Davidson College
Senior Session: "Should You Pay for Printing at Davidson College?"
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Correcting the Externality of Free Printing at Davidson College:

Pollution Abatement Taxes versus Marketable Printing Permits

Section I. Introduction

Public printing facilities currently pose a problem of negative externalities at Davidson College. At present, printing costs are included in tuition, meaning there is no per-use or per-page fee on student printing in public Information Technology Services labs, academic classrooms, or the Library. These transactions allow for the generation of waste, specifically by the amount in excess of the value each student places on a given printed page.

Each day thousands of sheets of paper are being cycled through the public printers dispersed across campus. It is not uncommon to visit a student computer lab and find a pile of unclaimed paper built up next to the printers. Can Davidson College achieve a socially efficient outcome? We propose two solutions whereby the answer is yes. First, we would assign property rights to the right to print a page and distributing these to students via initial bulk purchase and auction. This will result in the right to print having an economic value. In the ensuing market, students will reveal their value of printing through buying and selling the permits. Alternatively, we propose using a "pollution tax." This system will require students to pay a per-page charge, or tax, for each page printed by the public printers on campus above a given page limit.

Going to the economic literature, we initially compare our solutions to each other and to alternative solutions (command-and-control and the *status quo*) and discuss why the literature

might prefer one approach or another. Our paper then considers the current demand, supply, and costs of printing on Davidson's campus. We provide an all-inclusive cost structure that allows us to determine the exact cost of one sheet of paper; we also submit an acceptable percent reduction.

Finally, we present the plans in detail. In doing so, we ask: what considerations must be overcome in creating an effective, sustainable, and user-friendly new market? Will the system result in outcomes consistent with the overall purpose of Davidson College? And is such a system cost-effective to set up?

Although currently a hypothetical solution to the college's wasteful paper usage problem, we find that the practicality of either system and the cost savings are reasons enough for Davidson College to implement either a permit structure or pollution tax to internalize the marginal external costs of printing, providing net benefits for the college.

Section II. Literature Review

Previous economic literature has extensive work on pollution and externalities, including both "Pigouvian" taxes and the efficiency of permits (as well as guidelines on creating and implementing permit structures). While none of the articles address the negative externalities involved in a system that allows for free printing, the basic concepts of these works can be applied to printing at Davidson College.

Pollution Tax Literature

Ronald Coase's "The Problem of Social Cost" tackles the issue of private costs deviating from social costs and how the problem can be rectified (1960). Dr. Coase argues that a "Pigovian" tax may not necessarily lead to an optimal condition. Ralph Turvey's "On Divergences Between Social Cost and Private Cost" comes to a similar conclusion of Ronald

Coase's paper. Turvey, however, adds a significant qualifier that is relevant in our paper printing project. Turvey notes that if one group, either the group that is producing the negative externality or consuming it, is too large there is room for intervention "*if* the state [college in our case] can ascertain and enforce a move to the optimum position at a cost less than the gain to be had, and *if* it can do this in a way which does not have unfavorable effects upon income distribution" (312). Turvey says, in order for the state to move to the optimal position, it must identify all options open to the group causing the negative externality and then see how those options affect the harmed group.

There have been many governmental actions, and even more are in the planning stage, to control industries or products that result in significant negative externalities. One such example concerns heavier taxing of alcohol products to reduce its negative externalities. Thomas Pogue and Larry Sgontz's "Taxing to Control Social Costs: The Case of Alcohol" provides a framework for implementing the optimal tax (1989). There are two sides to the case for taxing alcohol. The first is that the external costs associated with the actions that result from alcohol are so high that taxes should be used to control alcohol consumption. The other side focuses on the individual satisfaction alcohol gives its consumers. This side argues that a tax on alcohol would punish the many who do not produce externalities in order to control for the very few who do (p. 235). The authors build their model accounting for the differences between the two types of alcohol consumers, abusive and non-abusive along with the external and internal costs that result from alcohol abuse. They come to a conclusion that tax rates should be at least double the then-current tax of 25% if abusers respond to price changes the same way the non-abusers do. This tax rate would lead to an estimated $2.008 billion dollar decrease in negative externalities and a $6.974 billion decrease in negative internal externalities, which more than make up for the

$1.473 billion loss of consumer surplus (p. 241). This paper shows that a tax can be an effective measure in reducing the consumption of goods that produce negative externalities.

A significant portion of the externality literature is focused on large-scale pollution/environmental control problems. One such example as Richard Howrath's paper, "The Present Value of Criterion and Environmental Taxation: The Suboptimality of First-Best Decision Rules" that focuses on carbon dioxide emissions (2005). The authors use first-best and second-best methods to determine the appropriate tax on carbon-dioxide emissions. The first-best decision rule has emissions taxes based on the net present value of emissions reduction. The second-best method sets emissions tax rates to optimize welfare for individual households (p. 322). These taxes can then be used as transfer payments (lump-sum recycling), to reduce marginal labor and capital tax rates (proportional recycling) or to reduce taxes in a specific sector (targeted recycling). The results show that for the first-best decision rule and proportional recycling the tax is initially set at $25 per ton of CO_2 in the year 2000 and gradually rises to $185 in the year 2100. This produces an annual reduction of emissions of 2.1 billion tons of CO_2 that gradually increases to a 12 billion ton annual reduction in 2100. The net welfare gain from this tax would be 18.2 trillion dollars. The second-best strategy for proportional recycling yields similar results (p. 330). Dr. Howorth shows that not only will a tax be effective in controlling emissions of a substance that produces a significant negative externality, but also that significant welfare gains can accompany the tax.

A successful application of a tax scheme can be witnessed in the program that the Netherlands created to reduce its industrial water pollution (Bressers and Kris 2004). Visible water pollution was noticed by the public in the 1960's and 1970's, which led to the Surface Water Pollution Act. This act regulated emissions over 500 m^3, pollution of oxygen-demanding

substances above 5,000 population equivalents (PE), any toxic substance, and/or certain categories of firms. Netherlands created a three-tiered tax system with 1995 fees approximately €36 per PE. The lowest level involved emissions less than five PE with taxes at either three PE's or one PE. The next level targeted companies with discharges less than 1,000 PE's and were charged in accordance with a chart that gave a determination of their emissions. If these companies believed that they were being overcharged they could ask for a precise measurement to reduce their fees. The highest tier involved companies over 1,000 PE's, and these companies were charged through measurements determined by water samples.

The fees were very effective in reducing the industrial gross discharge of oxygen-demanding substances. From 1975 to 1985 the discharges were reduced from 15.3 to 5.9 million PE's and, in 1995, were reduced further to 3.3 million PE's (p. 98). Many factors led to the policy working so well. There was a social concern for pollution that needed to be addressed by the government. The fees were fair in that industries that polluted more had to pay higher fees. The fees could not be avoided and monitoring of the costs was not difficult (p. 109). There was relatively large short-run pollution elasticity, and finally, there was still an incentive for companies to develop methods to reduce their pollution emissions. The Netherlands case gives a fine example of how an equitable system can reduce pollution without imposing extraordinary costs on the polluters.

Printing Permits Literature

Coase (1960) is one of the first major economists to analyze social costs. He aims to redefine how people think about externalities. Coase uses the example of a farmer and a cattle-rancher; the cattle often wander into the crops of the farmer and destroy them. The Coase theorem states that if property rights are clearly defined and there are no transaction costs, a

private solution to an externality is the most efficient way to resolve the conflict. The Coase theorem does not specify who should pay for the destruction; as long as property rights are defined, an efficient solution is reached.

Coase expands his analysis to include the possibility of transaction costs. In the case of the farmer and the cattle rancher, an agreement will only be made if the benefits of the agreement exceed the costs of reaching an agreement. Yet with paper printing, the situation is more complicated. One individual does not determine the difference between private and social costs, but it is instead the summation of all of the private costs and social costs that results in the overall social cost exceeding the private cost. It would be impossible to come to an agreement with each individual to try and equate private costs and social costs. When determining how to handle an externality, people must bear in mind that a change in an existing system will lead to improvements in some areas but might make other areas worse. Thus, when determining how to handle the problem of social cost, the total effect of a policy must be considered.

Ruff (1970) makes it clear that pollution is primarily an economic problem. Once a society achieves affluence (such as the United States), it begins to become concerned with the problem of pollution because its immediate needs are already met. Curbing pollution becomes a matter of cost-benefit analysis: abatement costs should never outweigh potential benefits. In his analysis, Ruff proposes four pollution abatement methods: direct regulation, mandatory reduction, reduction subsidies, and a price-based system. Direct regulation and mandatory reductions are similar, but the former implies a company must follow specific guidelines in order to reduce pollution while the latter does not specify how the reduction is achieved. If certain circumstances are met, a price-based system is the most effective of these four ways to reduce pollution.

If private and social costs and benefits can be identified, then a competitive market yields the most efficient outcome. Under the market based system that Ruff describes, the price of pollution would be set by an authority. Ruff's argument for a price based system is not purely theoretical; the Rhine River in Germany provides a real world example of how a price system works. Authorities of the Rhine determine the acceptable levels of pollution in the water (a level that will not destroy fish). Authorities simply charge firms according to how much waste they produce. If pollution levels begin to rise, the authorities raise the price of pollution and pollution levels will be reduced. While this tax system differs from the permit system presented in this paper, both systems are market based systems, and the Rhine provides a real example of an effective outcome reached through a market based system.

Walbert and Bierma (1988) describe a simple game that can be played in order to explain the benefits of marketable pollution permits. The game consists of firms that have current pollution levels of SO_2 and certain costs of reducing pollution. The government then decides it wants to reduce pollution to a specified lower level. The three options to reduce pollution in this game are 1) uniform emission limits – every firm can only emit 30 lb/hr of SO_2; 2) uniform percentage reduction – each company must reduce its pollution by a certain percentage; and 3) marketable emission permits – permits are either auctioned off or distributed to firms, who once they have them can decide to sell them to other firms. In each of these three cases pollution will be capped at the same amount. However, since different firms have different costs associated with reducing pollution, the permit system will allow the firms with a higher cost of reduction to purchase permits from firms that can more easily reduce pollution. Thus, the same level of reduction is achieved under the permit system at a lower cost.

Woodward (2005) takes the text book example of pollution permits and analyzes the real world effectiveness of a permit system. He explains that market systems (permit structures) have significantly reduced abatement costs while also increasing pollution abatement in sulfur dioxide emissions. The 1990 Clean Air Act created a system of marketable permits for SO_2. The program targeted and met a 50 percent reduction in SO_2 emissions compared to the 1980 level. The cost savings of this program compared to a command-and-control approach is estimated to be at $1 billion annually.

While a permit system can be effective, Woodward emphatically clarifies the importance of specifying details while creating a permit market and realizes that a permit structure is not always optimal. A successful permit program must be flexible, simple, and have clearly defined rules. An effective system must also be enforceable and have low transaction costs. Permit systems for water have not been an overwhelming success because water transfers require significant costs and trades are often not permitted by authorities. Under the Fox River trading program established in 1981, the first trade took place in 1996. Woodward warns us that market constructionists who do not pay attention to details will create a faulty system.

Further emphasizing the need for details, Colby (2000) provides a detailed outline of all the considerations an economist must mull over when creating such a market. Her cap-and-trade features provide a thorough blue-print with important caveats to consider, such as initial allocation of rights, the trading mechanism that will be put in place, and how trades will be approved. She also considers issues such as how assessing fees, limiting entry, and focusing on equity. Currently, cap-and-trade systems exist for SO_2 emissions, fishery quotas, and water usage. Due to the regulatory nature of the electric utility industry, firms have been more accepting of the cap-and-trade system for SO_2 emissions, as opposed to the reluctance expressed

by the fishing and water industries. Since the regulation has been accepted in the electric utility industry, a strong market for SO_2 permits has emerged and the cap-and-trade system for SO_2 has been more successful than that for fishing and water.

The subject of printer paper abatement has thus far been ignored by the economic literature. We have searched the literature to try and find smaller-scale implementations of tax systems, but we were unable to find any such papers. No literature has been published on printer paper abatement, especially none explaining a permit structure. If Davidson College chooses to implement a permit structure, it would be the first institution out of our peer group (and all colleges and universities) to execute this economically efficient method.

All schools that charge for printing rely on the tax method. Examples of peer colleges (strongly academic, small liberal arts schools) that do this include: Amherst College and Wellesley College (for color printing, exclusively). Pomona College gives each of their students a printing quota that they cannot exceed—an example of the command-and-control method. Swarthmore College tracks the amount of printing and has created the Paper Conservation Campaign, but its reduction method provides only tips to students as to how they can conserve.

Section III. Alternative Solutions & Criticisms of Proposed Solutions

When deciding whether a permit system should be implemented at Davidson, the alternative solutions must be addressed. The alternatives to a permit system or a tax system are to stay with the *status quo* or to implement a command-and-control system. Each system has its benefits along with its drawbacks.

Status Quo

Currently at Davidson College academic printing is free for students. A student may enter a computer lab and print as many pages as he or she needs for an assignment. The costs of

printing are then paid for by the school. This system has a number of advantages. The main advantage of the current system is that it does not incur any new costs to the school. If student printing were to be monitored, it would require new software to monitor student printing, and there would be added administrative costs to monitor the system and fix the server when problems arise. According to Davidson's ITS, a print monitoring system would require a new computer in each major lab in order to monitor printing. All of these start-up costs are avoided if the current system is kept in place.

Another reason in favor of the *status quo* is simplicity. Lumping printing fees into student tuition or other revenue sources eliminates transaction costs. The existing framework also minimizes dependence on untried new technologies; if the server for the print monitoring software were to crash, all printing on campus would stop; this is not a concern under the current system. Also, computer lab administrators would be able to focus on other computing needs if they did not have to monitor the print system.

Lastly, the current system provides a maximum level of equity to students. Many students come from different economic backgrounds. Under the current system, those who might not have the financial capacity to pay out-of-pocket for their printing needs do not undergo any further hardship. It should be noted that all students, including those on financial aid, are already paying for socially inefficient—i.e., wasteful—printing levels (or having that printing level subsidized for them).

The problem with the current system is that massive quantities of paper are printed and not all of this is socially desirable. Since students pay no fee for printing, if there is any positive value associated with printing a page, that page will be printed. Since the private cost of printing (zero) is always less than the social cost of printing, the amount of pages printed exceeds the

socially desirable number of pages. We have measured that anywhere from 12 to 15 percent of paper have can be wasted on a given day.[1]

Under the current system two steps could be taken to attempt to reduce the number of pages printed. First, signs could be posted reminding students that the printers are supposed to be used for academic purposes. Due to Davidson's strong Honor Code, a "personal use" jar could be put in the lab and students would pay on their way out for the personal printing. This method has been tried unsuccessfully in the past, likely not due to dishonorable behavior but rather inconvenience and inefficiency (ITS staff described several instances of students not having proper change to leave as payment, using paper "IOUs" that then needed to be settled, etc.). A second method educates students about the cost and social waste of excess printing. Signs could be posted throughout the lab indicating how many pages have been printed and encourage students to attempt to reduce the amount they print. This method is a form of voluntary restraint, essentially a conservation approach, and the key to this would be the students' willingness to change their printing habits when they have no economic incentive to do so.

Command-and-control

Another alternative is a command-and-control approach. Under a command and control system the school would set an upper limit on the number of pages that each student prints. This type of system is the most widely used by the government to control negative externalities (Ruff 1970). This system has a clear advantage: a set reduction in the number of pages printed. It also is simpler than the permit system (though not the tax system) because no market would need to be created for students to exchange printing rights.

[1] We conducted our measurement by counting the number of discarded pages by several campus printers versus the number printed over a half-day span. We measured at varying periods (mid-day, evening, etc.) and on differing days.

While uniform limits on printing are straightforward, the system still requires many of the costs that either the tax or the permit system would require. These include tracking student printing allotments, setting up initial allocations, determining the socially optimum level of printing, etc. Also, there are much greater costs to students imposed under a command-and-control approach as opposed to a permit system. Since different students have different needs, students with high printing demand would be severely punished under the command-and-control system. Some would have excess printing capacity (still wasteful) and some students would have printing shortages. As with the SO_2 permit system cited earlier, marketable printing offers a potentially lower-cost alternative to a command-and-control system (Walbert and Bierma 1988). It is estimated that the SO_2 permit system in the United States achieves a costs savings of $1 billion a year over the command-and-control alternative (Woodward 2005).

Tax System Criticisms

A tax system at Davidson has its drawbacks. There are three main problems with a tax system when compared to the permit system. The first is that while there is a reduction in the number of pages produced, the actual amount of the reduction is not known until the end of the semester.

Second, Collinge and Oates (1982) explain why taxation does not abate pollution as well as a market system. First, they define a Pigouvian tax: a tax on an externality equal to the difference between the marginal private cost of the activity causing the externality and the marginal social cost of the activity. In order to be an efficient solution the marginal value of the firm's output must equal the marginal cost. Secondly, to be a long run efficient solution the total value of the firm's output must not be less than the total cost. While the Pigouvian tax meets the short term criteria, it does not necessarily meet the long run criteria. If the marginal social

damage in an industry is increasing, such as pollution emitted by a factory, than the average social damaged caused by producing waste is less than the marginal social damage of the last unit of waste. Therefore, setting a tax equal to the marginal social damage results in firms being taxed a dollar amount greater than the dollar value of pollution they emit. Even though the dollar cost is the same per page the total per unit cost (dollar cost plus social cost) could be increasing for pages printed at Davidson. Therefore, to accurately match costs, students would face different costs for different pages printed. A tax system would not allow this to happen.

Finally, the tax may prove to be unpopular because it is a more visible cost and might "creep" upwards from year to year, sparking student complaints. Student participation or "buy-in" is a critical component in the successful adoption of campus initiatives of this kind, and a marketable permit system might generate enough curiosity to succeed in this regard.

Permit System Criticisms

Despite the many advantages to a permit system, there are many disadvantages that detract from it being a viable choice for Davidson College. The first drawback would be the involved system that would not only have to manage each students permit account but also allow for a market where students can buy/sell permits. This would not only be a more expensive system to implement, due to the actual market, but it would involve a lot of the administration's time to come up with the proper allotment of permits, a proper price, and the actual initial sale of the permits. These time costs would be significant and would be repeated every year as the permit system is modified to respond to changing times. Like a tax system, there would need to be time set aside to teach students a new system. A permit system is more complicated than a tax system and could lead to initial confusion as to how the system works. The most significant

disadvantage is that the system relies on students actively taking part in trading permits in the market. There is no guarantee that students would embrace this inconvenience.

Section IV. Tax System Structure

A tax system blends practicality and feasibility with efficiency gains over the current situation that exhibits negative externalities. While some of the current cost of printing is internalized in the form of the small student fee hidden in student tuition, a more effective solution would result from what is essentially a "pollution tax" on paper waste. Students are likely to face very low costs of pollution abatement; therefore, a tax will be highly effective as rationally acting students opt to reduce their printed jobs over paying the tax. In the following section of the paper we intend to prove that if the college switches to an electronic program under which students are charged a per-page tax of $0.05 for each page printed above 800 pages, it will result in greater efficiency for the college as a whole.

The Goal

Ordinarily when determining optimal tax levels, policy makers turn to the marginal cost and marginal benefit of pollution abatement. However, in this case the marginal costs and benefit for each printed page reduced are somewhat unique. The marginal benefit of each page not printed is the cost of printing, with these savings on-going into the future. The costs of abatement are essentially all up-front and fixed, with average costs of abatement equal to the annual costs of the program per page, but the marginal cost being roughly zero.

Given that marginal cost and benefit per unit cannot be used as an effective guide, it is necessary to consider other factors when determining the tax structure. The audit of paper waste in Davidson College's primary computer lab revealed that 16 percent of paper is wasted. If a reduction in printed pages equaled this volume, it would ultimately reduce printed pages from

5,319,635 to 4,468,493 annually. Using this percentage as a guideline would place the per semester page limit for students at 1,314 pages. To students who rarely consider the actual number of pages they print this seems to be an exorbitantly large number and is unlikely to curb careless behavior. It seems apparent that there are a number of zero-cost opportunities for students to reduce their print totals outside of reducing carelessness, which is what the waste audit primarily captured. For instance, students could share printed readings for class or print them in such a way that requires less paper. New "technology" could be developed in the form of a system of shelves in the computer lab where students could leave their completed readings for other students in their class to pick up instead of printing out a fresh copy.

We believe that students possess a large capacity to change their printing behavior. Consequently, a more stringent goal than a 16 percent reduction will be effective in reducing pages printed among students. Therefore, the goal for this program will be an 800 page limit for students per semester. These 800 pages will be a tax-free bracket.

Once students exceed this page limit they will be charged a tax of $0.05 for each additional page. The $0.05 tax level was decided based on the fact that the low cost of pollution abatement for students warrants a small charge in order to be reasonable, but it needs to be large enough per student so that students opt to reduce some paper use rather than simply pay the tax for each page. Since students appear to be unaware or unconcerned with the cost of printing, the tax level was decided based on what students perceived the cost of printing to be. To determine this information, students would look to other schools for information on "fair" print prices. Researching other schools in the same region and schools with similar liberal arts foci found the average charge to be around $0.05. Further, the current charge for photocopies is $0.05, which students will likely assume to be a reasonable charge for printing. Price controls are more likely

to be effective in pollution abatement if they make a statement about the value of the reducing pollution. Using a page limit of 800 and a price control of $0.05 sends the most appropriate message to students about the value of printing.

The Means: Regulation, Administration and Monitoring

One of the primary strengths of the tax system is its simplicity and its proven success at other institutions such as Amherst College. The necessary software programs are easily identifiable and can be tailored to a network system such as the one used at Davidson. The particular software manufacturer investigated for the purposes of this study was Pharos, a company whose Uniprint system, designed specifically for higher education, has found success at numerous colleges and universities including Amherst and the University of Cincinnati. The Salt Lake City Community College used a program very similar to ours in which they allowed students 250 pages each semester for free and charged $0.03 for every page after that. Installing the Uniprint system on computers at Davidson College would cover nearly all of the administrative and regulatory concerns associated with our program. Students would be forced to send all print jobs through a central server rather than to a specific printer and then swipe their student ID card at a printer to release the print job. The act of releasing print jobs at the printer will further encourage students to think twice about the merits of their particular print job since students will again have the option of deleting their print job when they swipe their ID card at the printer.

Hurdles/Concerns

There may be some concerns over the implementation of a per-unit charge after eight-hundred pages have been reached. One equity concern may result if a person's particular class requires a substantial amount of printed documents. One relevant example would be the Medical

Ethics class, which requires a student to print legal cases which he or she then brings to class each day. The cases usually range from 10-20 pages but some reach sixty or more. One way to solve this problem would be for a packet of the legal cases to be bundled and sold by the bookstore, similar to how readings are done in other departments. Financial aid or scholarships that cover the costs of books could then be used to pay for the packet.

Another concern would be departmental printers that are not connected to the network and, therefore, cannot be regulated. One example would be the Chemistry Library computer that is open to the public but would not be regulated under the system because it is controlled by the Chemistry department. Such departments would need to take steps to prevent students from flocking to their printers for free printing.

We exclude the departmental printers from our tax system analysis for the following reasons. First, arriving at a meaningful estimate from available data required substantially more inferences and assumptions than other printing options. Second, these printers are available only to a subset of the student population. They are also, in most cases, carefully regulated by faculty and departmental assistants. These printers are specified to be used not just for academic use generally, but for narrower, specific academic purposes (i.e., the class a student is enrolled in, an authorized independent experiment, etc.).

One of the major obstacles to the successful implementation of a tax system at Davidson College would be student opposition. The status quo is very convenient for students, even if it does lead to the occasional backup at printers. The school, in concert with certain student groups such as the Environmental Action Committee (EAC), would need to lead a publicity campaign to inform current students of the purpose for the change and the benefits that will result from the change. The school paper could address the issue, which could lead to a healthy campus debate

on the merits and drawbacks of the system. Freshmen orientation could address questions new students have about the printing process along with the reasons that the system was imposed. The most important aspect is to disseminate information concerning the per student amount of paper that is printed at the college. Further, Davidson's population completely turns over every four years so by the fourth year no student on campus will even remember the transition. If it is felt that student opposition will be particularly strong, the page limits could be adjusted so that seniors, who have experienced the current system the longest, could have a greater initial allocation of free pages than freshmen who will learn new techniques for saving pages at the printer from the start.

As with any change, there will be some adjustment necessary to become comfortable with the new system. Specifically, there may be some increased transaction costs, in the form of student and staff time, which is a result of students not understanding how the system works. These types of transaction costs will only be seen at the initial implementation and maybe for a week or two at the beginning of each school year with new freshmen. A bigger concern with the Pharos system could result from errors with the printer. A mechanism would need to be introduced where there is an ability to reimburse a student's account if there were printer errors that compromised the printed document.

Section V. Permit Structure

The permit system's design in its entirety follows here. We use the permit structure blue-print proposed by Colby (2005) as topic headings below to describe our structure:

Nature of right to be traded

Property rights will be auctioned and traded, in the form of permits for students to print paper at public printers at Davidson College. For budget and print tracking ease, each permit will

equal ten sheets of printer paper. (Throughout this paper, one page is synonymous with one sheet of paper.)

Initial Allocation of Tradable Rights, to whom

The initial allocation of permits will follow the three-step process listed below:

I. Academic Use

II. Initial Per Student Allocation of "Discretionary Permits"

III. Initial Auction of Further "Discretionary Permits"

The sum of I, II, and III will be our targeted number of pages, i.e., the number of (III) auctioned Discretionary Permits will be determined by the target number of pages, less (I) academic need and (II) per student Discretionary Permits. In future semesters, if the market price of permits settles at a value lower than the cost of printing, the target goal may be contracted.

(I) Academic Use will be defined as the number of permits students have a right to purchase, based on per-course estimates determined by professors. Each faculty member will estimate the number of pages students will need to print for a given course. The professor will make these estimates for each course that they teach and update these estimates at the beginning of each semester to incorporate feedback from students (whether the limit was too high or too low—these may questions included on Davidson's standard end-of-course evaluations). The professor will round the number of pages up to the nearest ten because one permit includes ten sheets of paper. When a student registers for courses, the per-class estimate for each of his or her courses will be summed together, giving the "Academic Use" allocation. The amount of permits distributed will equal the total

page amount divided by ten (since one permit equals ten sheets). We have two suggestions for how the students will receive these permits:

(a) Students can buy the permits along with their textbooks from the bookstore at the beginning of the semester. This has a couple of positive aspects. First of all, the school will receive revenue equal to the total cost of the paper, thus eliminating the school's cost burden. According to our cost function, the permits will be purchased at the fixed cost of 15 cents. Second, by selling the permits through the bookstore, students eligible for textbook cost reduction financial aid can also buy their printer paper at a reduced, income equitable cost. A disadvantage to this system (consequently related to our first advantage) is that the burden of academic printing costs falls entirely on the student. Though we want to reduce the amount of wasteful printing committed by students, we feel pure academic usage should initially be provided by the school.

(b) Thus, our second (and preferred) suggestion is that the school initially credits the academic permits (as determined by class schedule) directly to the student printing account.

(II) Recognizing that students who do not bring a printer to campus will have printing needs beyond the classroom, each student should have the right to purchase, at a fixed price of 20 cents per permit, an amount of discretionary permits. Examples of need for discretionary printing include letters, correspondences, hard copy of non-academic documents, résumés, etc. The maximum number of these permits shall be set at 50 per student per year (500 pages). Because these are not for academic

means, we suggest distributing these permits as we described above in section (a)—in the bookstore at the beginning of the semester with financial aid considerations.

(III) Further Discretionary Permits will be auctioned off in the style of a Dutch auction. Named after the structure of the Dutch tulip auctions, the school initially asks a high price for the permits. The school will then reduce the price until all the permits are sold. This auction shall take place at the beginning of each semester over a three day period, for which prices will be adjusted twice a day. While students can wait until the prices drop, they run the risk of all the permits being sold. The Dutch system, for our purpose, is superior to the English system. Under the English system the price for a permit would be bid up until a given point and the person offering the highest bid at that point would receive the permit. There will likely be over 200,000 permits distributed in this auction and bidding in the English fashion for individual permits takes too much time and students would become frustrated when they get outbid at the last second. Under the Dutch system a student will be able to buy a permit instantly and will only need to place one bid per instance of desired permits. The number of permits for these auctions will be derived by taking the desired number of pages and subtracting the (I) academic use and (II) initial discretionary use.

Following the initial allocation phase, each student's total permits purchased from (I), (II), and (III) will be summed into each student's account. As students print a sheet of paper from public computers during the semester, the software will deduct one-tenth of a permit from their accounts. Students may also choose to auction bundles of paper in the permit market, deducting

from their allocated stock. Students can "charge up," or augment, their number of permits by purchasing permits in the marketplace.

Student organizations in need of permits will have members bid for the right to print pages in the permit market. These authorized student members will be reimbursed out of their annual budgets as allocated by the Activities Tax Council. (One such system might involve the option to check a box on a print form indicating that the print job was for an organization, which the student may then select from a list. The president or treasurer would then later approve that the use was for the organization, and funds would be transferred.)

Initial Allocation of Rights

Based on meetings with Davidson staff members, we believe a ten percent reduction in the output of public printers at the Davidson College campus is feasible. Given that the current output from these sources is approximately 5.3 million pages, we will auction approximately 477,000 permits ([5.3million pages * 90 percent] / 10), or 4.77 million pages. Once the academic printing needs are determined, students will have the option to purchase 50 additional permits at a price of 20 cents per permit. Then, all remaining permits will be auctioned off in the Dutch auction style stated earlier.

Trading Mechanism

Our trading mechanism will be an online software program that matches available supply to available demand. An example of such software is the Visual Auction Software 8.5, produced by Beyond Solutions, Inc. With this software, students will list their excess permits available for purchase. Students needing to purchase additional permits will submit bids. This software will function exactly as the initial allocation Dutch auction. If suppliers list at a price too high, no one will buy their permits. Since there are multiple sellers in the market place, they will have an

incentive to price their permits below other permits listed. Since there will be such a large quantity of permits, it will be difficult for any one person to monopolize the market.

Trading Approval Process

To ensure efficiency and a fast turnover rate, the transaction will be finalized once a bid is submitted. A permit purchased on the market can then be used instantly after being purchased. This is where the advantage of the Dutch auction is seen. Under the English system students would have to wait to see if their bid was the winning bid. This waiting period would serve as a large inconvenience to students and would likely lower the amount of trading.

Accounting/monitoring/reporting

The cost of the auctioned permits will automatically be taken out of the bidder's student account—with a debt the student will have to pay before the completion of a year, as with all other student account debts. The seller will have an option presented as to where that transacted money will end up: it can either end up on their Catcard (a student ID linked to student accounts such as declining balance, meal plans, etc.), their student account (as an asset), or their preferred banking account. The option will be on the software itself as three links and the student can decide for each transaction. Once the money has transferred, the server will update its records and allocate the correct number of permits to the bidder and seller's account.

The monitoring system will also update all students through email, on a semi-monthly basis, the amount of permits one owns and how much they own relative to the whole student body (above average, below average, etc.). This report will help encourage students to use the permit system and either sell or buy if beneficial.

Enforcement/compliance incentives

First and foremost, students absolutely cannot print without permits in their service space. When they choose to print their document or webpage, they cannot continue unless their account can supply permits. This leaves little room for noncompliance. The only failure of the system we may have is if the students are not compelled to sell permits *or* if students do not buy permits in time for important paper due dates. We propose two incentives to encourage permit market compliance.

First, to promote transactions, each time a student enters into a transaction, he or she will be entered into a drawing. At the end of the semester two winners will be chosen to receive a $25 gift card. Second, to discourage frantic, last minute attempts to buy permits, the students will have a chance to buy "emergency" permits from the college administration at a very high price (four dollars per permit) as a penalty and charged to the student account. This will ensure that papers can be printed on time for approaching due dates but will also heavily discourage students from waiting to the last minute for buying permits. Of course, those eligible to obtain the initial packets of paper at reduced costs due to need-based financial aid will also be penalized at a lesser degree, though a penalty is necessary for everyone to avoid noncompliance.

Fees to cover administrative costs

The present value from reduced costs in future time periods and revenue generated from permit sales will cover the initial start-up costs of the system (to be discussed in detail in Section 5). In addition, students who earn penalties or pay other fees will provide a limited revenue stream.

Linking use levels to resource conditions

If the initial target goal is too generous, it may be reduced in future years. Unused permits will not be carried over to the next semester. Instead students will receive five cents per

remaining permit from the school. The low sell back price will encourage students to become engaged in the market.

Unlike consumption of natural resources, at Davidson the resource constraints are not scarcity of printable paper or ink cartridges, but scarcity of financial resources to purchase them.

Limiting entry

Nothing may be done to stop students from printing on their own personal printers. Such use *does* reduce Davidson College's environmental footprint (in the sense of waste directly attributable to college departments, like ITS or the library). The availability of these options might cap the market value of the permits at the private cost of printing, a potentially desirable equity outcome. Adding economic value to the right to print a sheet of paper through property rights guarantees a more efficient outcome.

Like under the tax system, the departmental printers pose a problem. Three concerns then arise: should not the pages from these printers count against our cap? Do these printers represent a leakage, or cheating, around paying for printing? Does it affect set up costs if these printers are included? Because the printers are solely for academic use, faculty can be asked to exclude the expected use on these printers from their course estimates, thus ensuring no extra pages are introduced. The overall deviance from the stated goal of reduction of ten percent should be minimal. Second, Davidson College's strong and working Honor Code can be used to ensure that students will not abuse these computers in the system, especially if there are disciplinary or academic consequences if any of this "cheating" or "stealing" is uncovered. Finally, computers and servers over the network could monitor these printers, and the college would already be paying a flat-rate fee for other outside services. We feel justified that, on these grounds, we can exclude these printers from further analysis.

Equity constraints or transfers

Our initial concerns for constructing a permit system centered on equity issues—mainly income equity and academic equity. First, we address income equity throughout our market by equating printer paper to textbooks. Lower-income students can be eligible for textbook fee reductions through need-based scholarships. Likewise, we propose selling permits alongside textbooks at the beginning of the semester (in the bookstore) and making them eligible for the same scholarships. Similarly, the penalty charged to students for running out of permits and buying them from the administration is also treated with financial aid considerations. The only other income inequity associated with this system arises from any forms of income inequity associated with the Financial Aid department, who makes their decisions of need-based scholarship independently of our permit structure.

Our other equity apprehension concerned academics: different majors necessitate varying amounts of paper usage (i.e. an English major, having more papers, may need more printer paper than a Math major). We work around this issue by having the professors of every student determine the number of pages needed per class. Consequently, the English major may have more permit allocations than the Math major, evading the possibility of academic inequity.

Section VI. Data Analysis

In order to analyze the efficiency of the pollution abatement systems, we collected relevant data and performed a cost-benefit analysis on the basis of Davidson College's bottom line. The three types of public printers available to students at Davidson College are ITS-supported printers, Library-supported printers, and the rare academic department-supported printers (principally the science departments, in their own specialized computer labs or facilities).

Table 6.1 shows the semester and annual counts of pages printed in fall 2005. These figures were arrived at by using straight-line use estimates for pages printed from July 1, 2005, to late January, 2006. Thus, these estimates may be conservative, as they weight three weeks in January to a full month of use in the earlier term. Given summer and winter break, and heavy periods of use around mid-terms and exams, we are confident that use will "net out" to these averages. These estimates suggest Davidson students print more than 5.3 million pages annually.

Table 6.1.

Computer	Pages Printed Per Semester	Pages Printed Annually
Belk Printer #1	89,953	179,906
Belk Printer #2	451,144	902,289
Knobloch Campus Center	404,033	808,066
Library: ITS Printer	626,279	1,252,558
Tomlinson Lab	1,714	3,429
Chambers 3130	29,100	58,200
Library, Music Lib Printers (3)	1,057,594	2,115,188
		5,319,635

The reader will notice the discrepancy between Belk Printer 1 and Belk Printer 2. In fact, each semester one printer serves as the "primary printer" and the other as a back-up when print jobs queue. The following semester they switch roles. Nevertheless the total pages printed between the two is a reliable estimate of how many pages are printed in the Belk Computer Lab annually.

We then identified the sources of costs for printing. These sources are the cost of paper, the cost of printer toner and cartridges, the maintenance on the printer, and the costs of the printer themselves (relevant given that printers are replaced after a certain volume of prints wears down the machine). Davidson College currently pays $25.50 for a box of paper. Each box

contains ten reams of 500 sheets, or 5,000 sheets of paper. Toner also averages $240 per printer, and lasts between 35,000 and 40,000 pages.

The printers themselves cost approximately $3,000. They are on a four-year cycle, during which each prints an estimated 1.5 million pages. The newest printers are consistently cycled into the highest-use areas (especially the Belk lab) and then "trickled-down" to lower use locations.

Finally, maintenance costs were more easily defined on a per-printer basis according to the ITS records. These were calculated by simply taking the total maintenance costs and dividing it among the six ITS printers, as maintenance costs per printer were approximately the same. The library printers are aggregated in our study so the maintenance cost reported for all three computers was left untouched.

With this cost information and total page counts, we determined the aggregate cost of printing and aggregate per-page cost of printing at Davidson College. Specifically, we expect printing in student public areas to run approximately $80,000 every year, at a cost of 1.5 cents per page. Table 6.2 shows the detailed information, extrapolated from Fiscal Year 2006-07 to date.

Table 6.2. Printing Use and Costs

Computer	Pages Printed Annually	Paper Costs	Maintenance	Toner Costs	Printer Costs	Total Costs
Belk Printer #1	179,906	$ 917.52	$ 740.00	$ 1,155.91	$ 359.81	$ 3,173.24
Belk Printer #2	902,289	$ 4,601.67	$ 740.00	$ 5,797.26	$ 1,804.58	$ 12,943.51
Knobloch Campus Center	808,066	$ 4,121.14	$ 740.00	$ 5,191.88	$ 1,616.13	$ 11,669.15
Library: ITS Printer	1,252,558	$ 6,388.05	$ 740.00	$ 8,047.77	$ 2,505.12	$ 17,680.93
Tomlinson Lab	3,429	$ 17.49	$ 740.00	$ 22.03	$ 6.86	$ 786.37
Chambers 3130	58,200	$ 296.82	$ 740.00	$ 373.94	$ 116.40	$ 1,527.16
Library, Music Lib Printers (3)	2,115,188	$ 10,787.46	$ 3,345.00	$ 13,590.22	$ 4,230.38	$ 31,953.06
Total Pages:	5,319,635				Total Costs:	$ 79,733.42

Tax System Cost-Benefit Analysis

Calculating exact savings based on the reduction in pages printed is difficult when one uses a price control as the proposed pay-for-print system does. One cannot predict exactly how much students will reduce their pages printed when subject to the page limit and per-page tax, particularly when lacking the necessary information regarding the elasticity of demand for the excess printed pages. Even though the page limit is set at 800 pages with a $0.05 charge above that limit, it remains difficult to tell how much this will affect the actual number of pages printed. If students have a perfectly inelastic demand for pages printed, although it seems this is not the case, then no saving will accrue from the pages saved. However, if the demand for printing is relatively elastic, students will adjust their printing behaviors a great deal. Based on the knowledge of current student attitudes toward printing, we feel that the elasticity is likely to be higher rather than lower. Ultimately, the only information currently available is the student demand for printing at no charge, which results in a quantity of 3,129 printed pages per student each year.

Given the uncertainty surrounding the actual reductions in printed pages and thus net savings we outline a few potential outcomes as a result of the tax program. The first of these outcomes is the "worst case scenario." In this analysis we assume a minimum reduction of 16 percent, since the results of the waste audit discussed previously revealed this value to be the percent reduction that students could achieve without any major change in their printing behavior. It requires that students do nothing more outside of simply being conscious of the number of pages they print over the course of the semester.

Because savings from pages not printed would accrue annually, we next determined the present value savings from this annual page reduction as a perpetuity. To do this, we assumed

that the money saved could be invested in the endowment over this period instead, so we averaged the inflation-adjusted returns on the Davidson College Endowment to use the appropriate cost-of-capital; these returns are presented in Table 6.3. The mean of returns over the past ten years—a period of average growth, exceptional growth, and recession—was 9.63 percent.

Table 6.3. Annual Returns to Davidson College Endowment.

Year	Return	Inflation-CPI	Real Returns
1995-1996	18.20%	2.80%	14.98%
1996-1997	22.60%	2.30%	19.84%
1997-1998	18.00%	1.80%	15.91%
1998-1999	14.40%	2.00%	12.16%
1999-2000	24.10%	3.70%	19.67%
2000-2001	-6.80%	3.20%	-9.69%
2001-2002	-5.10%	1.10%	-6.13%
2002-2003	2.30%	2.10%	0.20%
2003-2004	18.30%	3.30%	14.52%
2004-2005	18.20%	2.90%	14.87%
			9.63%

Source: Davidson College Investment Returns
http://www2.davidson.edu/administration/inv/inv_returns.asp

The 16 percent or 851,141 page reduction in annual printing totals translates to a savings of $12,757.35 using the per page cost of $0.015. Given the average return for the endowment over the last ten years was 9.63 percent, the net present value of the savings would be $132,434.17. Under this scenario we expect to have zero tax revenue. We expect that students will find it much cheaper to reduce printing than to pay the tax at least up until 16 percent. Also, we want to estimate if the program carries net benefits outside of the tax revenue. Therefore, the savings from reducing printed pages in this case are equal to the benefits of the program as whole. Given aforementioned estimated costs of $117,819.44, a 16 percent reduction in printed pages and net benefits of $132,434.17, Davidson College will save $14,614.73.

While $14,614.73 may not seem like a huge amount of earnings for the college, one must keep in mind that this analysis was done assuming students only reduce their printing by 16 percent with no tax revenue. Again, the goal is not to generate revenue for the college but to reduce the wasteful actions that students exhibit when printing. We feel that students have the

ability to reduce their printed pages by much more as they begin to adapt their printing behaviors and learn new mechanisms for saving pages. However, it may have been misleading to perform the cost benefit analysis with out this worst case scenario because it is likely that this large reduction will not occur until a few years after the implementation of the program as students adjust their printing behaviors. We also want to avoid the conception that the program is intended to generate revenue for the college when it seems that the greater goal is in the reduction of paper waste.

A second possible scenario for potential savings is that students only reduce their pages printed by 16 percent and pay the tax on all pages over 800. Thus, our benefits would include the savings from reducing printed pages by 16 percent, as in the previous case but here we include tax revenue. If students were able to reduce their printed pages to 800 per semester in order to avoid the tax it would result in a reduction closer to 50 percent. However in this potential outcome we assume that students demand for printed pages is slightly more inelastic and they are unable to avoid the tax after reducing the overall pages printed by 16 percent. So our benefits now stem from two sources: reduced paper savings and tax revenue. The net present value of the page savings are the same as those listed above, $132,434.17. The tax revenue would be quite significant since a 16 percent reduction means that each student prints 1,314 pages each semester and pays the tax on 514 of those pages per semester. The total tax revenue for the student body on an annual basis is then equal to $42,557.05. The net present value of this annual revenue is equal to $441,785.20. Adding this revenue to the net present value of the paper savings from the previous scenario, $132,434.17, yields total benefits equal to $574,219.37.

Initiating the project does carry costs. Software would need to be bought and installed to track and to charge student printing accounts. A dedicated server would need to be set up to run

the print-monitoring systems. Dedicated computers would also be needed for each lab location. Rather arbitrarily, we assigned the cost of labor under the following assumptions: a college IT specialist would need to spend 100 hours on the project, at a cost of a $15 hourly wage; in year one and beyond, student IT employees' help would be needed to fix glitches, monitor the system, and possibly amend accounts for bad print jobs. We valued this productivity at 50 hours annually, at a wage of $10 per hour. Finally, we allotted a cost overrun of $2,500 in year one and $1,000 in subsequent years, to avoid conservative estimates. (This amounted to roughly five percent of year one's projected costs, and more than ten percent thereafter). While Davidson College does not pay taxes under some circumstances, we were uncertain if those educational exemptions would apply in this instance. Thus, we inflated our costs by a tax rate of seven percent. Finally, we used the average return on the endowment as the cost of capital to find a NPV of all set-up costs. Given our estimated costs of $117,819.44, we find a net benefit of $456,399.93. Table 6.4 shows the breakdown.

Table 6.4. Projected Set-Up Costs: Tax System

		Time Period 1st Six Months	2nd Six Months	Year 0	Year 1	Year 2	Year 3+
Computer Software							
Dedicated Server	7K-10K	$10,000	$ -	$10,000	$ -	$ -	$ 1,000.00
New Computer							
--Belk		$ 3,000.00	$ -	$3,000	$ -	$ -	$ 750.00
--Union		$ 3,000.00	$ -	$3,000	$ -	$ -	$ 750.00
--Chambers		$ 3,000.00	$ -	$3,000	$ -	$ -	$ 750.00
--Library		$ 3,000.00	$ -	$3,000	$ -	$ -	$ 750.00
Additional Labor							
100 hours (initial), wage:	$15	$ 1,500.00		$ 1,500.00			
50 hours (annual), wage:	$10	$ 500.00		$ 500.00	$500	$500	$500
Acct. Tracking OS and Card Reader Eq.							
Fee with 10 or more printers		$ 15,500.00	$ -	$ 15,500.00	$ -	$ -	$ -
Annual fee--17.5% above costs	17.50%	$ 2,712.50	$ -	$ 2,712.50	$ 2,712.50	$ 2,712.50	$ 2,712.50
Total (1)	(1)	$ 42,212.50	$ -	$ 42,212.50	$ 3,213.50	$ 3,214.50	$ 7,212.50
(1) + Tax	(2)	$ 45,167.38	$ -	$ 45,167.38	$ 3,438.45	$ 3,439.52	$ 7,717.38
NPV(2)	(3)			$ 45,167.38	$3,136	$2,862	$ 66,654.10

Present Value of Total Cost $117,819.44

Since the ultimate goal of the program is to reduce paper waste, we hope that students choose to reduce their printed pages by greater than 16 percent when facing the per page charge. If students are responsive to the price control expected revenues would ideally be much less than those cited in the scenario with tax revenue. For this reason, we feel that the college should make the decision to implement the program based on the "worst case scenario" rather than based on the hope of large tax collection revenue.

Permit System Cost-Benefit Analysis

The cost per page is $0.014989. For simplicity, conservatism, and hedging against future cost increases, during administrative transactions (selling rights at-cost, etc.), this cost would be $0.02 per page, or $0.20 per permit. It is necessary to set the level of the cap to find the savings resulting from the cap-and-trade system. For the permit system, we chose a conservative goal of a 10 percent reduction in student printing. We believe this will largely preserve legitimate use but eliminate most waste, while allowing for a margin of error short of the 16 percent threshold observed in printing behaviors in the Belk Computer Lab. The 10 percent reduction equates to a

reduction of 530,000 pages annually, at a cost-savings of $7,973.34. Valuing the savings as a constant perpetuity, the net present value (NPV) was $82,771.35. Thus, so long as the NPV of the costs to set up our program are less than $80,000, the program would save Davidson College money.

Our model also projects some revenue sources. First, students would have the right to purchase up to 500 pages at-cost each year for their personal discretionary use. Because these pages will likely be auctioned at a price greater than or equal to at-cost if students fail to take advantage of the full allotment, we safely can project that Davidson College will receive *at least* a revenue of $0.02 per page for these 500 pages. Students would face a cost of $10.00 if these permits are bought for $0.20 each. (Though the current per-page cost is estimated at approximately 1.5 cents, we set the cost at two in because: there will be administrative costs at the time of selling that cannot be currently projected, it allows a cushion for cost inflation in the future without necessitating price changes, and results in convenient, round numbers for purchasers). Assuming an enrollment of 1,700 students, the college would receive $17,000 annually from this revenue. The NPV of this revenue is $176,477.19. The Net Present Value of Savings and Revenues totals $252,255.98.

The permit system has all the same set-up and on-going costs as the tax system. In addition, we projected the need to purchase auction software both for initial installation and on-going licenses. We used the average return on the endowment as the cost of capital to find a NPV of all set-up costs. This value was $138,342.63. Table 6.5 shows the estimation.

Table 6.5. Projected Set-Up Costs: Permit

		Time Period		Year	Year	Year	Year
		1st Six Months	2nd Six Months	0	1	2	3+
Auction Software							
Initial Cost, 6 Months Free Webhosting		$ 2,995.00	$ -	$ 2,995.00	$ -	$ -	$ -
Storage		$ 500.00	$ -	$ 500.00	$ -	$ -	$ -
Monthly Fee		$ -	$ 348.00	$ 348.00	$ 696.00	$ -	$ -
Dedicated Server (beginning year two)		$ -	$ -	$ -	$ 2,000.00	$ -	$ -
Computer Software							
Dedicated Server	7K-10K	$10,000	$ -	$10,000	$ -	$ -	$ 1,000.00
New Computer							
--Belk		$ 3,000.00	$ -	$3,000	$ -	$ -	$ 750.00
--Union		$ 3,000.00	$ -	$3,000	$ -	$ -	$ 750.00
--Chambers		$ 3,000.00	$ -	$3,000	$ -	$ -	$ 750.00
--Library		$ 3,000.00	$ -	$3,000	$ -	$ -	$ 750.00
Additional Labor							
100 hours (initial), wage:	$15	$ 1,500.00		$ 1,500.00			
50 hours (annual), wage:	$10	$ 500.00		$ 500.00	$500	$500	$500
Acct. Tracking OS and Card Reader Eq.							
Fee with 10 or more printers		$ 15,500.00	$ -	$ 15,500.00	$ -	$ -	$ -
Annual fee--17.5% above costs	17.50%	$ 2,712.50	$ -	$ 2,712.50	$ 2,712.50	$ 2,712.50	$ 2,712.50
Cost Overrun							
First Year	$2,500	$ 2,500.00	$ -	$ 2,500.00	$ -	$ -	$ -
Annually	$1,000	$ -	$ -	$ -	$1,000	$1,000	$1,000
Total (1)	(1)	$ 48,207.50	$ 348.00	$ 48,555.50	$ 6,908.50	$ 4,212.50	$ 8,212.50
(1) + Tax	(2)	$ 51,582.03	$ 372.36	$ 51,954.39	$ 7,392.10	$ 4,507.38	$ 8,787.38
NPV(2)	(3)			$ 51,954.39	$6,743	$3,750	$ 75,895.57
Present Value of Total Cost		$138,342.63					
Tax Rate	7%						
Discount Rate	9.63%						
Initial Hours	100						
Annual Hours	50						

Performing a Cost-Benefit Analysis, Davidson College earns $120,905.92, or $11,646.83 annually, through the permit program—*excluding* any revenue generated from the auction. Davidson also reduces its environmental footprint by over one-half million sheets of paper.

At what level of reduction over current levels would Davidson College need in order to justify the costs of the program, barring any revenue sources? To cover the NPV Costs of $138,000, the college would need to reduce its student printing consumption by 16.71 percent, or 888,911 pages. Such an amount is only marginally more than our observed waste threshold of 16 percent, and it could probably be achieved without great hardship to students.

VII. Recommendation

Because the Net Present Value of the Cost-Benefit Analysis is positive, because students face a low initial sticker price to participate in the system (zero through 800 pages per semester for the tax system; $5.00 per semester plus permits bought through auction for the permits), and because the program reduces environmental waste while improving economic efficiency, we recommend that Davidson College form a committee of IT professionals and student representatives. This committee will further explore the technical feasibility of implementing either system, and having done so, choose one and then develop a plan and timetable for that implementation.

We hope the reader will note that the absence of a strong, functioning Honor System and/or diseconomies of scale via the number of computing facilities provided for student use may preclude other universities from adopting identical strategies (although the tax system has already been shown to be easily replicated). On the whole, however, our method of analysis is transferable to other institutions, who may then evaluate their own feasibilities.

On the question of, "Will the system result in outcomes consistent with the overall purpose of Davidson College?" We believe that either program is in fact consistent with that mission. It will reduce non-academic use of public computing facilities while not being disruptive to academic work at Davidson College. It will offer the college an opportunity to "practice what it preaches" in the classroom in the actual world. Moreover, the financial savings generated may marginally slow rising tuition or be diverted to provide funds for other activities that more efficiently advance the educational purpose of the institution.

VIII. Conclusions

In this paper, we have identified the negative externality of free public printing at Davidson College. We conclude that the most innovative and efficient way to introduce abatement is a cap-and-trade system. However, we also conclude that the simplest and most cost-effective way to achieve the abatement is the tax system, which is a strong alternative at an efficiency and small equity loss. In order to do this we closely examined the current free printing structure at Davidson. Given the costs and benefits of the current system, two alternatives were addressed. These alternatives were a command and control system and a marketable permit structure. Citing the works of Colinge and Oates (1982) and Woodward (2005) it was shown that a permit structure is preferable to a tax or a command and control system on efficiency grounds.

We have proposed, on one hand, a simple tax-based system to reduce printing at Davidson College. The program charges five cents for each page printed in excess of 800 pages per semester. The negative externalities associated with printing can be best addressed by this price mechanism. While initial student reaction to the implementation of the system may be negative, proper education will allow the system to overcome this initial hurdle. One exciting aspect of the system results from the potential for student innovation to adapt to the new system such as introducing new methods for sharing documents in certain classes. Further, the turnover in the student population after four years guarantees that any resistance met will only be a short term issue.

The elaborate permit system described in this paper has three parts to the initial allocation of permits: (I) academic use, (II) per student allocation, and (III) auction allocation. Once students have their initial allocation of permits, they are free to trade their permits in the open market under a Dutch style auction. Great care was taken to design a system that paid due

attention to academic and financial equity for students, who would face the burden under the new system. Software programs such as Visual Auction Software 8.5 exist that can execute the permit system that has been described. Through these techniques, Davidson College can take the lead in experimenting with this form of pay-for-printing. Follow-up analyses should be conducted to determine the success of the program and to tweak it where appropriate. If successful, the college should export its model to other universities, to achieve both financial and ecological benefits.

We determined that either system would generate substantial annual and horizon-value savings for Davidson College. Either system may achieve an important second goal: changing perceptions about printing at Davidson College. If innovation and maximum efficiency are determined to be worth the added complexity and marginally higher cost, we recommend the permit system. If feasibility and ease-of-use are the priorities, we recommend the tax system.

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