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SUSTAINABLE NOTEBOOKS: WHO CARRIES THE COST?

Research-in-Progress

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Abstract

The portable computer or notebook has become an integral and even essential aspect of modern life. Year-in-year its price to the consumer falls while its performance grows, yet recent analysis suggest that pound-for-pound its environmental costs are amongst the highest of any product on the planet. In this paper we explore the market price of “sustainable” notebooks. Drawing on the framework of the ‘tragedy of the commons’ we postulate that as manufacturers shift costs away from the commons to comply with sustainability standards, the cost to the consumer will inevitably rise. We test our hypothesis by comparing the prices of EPEAT Gold certified notebooks with uncertified portable computers. The results are discussed, alternative hypotheses explored and further research outlined.

Keywords: Tragedy of the commons, notebooks, sustainability, price analysis

Introduction

The portable computer or notebook is ubiquitous; its sales have recently surpassed those of desktop machines, and wherever one looks in a modern city – train, bus, café and office – one will see peoples' faces washed in the pale light of a notebook's florescent screen. Its pervasiveness has been fueled in part by a year-in-year fall in price (both nominal and real) to the consumer – notebooks which ten years ago would retail for \$2,000 can now be purchased for as little as \$300 (Scheck and Chao 2009). Against this backdrop a recent report came as quite a shock: the manufacture and distribution of a ten pound notebook computer requires an estimate 40,000 pounds of materials to be processed and distilled (Anderson, 1998, p. 9). Moreover, the average lifespan of that notebook is only three years, and at the end of that lifespan the device will end up in a landfill along with 55 million other units each year (Klatt, 2003). Combine this with the environmental costs of manufacture, powering and disposal of the device and \$300 notebook suddenly looks very, very expensive.

This has not gone unnoticed by the public, politicians and manufacturers alike – there is an increasing awareness of the wider ecological and social costs associated with products such as computer notebooks (Matthews & Matthews, 2003). From the manufacturers' side, prompted by consumers, pressure groups and politicians, there has been drive produce more sustainable offerings. In this paper we explore the market price of "sustainable" notebooks. Drawing on the framework of the 'tragedy of the commons' we postulate that as manufacturers shift ecological and social costs away from the commons to comply with sustainability standards, the cost to the consumer will inevitably rise. We test our hypothesis by comparing the prices of EPEAT ("Electronic Product Environmental Assessment Tool") Gold certified notebooks with uncertified portable computers.

The paper is set out as follows. First we review the ecological impact of the notebook – the total 'real' cost of the product. Second, we introduce the tragedy of the commons framework from which our hypothesis is developed. Third, we describe a study of in which we compare the prices of sustainable-certified and non-certified notebooks, controlling for factors such as processing power and screen resolution. Finally, the results are discussed, alternative hypotheses explored and further research outlined.

The real cost of the notebook

The average cost of a notebook computer has continued to decline year over year. These reductions in price coupled with a corresponding increase in performance have resulted in the rapid growth in performance per dollar and thus in consumer value. This powerful combination has led to the year over year growth in notebook. IDC forecasts the sale of PCs in 2009 will amount to 282 million units worldwide and 62 Million units in the US, with portables making up 33 million units (53%) of the total 2009 US PC market. (Bell & Daoud, 2009). With an estimated lifespan of three years and an approximate average of 26 million notebooks sold per year in the US over the period 2004 through 2009 the enormity of scale is obvious.

However, although the cost to the consumer has fallen, there is increasing realization that this cost represents a fraction of total 'real' cost to manufacture, distribute, operate and dispose of a notebook computer. Various researchers have investigated aspects of lifecycle assessment of notebook computers. Williams (2003) evaluates the environmental impact of manufacturing computers, Cole (2003) their energy consumption. Work by Lu et al. (2006), Hieronymi and Schneider (2003) examine governmentally mandated disposition programs. Klant (2003), the recycling of personal computers. Unfortunately, none of the existing research provides either a full cradle to grave LCA assessment of notebook computers let alone a wider sustainability assessment of the full impact of a notebook computer. The conclusion of all these studies is that the cost of a notebook to the consumer represents a fraction of its total wider environmental and social cost – by a multiple of ten (Computers and the environment: understanding and managing their impacts, 2003). This is increasingly being acknowledged (Williams, 2003) and action taken to remedy matters. Thus manufacturers are voluntarily (in some cases) and under regulatory coercion (in others) adhering to criteria of sustainable production. The key question is – who will end up bearing the cost? To understand the logic of how notebook manufacturers got into the position of producing massively unsustainable notebooks, and who might bear the cost of sustainable manufacturing we turn to the tragedy of the commons.

The tragedy of the commons

So how can we account for the disparity in price to the consumer and cost to the planet? One answer lies in a theory developed Rev. William Forster Lloyd (1833) in the 19 century: the tragedy of the commons. Simply put this theory describes the mechanism by which utility-maximizing individuals, when coupled with a collective resource (the commons) that leads to the depletion and eventual destruction of the resource and potentially the individuals who benefited from it. In the more bucolic language of Rev. Lloyd, individual herdsman graze as many animals as possible on the commons because the cost of feed is share by all those who graze the commons, but the benefit of the stock accrues only to the individual herdsman. The corollary of this is that over time the commons becomes overgrazed and non-productive – the animals die and all suffer. The tragedy of the commons is thus a conceptual categorical miss-specification: individual maximization with a collectively held resource results in disaster. Collective resources need collective-level thinking, and critically, collective-level coordination of action.

Thus, from the tragedy of the commons perspective the disparity in price to the consumer and cost to the planet is a logical corollary of this categorical miss-specification. Manufacturers seek to maximize utility by off-loading the real cost of manufacturing, distribution and disposal to the commons (in this case the planet) through pollution, depletion of resources, exploitation of workers in developing countries etc. The difference between the cost to the manufacturer and actual cost, are born by the planet and all its constituent life forms - over many decades and even centuries.

Applied to the notebook - As the research that does exist shows, the impacts of a notebook computer far exceed their nominal costs. Manufacturers and consumers are distributing the real costs across the commons. The seeming inevitability of this flows from the logic that to be competitive, manufacturers must make choices that compromise the environment in the name of competitiveness and consumers are more than willing to have them make such a tradeoff in the name of affordability. Thus, the tragedy of the commons gets reenacted over and over again. This leads us to the proposition:

P1: The price of sustainably produced laptop will be higher than the price of one developed to conventional standards.

What constitutes a sustainable notebook?

How then can we measure the economic, ecological and social impacts; the sustainability of a notebook? Conversely, how do manufacturers assess and describe the sustainability of their products? There are a variety of measures that are used. Life cycle assessments are almost exclusively used by producers as a means of gauging and evaluating the efficiency and impact of products and services within the production process. Externally, various measures are used ranging from energy efficiency to ecological impact and several extend to social impact as well. These measures fall into a hierarchy ranging from mandatorily established guidelines through full sustainability measures.

Legislative and regulatory guidelines establish mandatory limits within which manufacturers must operate. Most focus on a specific component of the overall lifecycle – with the majority focused on waste reduction and elimination. Among these, the EU’s Waste Electrical and Electronic Equipment Directive (WEEE Directive) stands out. The WEEE sets requirements for reduction of hazardous materials, mandatory manufacturer takeback and recycling/reuse for consumer electronic products. The stated objective of WEEE is “...the prevention of waste electrical and electronic equipment (WEEE), and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste. It also seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment...” (WEEE Directive) Other similar programs include Taiwan’s Waste Disposal Act Amendments (AWDA) and Japans mandatory appliance recycling regulations (Lu 2006). In the United States, there is currently no national legislation of this sort, although at the time of this article, 18 states and New York City all have enacted legislation ("State Legislation," 2009).

It is only through voluntary programs that we gain insight into the sustainability of various products. These voluntary reporting programs can be subdivided into self-reported ratings often called “green” symbols or claim statements and “eco-labels” that are awarded to certain products by third-party organizations that established and

administer label criteria. We will focus on eco-labels as formally defined by ISO 14020 - Environmental labels and declarations(2000). An "ecolabel" identifies the overall environmental characteristics of a product based on life cycle criteria. There are a multitude of eco-labels in use today; Appendix 1 provides an overview of many of them including a guide to the type of rating they provide: energy, ecology, or sustainability.

The study

Methodology and Sample

We test the tragedy of the commons hypothesis by comparing the selling price of notebook computers produced sustainably with those produced to normal marketplace standards within the US market. If our hypothesis holds, it will be more expensive to produce a sustainable notebook computer than a normal one. Voluntary eco-labels provide us with a convenient means of assessing the sustainability of various notebook computers. Among these eco-labels, EPEAT offers the most comprehensive data and applicability to the US market.

EPEAT is a not-for-profit organization dedicated to providing information on the environmental characteristics of select electronic products. An EPEAT eco-label that indicates that a given product has attained one of three tiers of EPEAT certification allowing manufacturers to differentiate their products in the marketplace. EPEAT ranks products in relation to 51 criteria. These criteria are fully detailed in the IEEE 1680 standard (2006). Most criteria are for environmental performance characteristics of the product. Some criteria relate to corporate-wide programs that encompass all products such as a Corporate Environmental Policy or an Environmental Management System. EPEAT offers three tiered ratings: Bronze (23 required criteria), silver (23 required and at least 50% of the 28 optional criteria) and gold (23 required and at least 75% of the optional criteria).

For our analysis we will compare notebook computer systems attaining the EPEAT Gold ratings to standard systems that have not received any EPEAT certification. Meeting the highest environmental standards, the EPEAT Gold rated systems would be expected to have the highest associated cost. Data was collected on 20 EPEAT Gold rated notebook computers and 20 standard notebook computers which have not received any EPEAT certification. All specification and pricing data was retrieved directly from the manufacturer's web sites on a single day for US models and pricing. Only mainstream brands were selected for the analysis. The attributes collected for each system are summarized in Table 1.

To determine the impact of EPEAT GOLD ratings on price we begin our analysis by conducting an ANOVA analysis of EPEAT Gold rated systems versus standard systems. A Levene Statistic test indicates that we reject the null hypothesis that the variance of prices for the two groups are equal (Levene=8.137, $p=.008$) but since the two groups of equal size, ANOVA should be robust to this violation of assumptions. Comparing the mean price of the two groups using ANOVA, we find that we reject the null hypothesis and conclude that there is a difference between the mean price of EPEAT Gold rated and standard systems ($f=13.7$, $p=.001$). These results are inconclusive however, because the data selected for EPEAT Gold rated and standard systems may not represent comparable machines and configurations.

Research has shown that there is a direct relationship between computer prices and constituent features. Harris and Dave (1994) for instance developed a model that established a clear price-performance relationship to predict notebook computer prices based on select component features early in the growth of the notebook market. Rutherford and Wilhelm (1999) built on this research, extended and revalidating it in a more mature and comparable notebook market, yielding similar results to those of Harris and Dave.

The Rutherford and Wilhelm model depends on measures of CPU performance, display performance, hard drive capacity, memory and brand. The significance of brand in their study was highly dependent on the specific brand and as such, we exclude it from our analysis. Further, memory has become a low-cost commodity item and we therefore exclude it from our analysis. We create a measure for CPU performance equivalent to the speed of the CPU times the number of CPU cores and we calculate a display performance metric as the total number of display pixels. Finally we introduce a new variable consumer model, a dummy variable indicating if the system is a consumer or business notebook determined by the manufacturers marketing literature. Our modified Rutherford and Wilhelm regression model is:

$$\text{Price} = \beta_0 + \beta_1 \text{ CPU performance} + \beta_2 \text{ Display Performance} + \beta_3 \text{ Hard Drive Capacity}$$

Table 1: Feature attributes

EPEAT	EPEAT Gold rated (1=yes)
ENERGY STAR	Is the energy star status of the machine mentioned in the marketing materials (1=on specification page, 2=mentioned in product literature, 3=predominate marketing feature)
SUSTAINABILITY	Is the EPEAT rating of the machine mentioned in the marketing materials (1=on specification page, 2=mentioned in product literature, 3=predominate marketing feature)
PRICE	Manufacturers e-commerce price in dollars
SPEED	CPU Speed in megahertz
CORES	Number of CPU Cores
CPU	CPU Type
MEM	Memory in gigabytes
HD	Hard drive capacity in gigabytes
GRAPHICS	Graphics capability (0=embedded, 1-high-performance discrete)
DISPLAY	Display Size
RESOLUTION	Overall screen resolution
WEIGHT	Weight in pounds
CONSUMER	Is this system marketed to business customers or consumers based on manufacturers web site. (0=business customers, 1=consumers)

Results

Analysis against our data yields results as shown in Table 2 comparable to Rutherford and Wilhelm results ($R^2 = .665$).

Table 2: Results of initial regression model analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	628.212	385.077		1.631	.112
CPU_Performance	-214.154	90.136	-.305	-2.376	.023
Display_Performance	.002	.000	.644	5.456	.000
Hard_Drive_Capacity	-2.918	.838	-.411	-3.483	.001

$$R^2=.583, R_a^2=.548, F=16.78, p<.0005$$

A test for the overall validity and utility of the model indicates that we reject the null hypothesis and conclude that at least one of the parameter estimates is not zero. Testing model assumptions, we find no multicollinearity issues (Durbin-Watson=1.8 > $D_u=1.66$), residual analysis indicates no issues with heteroscedasticity but identifies three

potential outlying observations with studentized residuals greater than 2. Cooks distance indicates they have no undue influence and additional analysis indicates that these observations should remain. Residual analysis further indicates the data are normal (Shapiro-Wilk=.868, p=.312). Thus we conclude that we have good model fit and valid results.

From this model, we see that CPU performance, display performance and hard disk capacity account for approximately 54.8% of the variation in price. Based on these, we return to our test of the tragedy of the commons hypothesis by proposing a model as follows:

$$\text{Price} = \beta_0 + \beta_1 \text{ CPU performance} + \beta_2 \text{ Display Performance} + \beta_3 \text{ Hard Drive Capacity} + \beta_4 \text{ EPEAT Gold}$$

In this model, we introduce one additional variable, a dummy variable indicating EPEAT Gold rating. If as hypothesized the selling price of notebook computers produced sustainably is significantly different from those produced to normal marketplace standards, we would expect that the addition of EPEAT Gold rating to the model would result in improved predictability by our model.

Running the regression analysis of this model indicates that while the model shows overall validity (F=13.307, p<.0005), the parameter estimate for EPEAT Gold rating is not statistically significant from zero (t=1.337, p=.190). Based on these results, we conclude that we fail to reject the null hypothesis and conclude that the price of EPEAT Gold rated systems is the same as that of systems produced to ordinary standards.

Discussion

The tragedy of the commons framework suggests that notebook manufacturers will actively seek to shift costs of production onto the commons to maximize profits. Indeed we find ample evidence of this. Previous research suggests that much of the cost associated with producing and distributing a notebook is indeed borne by the commons. Sustainably developed notebooks are produced with the expressed intent of reducing the cost to the commons and as a result some of these costs are likely to be transferred to the consumer. Thus we hypothesized: The price of sustainably produced laptop will be higher than the price of one developed to conventional standards.

Contrary to our hypothesis, the results of our study indicate that notebooks produced to high sustainability standards do not differ significantly in price from those produced to de facto norms. These converse findings lead us to explore alternative hypotheses – an important issue given the trend of notebook manufacturers adopting more sustainable manufacturing practices. We offer three alternative hypotheses for our findings: First, manufacturers may be swallowing the additional cost of sustainable notebooks (resulting in reduced margins) in order to remain competitive. Second, sustainable manufacturing may be more efficient than traditional practices thereby reducing costs. Third, costs may be shifted to other non monitored aspects of the commons. While each of these hypotheses offers plausible reasons for there being no difference in price between sustainably and non-sustainably produced laptops, none stands out prima facie as a sole explanation. Rather, the validity of each of these hypotheses supports the notion that a complex mix of factors may underlie the results. What is clear is that more research is needed.

Conclusion

Today, the portable computer or notebook is no longer an accessory it is part of the very fabric of modern life. Yet recent analysis suggests that these machines environmental impact is unsustainable. Drawing on the framework of the ‘tragedy of the commons’ we postulated that as manufacturers shift costs away from the commons to comply with sustainability standards, the cost to the consumer would inevitably rise.

To test this hypothesis we explored the market price of “sustainable” notebooks. We tested our hypothesis by comparing the prices of EPEAT Gold certified notebooks with uncertified portable computers and found no significant difference. These results led us to propose three alternative hypotheses to explain this outcome. We conclude by speculating that there may be a complex mixture of factors driving the pricing strategies of sustainable notebooks. Further research is needed to understand these mechanisms and their outcomes.

Appendix 1 Eco-Label Providers

Eco-Label	URL	Region	Overview	Rating Type
EPEAT	http://www.epeat.net/	USA	A system to help purchasers evaluate, compare and select electronic products based on their environmental attributes. The system currently covers desktop and laptop computers, workstations and computer monitors. EPEAT is based on the IEEE 1680 family of standards for electronic product environmental assessment. Desktops, laptops and monitors that meet 23 required environmental performance criteria may be registered in EPEAT by their manufacturers. Registered products are rated Gold, Silver or Bronze depending on the percentage of 28 optional criteria they meet above the baseline criteria. EPEAT operates an ongoing verification program to assure the credibility of the registry.	Environment
ENERGY STAR	http://www.energystar.gov/	USA	ENERGY STAR certified computers meet energy use guidelines in three distinct operating modes: standby, active, and sleep modes. ENERGY STAR qualified computers must also have a more efficient internal power supply.	Energy
EcoLogo	http://www.ecologo.org/en	North America	Provides customers – public, corporate and consumer – with assurance that the products and services bearing the logo meet stringent standards of environmental leadership.	Environment
Eco Flower	http://ec.europa.eu/environment/ecolabel/index_en.htm	EU	It is a voluntary scheme designed to encourage businesses to market products and services that are kinder to the environment and for European consumers - including public and private purchasers - to easily identify them.	Environment
Blue Angel	http://www.blauer-engel.de/en/index.php	Germany	Awarded to companies as kind of a reward for their commitment to environmental protection. They use it to professionally promote their eco-friendly products in the market.	Environment
TCO Development	http://www.tcodevelopment.com/	Sweden	TCO labelling requirements include low energy consumption and restrictions in the use of environmentally hazardous substances. TCO-labelled product must meet specific ergonomic, picture quality and sound quality requirements. In addition, its noise level and electrical and magnetic fields must be kept to a defined minimum.	Energy Hazardous Mtls Usability
Nordic Swan	http://www.svanen.nu/Eng/	Norway, Sweden, Denmark, Finland, Iceland	Nordic Ecolabelling has the commission to promote a more sustainable consumerism with the goal of creating a sustainable society. This is done by a voluntary license system where the applicant agrees to follow a certain criteria set outlined by the Nordic Ecolabelling in cooperation with stakeholders. These criteria include environmental, quality and health arguments. The criteria levels promote products and services belonging to the most environmentally sound and take into account factors such as free trade and proportionality (cost vs. benefits).	Environment Social Impacts
Eco Mark	http://www.ecomark.jp/english/	Japan	Certification Criteria for every product category takes the environment, the life stage (resource extraction, manufacture, distribution, use, disposal, recycling) of products into consideration. By indicating Eco Mark on a product it is certified as being useful for environmental preservation. Also for consumers who wish to be in environmental - friendly living condition can make choice of products more easily.	Environmental
Green Seal	http://www.greenseal.org/	US	Provides science-based environmental certification standards that are credible, transparent, and essential in an increasingly educated and competitive marketplace. Our industry knowledge and standards help manufacturers, purchasers, and end users alike make responsible choices that positively impact business behavior and improve quality of life.	Environmental
Climate Savers	http://www.climatesaverscomputing.org/about/tech-specs/	US	Members commit to specifying systems that meet or exceed the latest ENERGY STAR specification for a majority of their corporate personal computer and volume server purchases. In addition to fulfilling purchase requirements, members also commit to use computer power management features whenever possible.	Energy

NOTE: All overviews are adapted from the Eco-Label web site's self descriptions.

Additional eco-labels can be found at: <http://www.globalecolabelling.net/> and http://ec.europa.eu/environment/ecolabel/other/int_ecolabel_en.htm

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