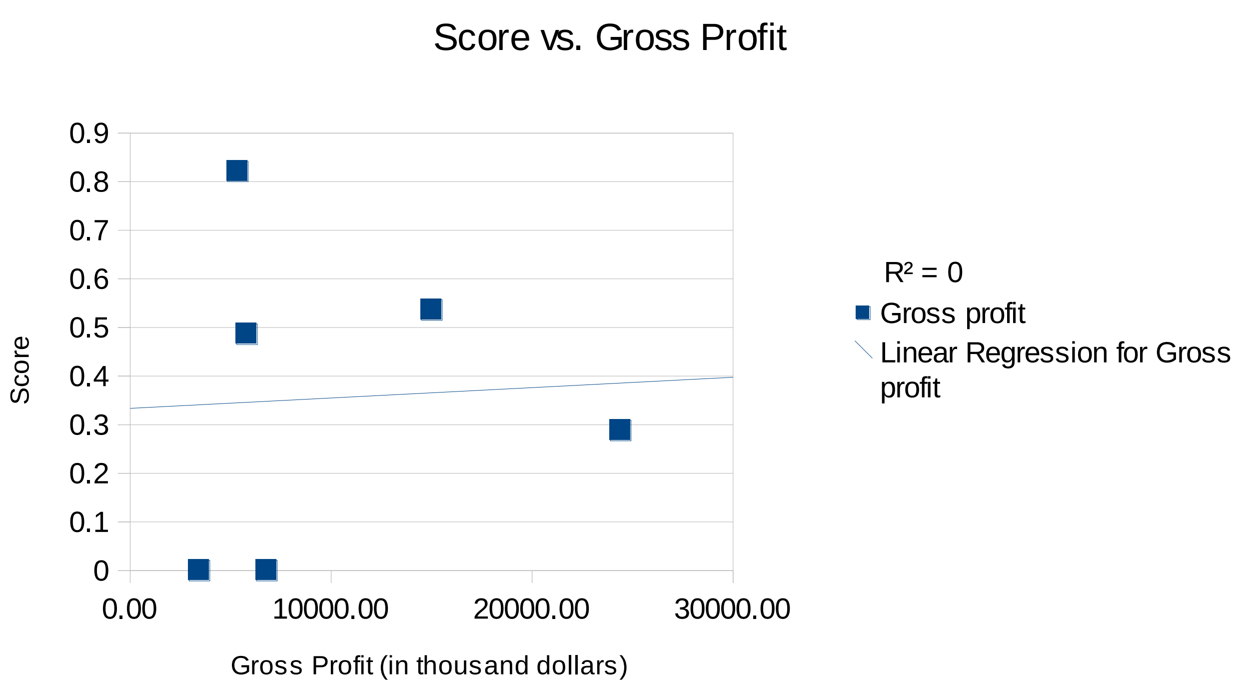


Figure 2: Graph of correlation between Gross profit and Score

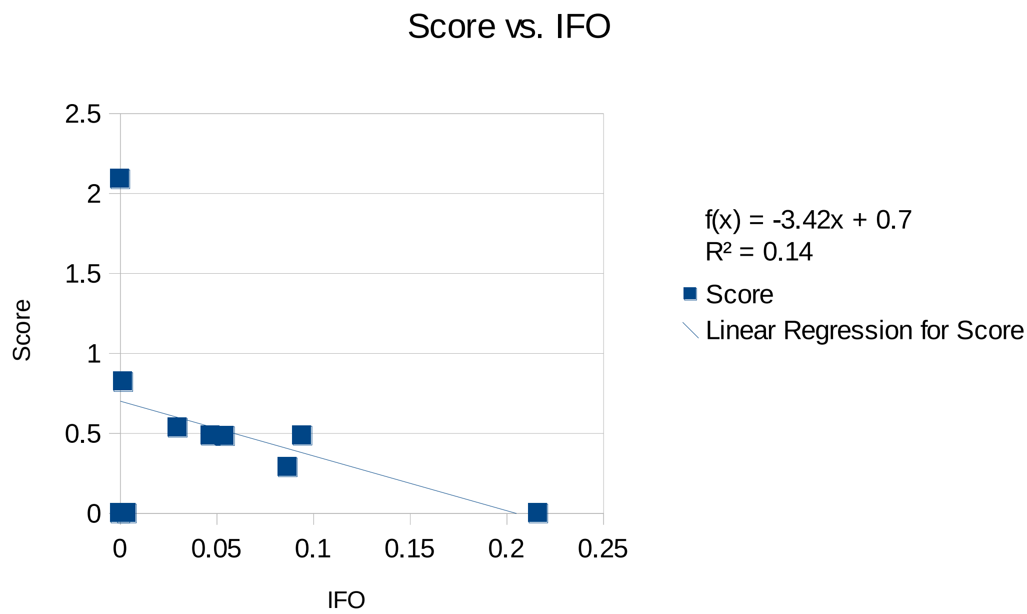


Figure 3: Graph of correlation between index of foreign operation and score

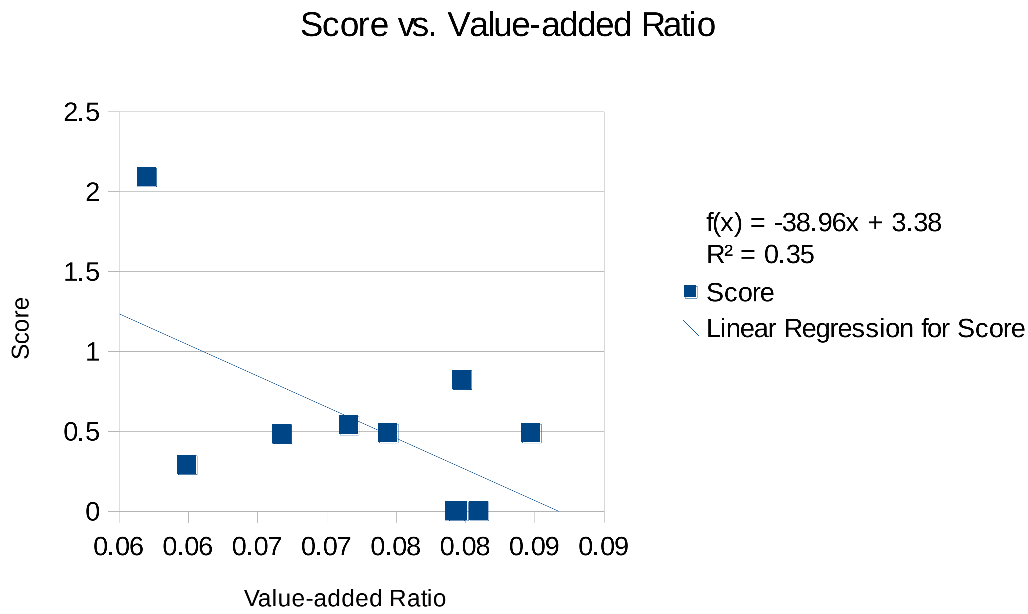


Figure 4: Graph of correlation between value-added ratio and score

Figures 5-8 are the correlation data using the contextual variables from 2009

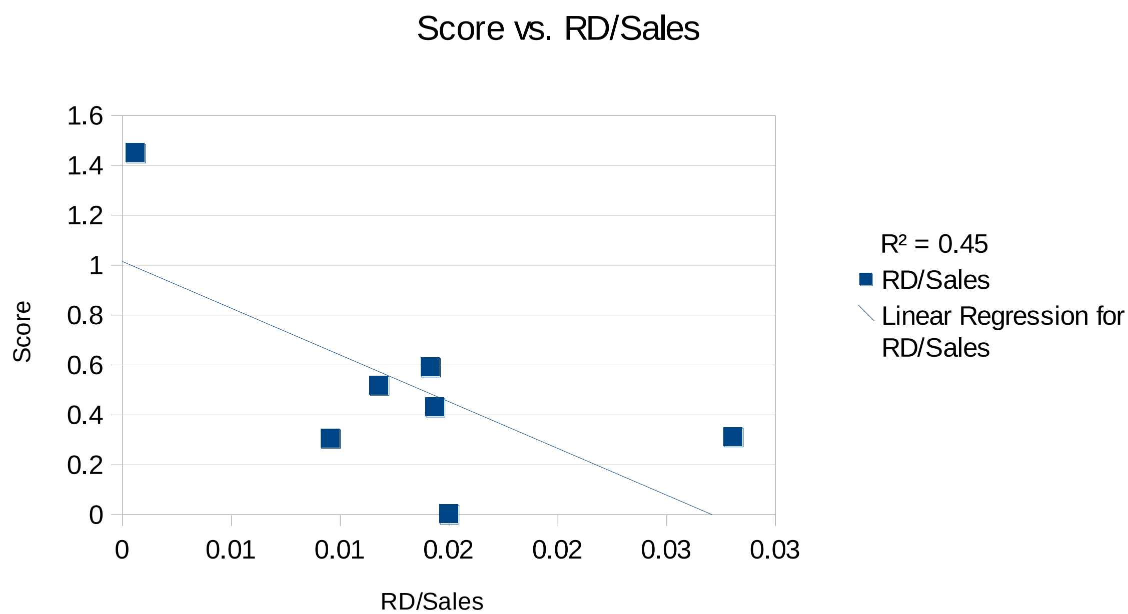


Figure 5: Graph of correlation between RD/Sales and Score

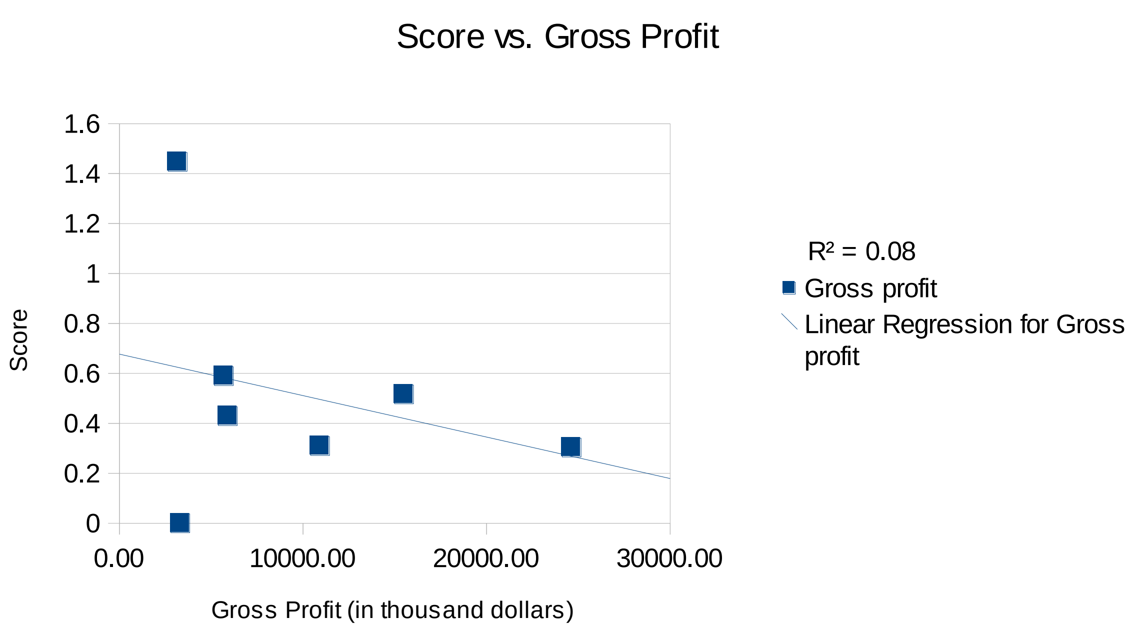


Figure 6: Graph of correlation between Gross profit and Score

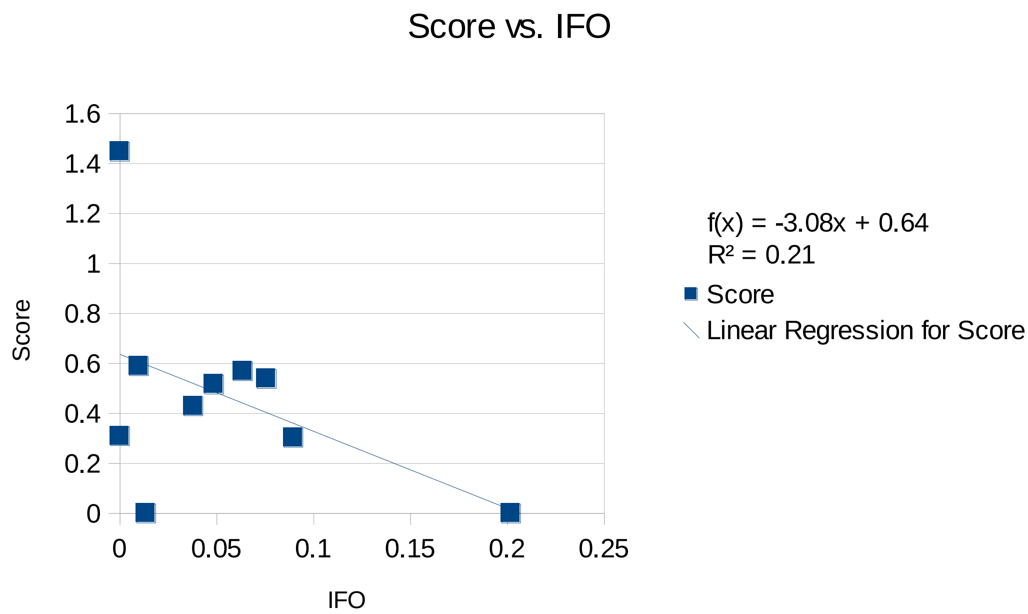


Figure 7: Graph of correlation between index of foreign operation and score

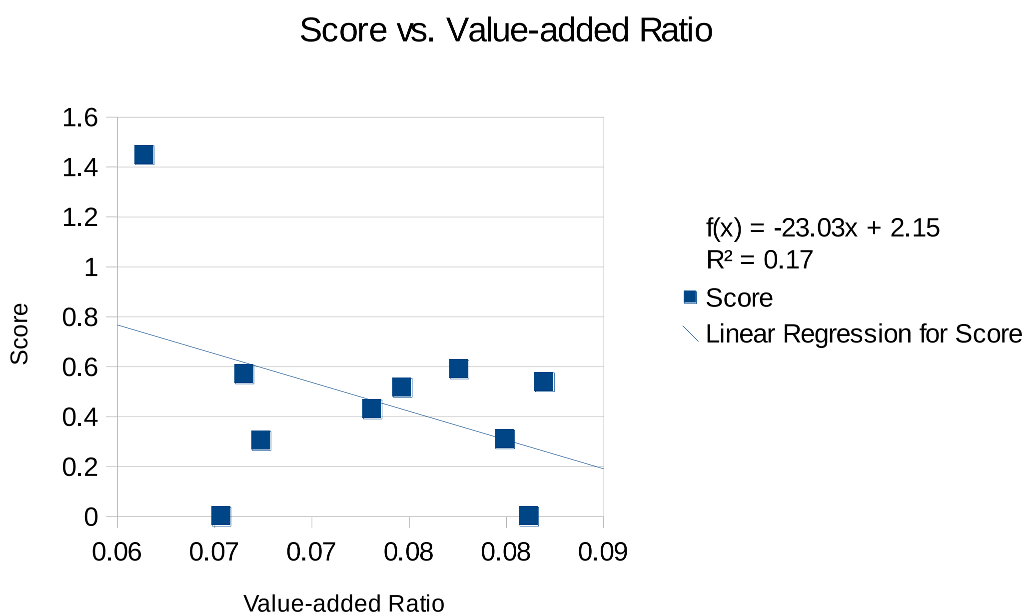


Figure 8: Graph of correlation between value-added ratio and score

Figures 9-12 are the correlation data using the contextual variables from 2010

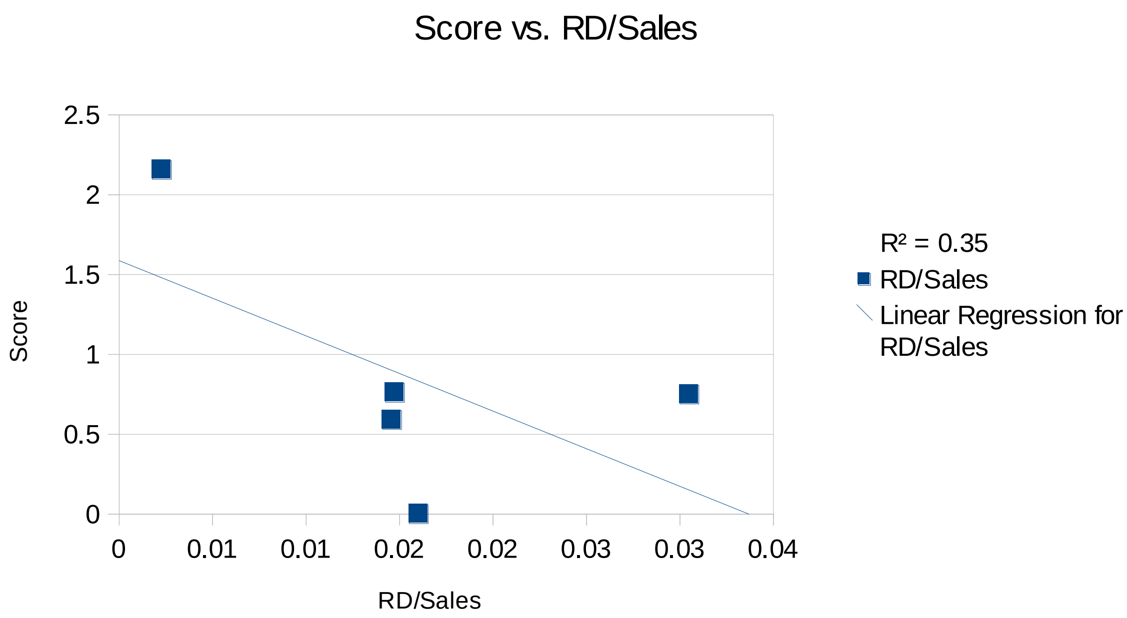


Figure 9: Graph of correlation between RD/Sales and Score

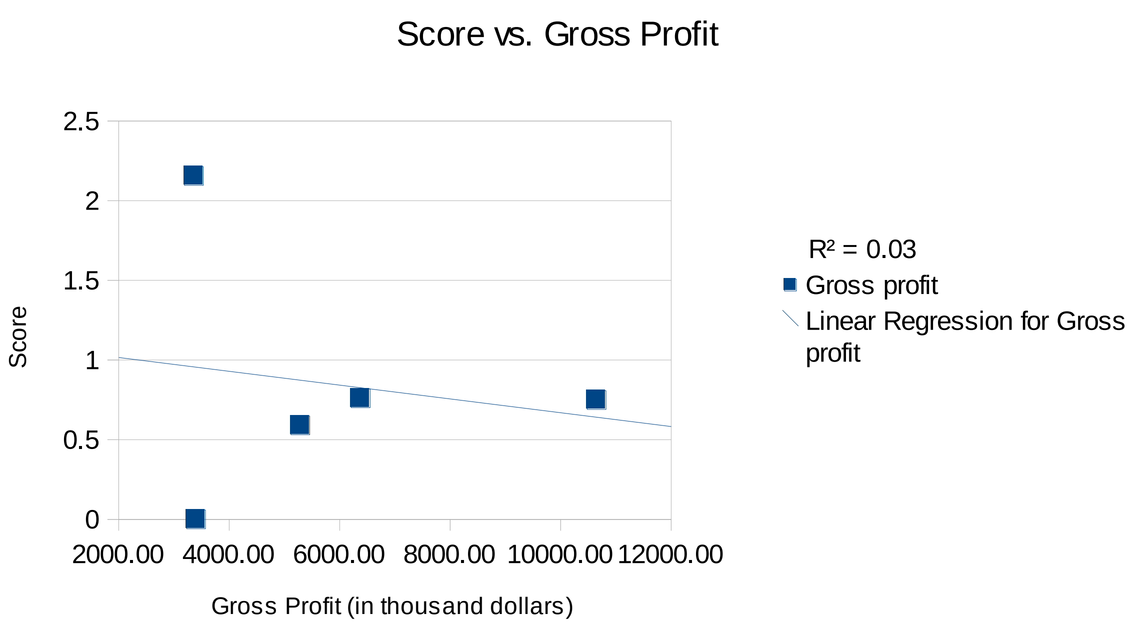


Figure 10: Graph of correlation between Gross profit and Score

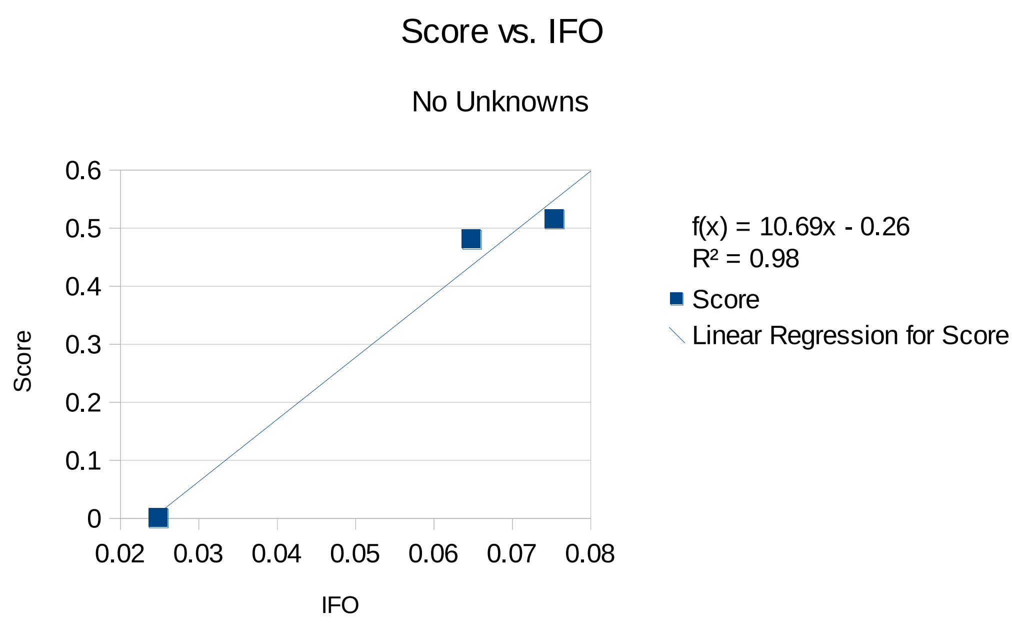


Figure 11: Graph of correlation between index of foreign operation and score; R^2 values are so high because only three companies had complete data for 2010

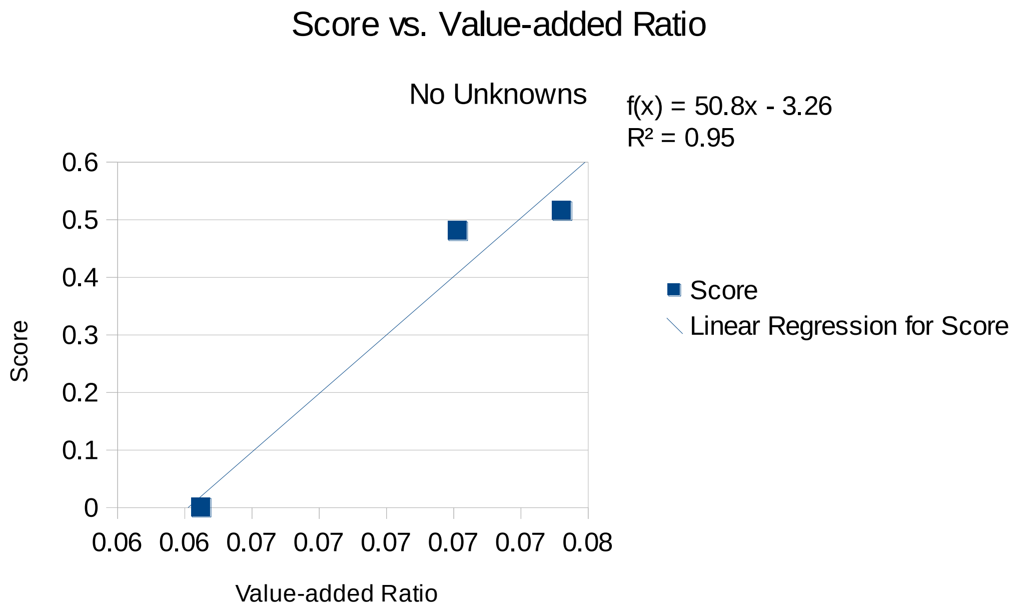


Figure 12: Graph of correlation between value-added ratio and score; R^2 values are so high because only three companies had complete data for 2010.

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