Identification of Future Printing Industry Trends

FINAL REPORT

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Introduction

This study addressed critical competitiveness issues in both the printing and paper industry sectors. This cross-industry effort was supported by two Sloan Foundation-funded centers: the Center for Paper Business and Industry Studies at Georgia Tech and the Printing Industry center at the Rochester Institute of Technology. The objective was to identify constraints and potential solutions for improved performance and quality of digitally printed papers. The project aimed at providing the pulp and paper industry with specific insights into customer needs, enhancing technical foundations for digital printing, and identifying areas for research that offer the greatest potential benefit for both the U.S. printing and papermaking industries.

Results

Constraints to printer performance and quality were identified through two separate surveys, one of printers and one of digital press manufacturers (1, 2). In both cases the surveys were executed by RIT using the RIT database, with a particular emphasis on the role that the paper substrate and printing process requirements play in limiting efficiency and quality.

The survey of digital print providers, conducted by M.A. Evans, aimed at identifying constraints and potential solutions for improved performance and quality of digitally printed papers (1, 3-9; Appendix I). In printers' decisions about which paper to purchase, the key factors identified were runnability and print quality. The leading paper characteristics considered when making a purchase were found to be toner/ink adhesion, accurate sheet dimensions, dimensional stability, and moisture level. Performance- and runnability-related factors were found to be more important than appearance-related factors. Overall, the price of papers charged by manufacturers to print producers was not a leading factor in the paper selection process; in particular, a company (printer) that makes the paper purchase decision together with the customer (print purchaser) was less likely to put high emphasis on price. Digital print providers were most interested in an extended product range, with more sizes, finishes, and basis weights available for their digital presses.

Using the above print provider survey data base, further statistical analysis was made by B. Jonen to evaluate digital printing firms' paper purchase decisions as linked to the firms' characteristics (5, 10). The intent was to identify which parameters of the printing paper played the largest role in each firm's purchase decisions. Jonen found that smaller, slow growing firms placed a higher weight on paper price, while faster growing firms primarily focused on runnability. Jonen said that one reason for this was that successful firms have a larger "opportunity cost" of foregone production; poor runnability and low image quality can differentiate between profit and loss in an industry with tight profit margins. Also, not surprisingly, printing companies that collaborate with their customers in the paper purchase decision were less likely to put emphasis on the paper price.

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M. Song compared the competition effect between the mature (quick printing) industry and the young (digital printing) industry (11) (Appendix II). The quick printing industry includes firms in traditional, conventional printing areas, e.g., short-run offset printing as well as document photocopying services, with generally short run lengths and turnaround times. The digital printing industry includes firms using digital printing equipment, e.g., using scanners to input images followed by electronic manipulation and formatting of the images prior to printing. Digital printing uses full-color presses such as the HP Indigo, Xeikon, Xerox iGen3, and Kodak Nexpress.

Song defined the competition effect as the effect of having one more establishment on the next period's net turnover rate. He found that the competition effect was negative and significant in both industries, but the effect was much larger in the mature (quick printing) industry. This confirmed the intuition that it is harder for a potential entrant to enter a more mature industry.

In the survey of digital press manufacturers, H. Vogl determined that dimensional stability, product uniformity, and toner adhesion were the primary parameters considered critically important by all respondents in limiting current performance / future innovation in production digital presses (2) (Appendix III). Vogl also found that the importance of other specific paper characteristics diverged, partly due to differences in the print hardware technology used. These characteristics included sheet filler transfer to fuser rollers, sheet recycle content, and sheet moisture level.

Vogl also pointed out: "when asked about paper characteristics important to optimal toner application, paper surface resistivity and moisture level were almost universally important. Surface resistivity and moisture level play an important role in toner density and evenness. Since fusing energy is evenly distributed on the substrate surface, unexpected variations in toner density result in less than optimal fusing of toner to substrate. Therefore, optimal toner fusing is, in part, based on substrate uniformity" (2).

With regard to the objective of identifying constraints and potential solutions for improved performance and quality of digitally printed papers, it is revealing that in both the print provider survey and the digital press manufacture survey, the leading paper "deficiencies" identified were:

- toner/ink adhesion,
- accurate sheet dimensions / dimensional stability

Toner Transfer Efficiency

Toner transfer efficiency is a function of the strength and uniformity of the dielectric force between charged toner particles and the charged paper substrate. Potential quality problems from poor toner transfer efficiency include:

- Mottle (uneven print density) and low image quality (discontinuities and variation in dielectric force)
- Lower ink density due to low surface resistivity resulting in charge dissipation
- Residual toner remaining on the photo receptor and being transferred to the next image.

Toner transfer efficiency is affected by surface energy (e.g., excess sizing) (12) and by parameters related to uniformity, including:

- Surface roughness (toner penetrates very little into paper surface)
- Surface resistivity (if high, charge builds up at random, attracting stray toner specks (13)
- Paper thickness variation (14)
- Sheet moisture uniformity or non-uniformity; can affect the dielectric force strength.
- Sheet permeability (for adequate penetration of toner for bonding)
- Distribution and density of filler within paper structure, as they affect surface charge
- Uniformity of bulk filler distribution (14)

Accordingly, approaches to control sheet uniformity are expected to positively affect sheet toner transfer efficiency.

Vikman and Sipi studied the applicability of FTIR-ATR spectroscopy, confocal Raman and UV Resonance Raman spectroscopy techniques to analyzing paper-ink interactions (light fastness), e.g., ink jet on coated papers (15). FTIR methods were useful in studying the adhesion of electrophotographic prints (15). The USDA Forest Service, Forest Products Laboratory, developed a new instrument to evaluate the adhesion of inks and toner loss on copier papers (16). This instrument induces wear in a folded area, ultimately causing toner layer fracture and loss which is measured using image analysis (16). Petterson and Fogden developed a laboratory method to monitor in-situ the spreading of individual toner particles during heating, and measure change in particle diameter and contact angle (17).

Leroy studied the thermal, rheological and physico-chemical mechanisms involved in obtaining good adhesion at the toner/paper interface - especially mechanical anchoring, adsorption and diffusion (18-20). Experimental modifications of paper roughness, surface energy and diffusion potential were evaluated (18-20).

With regard to toner, toner with small, narrow particle size and toners blended with additives for adhesion control during transfer were preferred (21-23). Future projections for high speed color laser printing, included further scale down of toner particle size, lower particle adhesion, low-temperature fixing, and increased use of technologies with polymerization toner as a core technology (24).

Uniformity

Sheet uniformity can be improved incrementally with on-machine processing changes. However, future large improvements may be related to control of the variability in the wood supply. For example, Qiao and Gustafson showed that pulping non-uniformity arises from (1) macroscopic sources such as intra-digester gradients and chip chemical concentration gradients and (2) significant heterogeneity on the single fiber scale (25).

Allem and Uesaka showed in the case of LWC papers, that microscopic measurements should be monitored at distance intervals smaller than about 20 microns (i.e., smaller than typical fiber diameters) in order to adequately characterize small-scale, sub-millimeter, variations of paper structure as they affect key paper printing properties (26). This would imply use of not just state-of-the art pulping and papermaking technology, but control of the wood supply as well.

Ince has pointed out that ‘selected species of trees grown in monoculture (single-species) plantations may have high intrinsic value …because of uniformity in fiber quality…but cultivating trees in plantations can be more expensive…..’ (27). Accordingly, the value proposition for improved uniformity with regard to digital printing must be understood.

Advances are being made in using sensing techniques to provide real-time characterization of wood properties to potentially facilitate wood sorting during harvest, e.g., to achieve a more uniform wood supply with specific wood property traits. For example, work at Oregon State University has developed acoustic technology to measure wood stiffness to allow in-forest sorting of veneer-quality Douglas fir logs (28). Schimleck et al and others have shown that NIR spectra can be used to estimate key wood properties (e.g., MFA, cellulose content, density) and to correlate them with sheet properties (29, 30). Schimleck extended that work to include calibration statistics developed using multiple height samples, to allow quantification of within-tree variation of wood properties (29).

Dimensional Stability

Courchene et al showed that cellulose microfibril angle (MFA) is a major determinant of southern pine handsheet hygroexpansivity (change in paper dimensions due to relative humidity changes), tensile strength, stretch, modulus of elasticity, and stiffness (31). Hence, they state that breeding for southern pine trees with decreased MFA is highly desirable for sheet mechanical properties. They also cite work by

Uesaka and Moss (1997) on Douglas Fir which indicated that wood fibers with higher MFA had greater hygroexpansivity (32). Litvay combined experimental work with mill modeling to assess economic impact of MFA on sheet strength (quantified by reduction in basis weight) (33).

Sustainable Forestry

The need for improvements in sustainable forestry to enhance specific wood, fiber, and sheet properties was recognized by the Agenda 2020 Technology Alliance in their 2006 Forest Products Industry Technology Roadmap (34). One of the seven technology platforms, Sustainable Forest Productivity, listed the following three highest priority Research Needs:

1. Update growth and yield models to account for changes in stand conditions, management practices, and environmental variables
2. Accelerate testing and deployment of clonal forestry systems for softwoods
3. Develop rapid, cost-effective methods for measuring wood properties that affect end uses.

Improved plantation tree crop economics will be important, in combination with tailored wood supply for specific end use applications (e.g., printing). There is significant current attention in addressing biomass feedstock supply economics (stimulated by the biomass-to-biofuels initiatives), related not just to stumpage (actual woody biomass cost which is up to about one third of the overall wood supply cost to the mill gate) but also to the other unit operations along the entire supply chain (including harvest, collection, any preprocessing, storage, and transportation) (35-37).

Within-Mill Economics

In this study the within-mill economics of increased uniformity using biotechnology (more uniform wood supply) was estimated based on the following assumptions: (1) decreased cooking temperature of 10% (38), (2) a 50% decrease in knotter and screen rejects, and (3) increase in machine efficiency due to less breaks and higher first grade production (less rejected paper). Impact using the IPST uncoated freesheet mill economic model was a decrease in overall mill operating costs of $5/ton and a 5.5% increase in first grade production (Appendix IV). Beyond these mill-related results, there is expected to be additional significant benefit of increased uniformity (e.g., narrower distribution of fiber microfibril angle in the wood) on sheet quality and subsequent printer performance (toner transfer efficiency, sheet hygroexpansivity) as mentioned above. The cultivation/harvesting cost for such plantation woody biomass would be the subject of a future study.

Conclusions

In printers' decisions about which paper to purchase, the key factors identified were runnability and print quality. The leading paper characteristics considered when making a purchase were found to be toner/ink adhesion, accurate sheet dimensions, dimensional stability, and moisture level. Performance- and runnability-related factors were found to be more important than appearance-related factors. Similarly, in a survey of digital press manufacturers, dimensional stability, product uniformity, and toner adhesion were the primary parameters considered critically important by all respondents in limiting current performance / future innovation in production digital presses. Accordingly, significant improvement in digital printing is expected to be achieved by minimizing variability in the wood supply, including use of single-species plantations with specific wood property traits and use of real-time characterization of wood properties to potentially facilitate wood sorting during harvest.

Overall, the price of papers charged by manufacturers to print producers was not a leading factor in the paper selection process. Smaller, slow growing firms placed a higher weight on paper price, while faster growing firms primarily focused on runnability, in part due to the larger "opportunity cost" of foregone production in an industry with tight profit margins. Also, not surprisingly, printing companies that collaborate with their customers in the paper purchase decision were less likely to put emphasis on the paper price.

Evaluation of the competition effect (the effect of having one more establishment on the next period's net turnover rate) between the mature (quick printing) industry and the young (digital printing) indicated that the competition effect was negative and significant in both industries. However, the effect was much larger in the quick printing industry. This confirmed the intuition that it is harder for a potential entrant to enter a more mature industry.

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PROJECT-RELATED PUBLICATIONS, PRESENTATIONS, THESES, REPORTS

PUBLICATIONS

- White, D., Evans, M A., Peter, G. F., "Trends in Digital Printing Papers", *Paper360,* 2(5): 10, Tappi-PIMA, May, 2007.
- White, D. E., Peter, G. F., Evans, M. A., "Effect of Recycled Paper Use on Print Quality", *GATF World Technology Forecas*t, February, 2005.
- White, D. E., Peter, G. F., Evans, M. A., "A Cross-Industry Systems Assessment of Future Printing and Papermaking Industry Trends", *GATF World Technology Forecast*, February, 2004.

PRESENTATIONS

- White, D., Evans, M. A., Vogl, H., Song, M., Jonen, B., Peter, G., 'Identification of Future Printing Industry Trends', Presented, 2007 Sloan Industry Studies Annual Conference, Cambridge, MA, April 25-27, 2007.
- White, D., Evans, M. A.., Vogl, H., Peter, G., "Identification of Trends in Papers for Digital Printing", Presented, 2007 TAPPI Papermakers & PIMA International Leadership Conference, Jacksonville, FL, March 14, 2007.
- White, D., Evans, M.A., "Identification of Trends in Papers for Digital Printing", Presented, PIRA Ink on Paper Conference, San Antonio, Dec. 7, 2006.
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- Peter, G. F., Sorce, P., White, D. E., Evans, M. A., "Role of the Customer in Productivity Improvements in the Printing and Paper Industries", Presented (GFP), Sloan Centers Conference, Atlanta, GA, April, 2004.

THESES

Jonen, Benjamin P., "An Empirical Analysis of Paper Selection by Digital Printers", M.S. Thesis, Georgia Institute of Technology, August, 2007.

REPORTS

- Evans, M., LeMaire, B., "An Investigation into Papers for Digital Printing", RIT Research Monograph, No. PICRM-2005-06, Rochester Institute of Technology, Printing Industry Center, Rochester, NY (2005)
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- Song, M., "A Tale of Two Industries: Competition and Turnover in the Digital and Quick Printing Industries", (November 2007)

Appendix I

Identification of Trends in Papers for Digital Printing

(Sloan Industry Studies Association Conference, Cambridge, MA April 25-27, 2007)

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Identification of Trends in Papers for Digital Printing

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ABSTRACT

A survey of digital print providers in the U.S was conducted to identify constraints and potential solutions for improved performance and quality of digitally printed papers. In printers' decisions about which paper to purchase, the key factors were identified as runnability and print quality. The leading paper characteristics considered when making a purchase were found to be toner/ink adhesion, accurate sheet dimensions, dimensional stability, and moisture level. Performance- and runnability-related factors were found to be more important than appearance-related factors. Overall, the price of papers charged by manufacturers to print producers was not a leading factor in the paper selection process; in particular, a company (printer) that makes the paper purchase decision together with the customer (print purchaser) is less likely to put high emphasis on price. Digital print providers are most interested in an extended product range, with more sizes, finishes, and basis weights available for their digital presses.

INTRODUCTION

A survey of U.S. print providers currently using production electrophotographic digital printing technology was conducted to assess the relative importance of the different properties of digital papers. The survey explored the reasons why certain grades are selected by print providers, and assessed gaps in currently-available digital grades. This study is directed towards the production segment of electrophotographic digital printing, and does not include the SOHO (small office and home office) and graphic arts inkjet markets. A full analysis of the survey results is published in a Printing Industry Center Report [1].

The Market for Digital Paper

Mirroring the growth of digital presses is the development of papers manufactured specifically to meet digital press requirements. Paper for digital presses is now the fastest growing category in paper manufacturing [2, 3]. In response to these market dynamics, paper manufacturers have launched new digital paper lines and expanded existing lines. Both printers and print specifiers are increasingly demanding a wider and more diverse selection of papers qualified for digital presses and an expansion of other media for use with these technologies (for example, self-adhesive labels, envelopes, identity cards, synthetic substrates, etc.).

In order to produce high quality images and good on-press runnability, electrophotographic papers require good dimensional stability and surface smoothness, small, evenly distributed additives and fillers, more tightly controlled and uniform moisture levels, controlled conductivity levels, and uniform charging characteristics for toner transfer efficiency. The chemical composition, spatial distribution of components, and thickness uniformity of paper are therefore more critical than in traditional printing papers. Thus, the design and production of high quality digital papers requires significant expertise. In addition to these technical factors, to fully exploit the fast turnaround capabilities of Print on Demand, printers may need to carry a significant inventory of papers. This poses challenges in an environment in which space and cash flow are at a premium. Where several print technologies are functioning within one print operation, a universal paper has significant economic advantages. In general, however, robust runnability and image quality require papers designed specifically for electrophotographic applications [4].

RESEARCH METHODOLOGY

A telephone survey of digital print providers in 2005 elicited 103 responses from print companies in the U.S. and Canada based on the Rochester Institute of Technology database. Following an exploration of company demographics, questions were asked to understand how and why different papers are selected for digital printing jobs. The following categories were explored:

- Paper grades commonly used for digital printing jobs
- Number of brands used and companies' relationships with suppliers
- Factors which affect brand decisions
- Relative importance of different paper properties and characteristics
- Paper characteristics needing improvement
- Limitations imposed by digital press design, and
- Paper cost changes in recent years

RESULTS

Respondent Company Demographics

The 103 respondent print companies have been in business from 3 to 197 years, with a median of 28 years; more than 30% have been in business for over 50 years. More than 50% of companies had fewer than 20 employees in 2004, with only 14% above 100. The median annual revenue for 2004 was approximately $1M, with 68% below $3M. This confirms the predominance of small- and medium-sized enterprises in the printing industry [5]. By the end of 2004, 28% of respondents owned one digital press, 19% had two presses and 16% had three presses. Only 20% own only digital printing technology; 72 have sheetfed offset presses, 14 have web offset presses, 13 have inkjet equipment, and 3 have flexographic presses.

Digital Printing Applications

Respondents identified the types of jobs produced with digital printing; the leading categories ranked as a "major portion" of the business were Marketing and Promotional Materials, Quick Printing Applications, and Direct Mail. When asked to indicate only one predominant job type, the leading application is again Marketing and Promotional Materials (24%), followed by Direct Mail (21%), Manuals and Documents (19%), and Quick Printing Applications (14%) (Figure 1). The outlook for Manuals and Documents, and Quick Printing Applications is diminishing, which may be due to the growing proportion of competing electronic document forms.

Paper Grades for Digital Printing Applications

Paper grade categories that respondents used for digital printing and their frequency of use were explored using grade descriptions designed to avoid resemblance to brand names or product ranges. Coated gloss is the leading grade, followed by premium uncoated, uncoated calendered, coated matte, uncoated uncalendered, and premium bond [Figure 2]. When printers were asked to select only one grade they used most often, the leader was coated gloss (32%), followed by premium bond (15%), and uncoated uncalendered (12%). The combination of gloss grades (coated and coated high-gloss) accounted for about 38% of grades used most frequently and ranked as very or somewhat frequently used by 82% and 59% respectively. This heavy usage of coated gloss correlated with the Marketing and Promotional Materials as the most important application. Most of the digital presses used by respondents in this survey are sheetfed. Eighty-five percent of survey respondents do not use webfed media at all, and 5% use webfed media only.

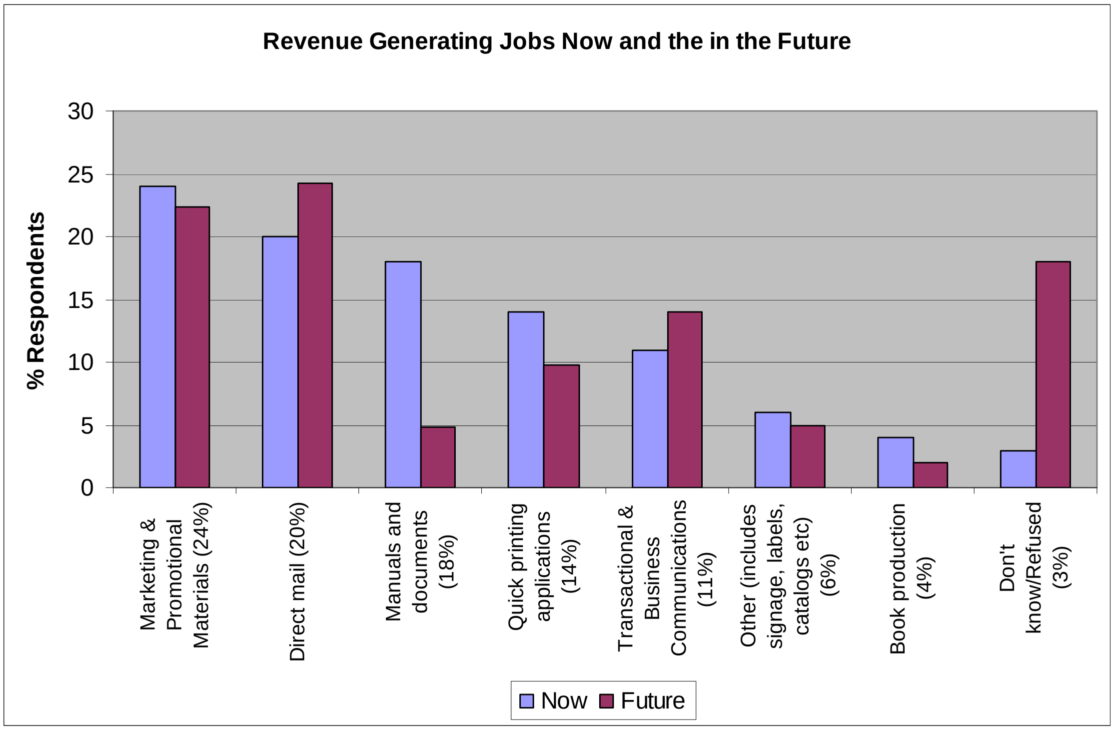

Figure 1 Predicted revenue generating jobs now and in the future.

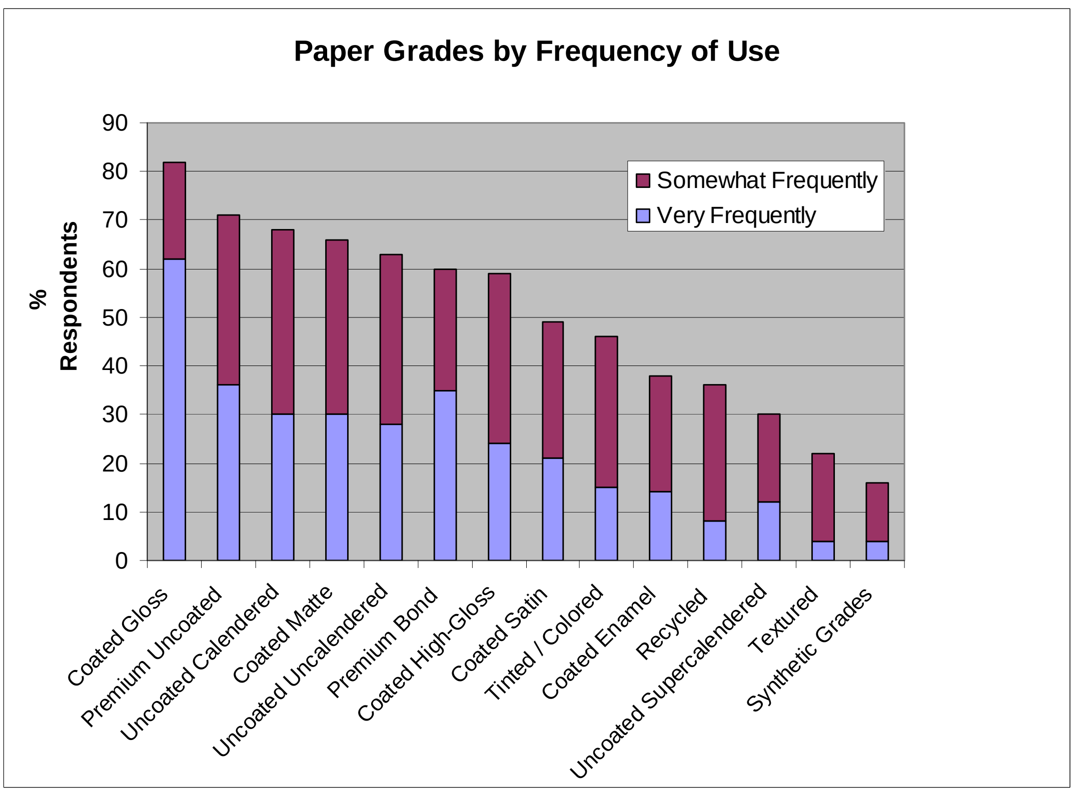

Figure 2 Frequency of use of paper grades for digital printing

The Paper Selection Decision

A degree of brand loyalty was evident, with the median number of brands at 5. 28% of respondents are limited to one brand of paper. Respondents were asked to rank factors relating to the paper purchase decision on an importance scale. “Runnability” was used in the context of no misfeeds or web breaks during a press run; “appearance characteristics” included brightness, whiteness, finish type, etc.; “product range” included weight, size, finish, etc; “availability of grade” referred to acceptable turnaround on ordering; and “multipurpose application across different printing technologies” refers to papers qualified for electrophotography as well as offset lithography or other technologies.

Runnability and print quality were ranked as having the most importance and were statistically equivalent (Figure 3). Price was found not to be a leading factor in the purchase decision for these digital grades in this survey. The difference between brands on the basis of these factors was investigated; about one third of respondents indicated that various brands showed major differences in runnability, availability, and print quality.

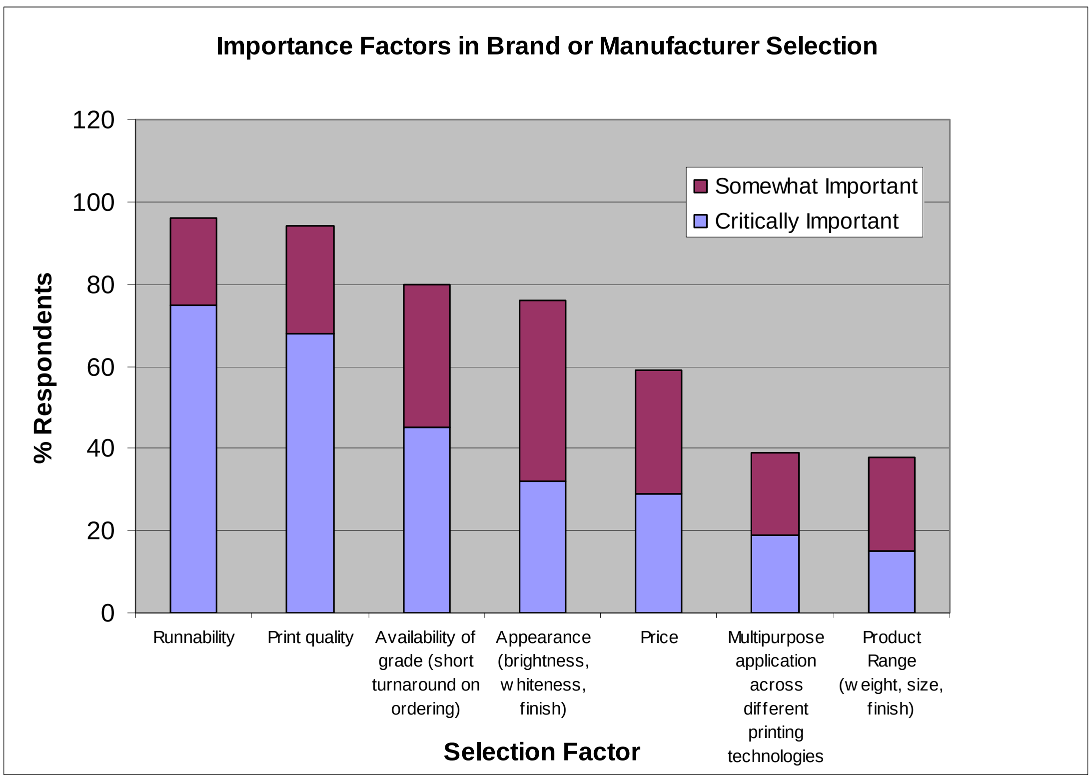

Figure 3 The relative importance of factors used to determine brand or type of paper.

Paper Characteristics

The properties and characteristics of papers that may be considered when selecting a grade were investigated for relative importance (Figure 4). When asked to identify the relative importance of all characteristics in a provided list, the leading characteristics were identified as toner/ink adhesion, uniformity, accurate sheet dimensions, dimensional stability, moisture level, and surface finish. When asked to identify only one characteristic as most important, the top three were the same, but with different weightings; 58 % of respondents identified toner/ink adhesion as most important, followed by accurate sheet dimensions (10%) and uniformity (7%). No respondents identified brightness as the most important characteristic. When parameters were combined, greater importance was attached to performance rather than appearance-related factors: when uniformity, accurate sheet dimensions, dimensional stability, moisture level, basis weight, storage and handling, stiffness, and sheet web strength are grouped the "critical" rating is 33% compared with 22% for appearance-related factors such as color, opacity, and brightness. Across a wide range of applications, and for all the most important revenue generating jobs, ink/toner adhesion was found to be the most important factor.

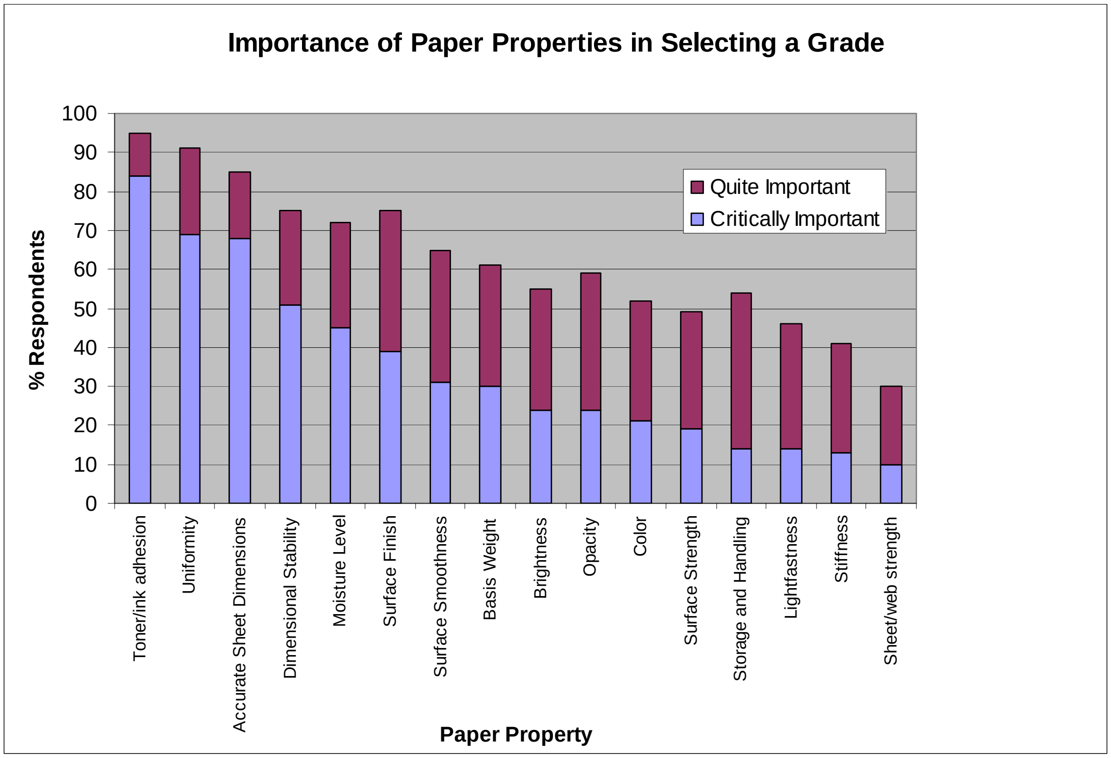

Figure 4 The relative importance of paper characteristics and properties in selecting a grade.

Desired Improvements

In an open question, forty four respondents reported that current product ranges are not sufficient at this time to meet all needs for digital document production, with specific comments calling for a wider range of sizes (10), more colors, a wider range of caliper/thickness and basis weights, and the ability to print on the same stock across different technologies. A range of comments related to the adhesion of toner or ink onto the substrate. Details of the comments on desired improvements are reported elsewhere [1].

When asked about limitations imposed by the digital press design, the leading limiting factors relate to product range: twenty respondents felt that they are limited in basis weight due to press limitations, but only one at the low end: fifteen are limited to sizes imposed by the press, and ten are limited by thickness. Adhesion and substrate pre-treatment was called out by fifteen respondents.

Statistical Analysis of Purchase Decision

This section attempts to understand the paper purchase decision of digital printing firms using statistical methods. An underlying idea is to link firms' paper purchase decisions to their characteristics. This will shed light on which aspects or parameters of the printing paper the surveyed printing companies put emphasis in their purchase decisions.

In particular the importance of price and runnability in the paper purchase decision were considered in the analysis. [Figure 1] provides motivation to look at these two aspects of the paper purchase decision. A majority of the respondents considers runnability important, but somewhat surprisingly the price does not seem to play a key role in their purchase decisions.

The discrete nature of the data obtained by the survey makes the use of a standard linear regression model impossible. Due to discreteness of dependent variables the logit model is used. The probability of a respondent choosing an answer is

$$\Pr(y=1\,|\,\mathbf{x}) = \frac{\exp(\mathbf{x}\boldsymbol{\beta})}{1+\exp(\mathbf{x}\boldsymbol{\beta})},$$

where $\mathbf{x}$ is the respondent's characteristics and $\boldsymbol{\beta}$ is a vector of the estimated coefficients.

The data set used in the analysis includes 93 companies. Ten companies had to be deleted from the data set due to missing values. Summary statistics are provided elsewhere [6].

Several sets of explanatory variables reflecting the firms' characteristics were created using the information provided by the survey. They include:

- Firms' demographics like the number of employees, the age, the revenue, etc.,
- Different printing jobs done by the set of printers in the firm (in particular the percentage of digital printers)
- Whether the firms do Digital Asset Management and/or Variable Data Printing
- Paper selection in the firm as well as possible restrictions imposed by the presses used in the firm.

Results for the Importance of Price

Starting with a full model insignificant variables were eliminated one after another until arriving at the final model shown in [Table 1] in the appendix. When interpreting the coefficients it is important to keep in mind that this is a nonlinear model. The coefficients do not represent the marginal effects on the probability of higher price sensitivity. However, the sign of the coefficients reflects the direction of change in the probability, allowing an intuitive interpretation.

The sign of the variable *Revenue* is negative. This implies that the higher the revenue of a company, the lower the probability that firms put a high weight on the importance of price in the paper purchase decision. The variable is statistically significant at a 5% significance level.

The variable *Employee_Growth* also has a negative coefficient, implying that a faster growing company puts less weight on the price of paper. This variable was included in the model, although it is statistically insignificant (p-value 0.63). The estimated sign still gives some information and can be contrasted with results on the importance of runnability.

Companies that print marketing materials put less emphasis on the price. Firms that print marketing materials actually care more about runnability. This suggests that while overall costs play an important role, companies are willing to purchase relatively more costly paper if this paper proves to have high runnability, which may reduce the actual production cost. On the contrary, if a company is involved in printing catalogs the company is likely to put higher weight on price. The coefficient is statistically significant at a 5% significance level.

The variable *together* shows the strongest economic significance. This variable indicates whether a firm makes the paper purchase decision individually or in collaboration with the customer. If the firm collaborates with the customer, the likelihood of putting high weight on the price of paper decreases. Thus, a firm that communicates with customers more might be able to pass on cost increases more easily.

The data set includes information on the ability of a firm to pass on cost increases to the customer information. This information is used to analyze a firm's price sensitivity further. The variable *Passon_percent* indicates the percent of the cost increase in paper a company is able to pass on. However, a large number of firms did not reveal this information. To account for this, a dummy variable was created, taking on the value 1 if the firm did not reveal its ability to pass on cost increases to the customer. [Table 2] in the appendix shows the results.

The overall fit is quite good with a likelihood ratio test of all coefficients zero yielding a p-value of 0.1033. The coefficient for *Passon_Percent* is negative indicating that firms that are able to pass on cost increases to the customer are less likely to put high emphasis on the price. If a firm does not have to bear the full effect of a cost increase, then attention will shift from price to other factors like quality/appearance . The coefficient is statistically significant at a 10% significance level.

Interestingly the dummy variable *Passon_NA* turns out to be significant, both economically and statistically. Additionally the sign turns out to be negative. A possible interpretation is that those companies who do not reveal their pass on ability belong to those companies that are able to pass on a high percentage of their cost increases.

This result supports the initial interpretation of the coefficient of the variable *Together*. Firms that make their paper purchase decision together with the customer seem to be able to communicate that increase to the customer and then pass parts (or all) of the cost increase on to the customer. This explains why firms that make the decision together with the customer tend to care less about the paper price.

Results for the Importance of Runnability

While both the price and the runnability of the paper affect the production cost, the fact that almost all the respondents ranked runnability as an important factor in the paper purchase decision suggests that overall runnability has a much stronger impact on the production cost. Note that only about 60% ranked price as such. Another interesting observation is that the correlation of the importance of runnability with the importance of price across firms is -19.7%. This suggests that firms who care about runnability care less about price and vice versa.
Again, a full model is estimated and insignificant variables are eliminated leading to the final model reported in [table 3] (appendix). The model fits well. The likelihood ratio test is rejected with a p- value of 0.0020.

The only variable from the set of demographic variables that turns out to be somewhat significant is *Revenue_Growth*. Although the p-value signals a rather low significance the implication is quite interesting. The faster a firm's revenue grows, the more the firm emphasizes runnability. Companies printing marketing materials are more likely to emphasize runnability whereas it was found earlier that they tend to care less about the price of the paper. This is in line with Evans and LeMaire (2005) who report that there is a "trend towards short run, variable data electrophotographic printing for targeted marketing applications [requiring] robust paper runnability".

As expected, the sign for *dig_printer_perc* is positive. The more a firm is involved in digital printing, the more it emphasizes the runnability of paper. Similarly *DigitalAsset* shows a positive sign. Evans and LeMaire (2005) argue: "Compared with many offset requirements, sheet properties for digital printing must be more stringently controlled … in order to meet the jam-free requirements of complex high-speed paper paths." The coefficient on *dig_printer_perc* is rather large indicating the central importance of the variable. Consequently a firm that has progressed further towards the digital printing is more likely to emphasize runnability in the paper purchase decision.

Portfolio has a negative coefficient indicating that the larger the purchasing portfolio of a firm the less the firm cares about runnability. One interpretation is that these companies care more about price than about runnability. The correlation between the importance of price and the variable *portfolio* is 7.4%, supporting this view.

The variable *Alone_customer* is significant at the 5% level and shows the predicted sign. This supports my claim that if the printing company delegates the paper purchase decision to the customer the emphasis on runnability will be lower. This is intuitive as the customer's main concern is the quality of the end product.

Summary of Statistical Analysis

The statistical analysis of two aspects of the paper purchase decision identified some interesting results about the paper purchasing behavior of digital printing firms. Smaller, slow growing firms tend to put a high weight on the paper price whereas fast growing firms primarily focus on the runnability of paper. Firms that are printing marketing materials care mostly about runnability. One possible reason is that many are involved in Variable Data Printing which puts higher requirements on runnability, as the loss of one sheet can disrupt the whole print process.

A printing company that makes the paper purchase decision together with its customers is less likely to put emphasis on the price of paper. Evidence was also found that companies able to pass on to the customer a high percentage of cost increases care less about the price. These results suggest that companies who collaborate with their customers on the paper purchase decision are more likely to pass on their cost increases.

The more a company is involved in digital printing, the more it emphasizes the importance of runnability. This makes sense because runnability requirements for digital presses are generally higher. Finally, if a company delegates the paper purchase decision to the customer, the importance of runnability is lower. That is probably because customers put a higher weight on other criteria such as the quality and appearance characteristics of paper.

CONCLUSIONS

The results of this study indicate that paper characteristics and purchasing factors related to efficiency of production predominate over considerations related to appearance and price. In many cases the entire economic viability of a print job depends on the quality of the substrate; poor runnability and low image quality can differentiate between profit and loss in an industry with tight profit margins. The data from this study suggests that production digital printing is not a commodity segment, but is performance- and value-based. Within the On-demand Printing in the digital production segment, there is a lower tolerance for waste (time and materials) and a higher need for productivity, which pressures paper manufacturers to produce more uniform products to higher specifications.

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Appendix:

Table 1: Estimation Results for the Importance of Price regression

Logit Regression

	Coef.	Std. Error	P-value
Intercept 2	0.3764	0.9761	0.6998
Intercept 1	1.9073	0.9970	0.0558
Revenue	-0.3450	0.1744	0.0479
Employee_Growth	-0.1787	0.3792	0.6375
PJ_Marketing	-0.5555	0.2936	0.0585
PJ_Catalogs	0.6535	0.2870	0.0228
Together	-1.0754	0.4325	0.0129
Score Test		3.89841	0.5641
	Log-likelihood at mean	-405.1	
	Log-likelihood at convergence	-367.7	

Table 2: Estimation Results: Price Importance related to pass on ability

Logit Regression

	Coef.	Std. Error	P-value
Intercept 5	-0.3877	0.3324	0.2436
Intercept 4	0.9741	0.3468	0.0050
Passon_Percent	-0.8258	0.5008	0.0992
Passon_NA	-1.0130	0.5202	0.0515
Score Test		0.1128	0.9452
	Log-likelihood at mean	-405.1	
	Log-likelihood at convergence	396.0	

[1] Note, this is a chi square statistic.

Table 3: Regression Results for the Variable Importance of Runnability

Binary Logit Regression

	Coef.	Std. Error	P-value
Intercept	0.0318	1.4985	0.9830
Revenue_Growth	0.5187	0.3910	0.1847
PJ_Marketing	0.4898	0.3794	0.1966
PJ_Book	-0.5623	0.3010	0.0618
Dig_Printer_Perc	2.1870	1.0937	0.0455
Dig_Printer_NA	0.2244	1.3726	0.8701
Digital_Asset_Train	1.5284	0.7027	0.0296
Portfolio	-0.7347	0.2924	0.0120
Alone_customer	-1.5976	0.7777	0.0399
	Log-likelihood at mean	212.42	
	Log-likelihood at convergence	163.80	

Appendix II

A Tale of Two Industries: Competition and Turnover in the Digital and Quick Printing Industries - (November 2007)

Minjae Song

Appendix II: A Tale of Two Industries: Competition and Turnover in the Digital and Quick Printing Industries - Minjae Song (November 2007)

1 Introduction

Recent literature on firm entry shows that competition is an important factor in explaining firms' entry decision in oligopolistic markets. For example, Berry (1992) captures the effect of competition on a potential entrant's entry decision by including the number of incumbents in its profit function. He shows that a model that does not account for this effect may overestimate the number of firms that a market can sustain. The effect of competition on firms' entry decision may differ among industries. It may depend on the fixed cost, the market size, or regulations, among other things. In this paper I assess if the competition effect differs by the maturity of the industry. I compare a young and an established industries, and test (1) if the degree of competition, measured by the number of incumbents per capita in the previous period, affects the net turnover rate and (2) if this effect is significantly different in the two industries.

Instead of considering a wide range of industries, I choose the digital printing industry as an example of the young industry and the quick printing industry as an example of the established industry. By comparing similar industries I control for other industry characteristics that may affect the turnover rate. For example, if one industry is more heavily regulated than the other, the same number of incumbents may have different impact on the turnover rate. However, as the digital printing industry has been replacing the quick printing industry in some tasks, their turnover rates are likely to be correlated. Hence, I test if the competition effect is affected when the two industries are considered together.

I use the US Census Bureau's County Business Patterns from 1998 to 2002. The quick printing industry is classified under NAICS 323114 and the digital printing industry under NAICS 323115. (For details of industry description under NAICS, see Office of Management and Budget (1998). Deitz (2003) provides an excellent summary of NAICS.) The Census Bureau defines the two industries as follows.

> "[The quick printing] industry comprises establishments primarily engaged in traditional printing activities, such as short-run offset printing or prepress services, in combination with providing document photocopying service. Prepress services include receiving documents in electronic format and directly duplicating from the electronic file and formatting, colorizing, and otherwise modifying the original document to improve presentation. These establishments, known as quick printers, generally provide short-run printing and copying with fast turnaround times."
> "[The digital printing] industry comprises establishments primarily engaged in printing graphical materials using digital printing equipment. Establishments known as digital printers typically provide sophisticated prepress services including using scanners to input images and computers to manipulate and format the graphic images prior to printing."

I take a reduced form approach, instead of using a structural entry model. Data availability is the main reason. For the structural approach one needs data on potential entrants, including those who decided not to enter. The airline industry is one of few examples without the data issue. Given a route connecting two cities airlines that previously operate at one of the cities are considered as potential entrants. On the other hand, data on the number of establishments is readily available at the US Census Bureau. The sample period is from 1998 to 2002, and I consider each state as an independent market. (The digital printing industry first appears in the census data in 1998.) Hence, I observe 51 markets for 5 years. The dependent variable is the net turnover rate, defined as the rate of changes in the number of establishments per capita. I measure the degree of competition by the number of incumbents per capita in the previous period. I control for the market characteristics using the state level census data.

The number of establishments per capita is significant and negative in both industries, suggesting that competition has a negative effect on the entry. Comparing the two industries, the competition effect is three times larger in the quick printing industry than in the digital printing industry. When the number of establishment per capita increases by one, the net turnover rate decreases by 188 percent in the quick printing industry while it decreases by 55 percent in the digital printing industry. This is consistent with an intuition that it is harder for a potential entrant to enter a more established market. However, when the number of establishment per capita is adjusted with the size of employees, the difference disappears while the competition effect is still significant. The results are robust when the two industries are considered together.

2 Industry and Data

The quick printing includes any conventional copying and printing activities. It uses low cost mid-range printers like Xerox, DocuColor, Canon engines, etc. The run length is generally low and the turnaround time is short. The digital printing involves longer run high quality graphics and complex variable data projects. It uses full-color presses such as the HP Indigo, Xeikon, Xerox iGen3, Kodak Nexpress, etc. Demand for the digital printing mainly comes from the business sector. According to Evans and LeMaire (2006), predominant job types of digital printers are business marketing and promotional materials, direct mail, and manuals and documents.

However, the border between the two has become blurred. The digital printing has taken up some jobs done by the quick printing previously. Moreover, availability of low cost digital printing is enhancing this trend.

Some printers do both the quick and digital printing. Evans and LeMaire (2006) report that the median number of years digital printers in their sample have been in business is 28 years with 30% over 50 years. Since the digital printing started in the mid nineties, these printers either switched from the quick printing to the digital printing at some point or do both.

I consider each state as an independent market for both industries, and use state level data from US Census Bureau to control for the market characteristics. Table II-A provides summary statistics on the number of establishment and market characteristics. The digital printer is less constrained by a location as it accepts orders through the internet and sends back printed materials by mail. Nevertheless, it is still constrained by the delivery charge which increases with the distance.

There were 441 digital printing establishments in total in 1998 and the number increased to 775 by 2002. There were 8,167 quick printing establishments in 1998, and the number went down over time and returned to the original level by 2002. California has the highest number of the quick printers during the sample period, followed by Florida and Texas. California also has the highest number of the digital printers. New York has the second highest number of the digital printers, followed by Illinois until 2001 and by Florida in 2002. Alaska has the lowest number of the quick printers during the sample period, followed by Wyoming and North Dakota. A few states have no digital printers in some periods. Alaska, North Dakota, and West Virginia have no digital printers for the whole sample period.

District of Columbia has the highest number of the quick printers per capita during the sample period, followed by Rhode Island until 2001 and by Vermont in 2002. District of Columbia has the highest number of the digital printers per capita until 2000, but falls below the average later. In 2001 and 2002 Nevada has the highest number of the digital printers per capita.

Tables II-B and II-C show the size distribution of the two industries during the sample period. US Census data provide categories of the size in terms of the number of employees. For each year I take the average number of establishment across states for each category. While the skewness hardly changes in the quick printing industry during the sample period, it increases from 1.51 to 2.91 in the digital printing industry, and it is mainly driven by the entry of small size digital printer

3 Empirical Specifications and Results

The dependent variable is a net turnover rate, constructed by dividing the net changes in the number of establishment per capita by the number of establishment in the previous year. Demand side variables include income per capita, disposable income per capita, the unemployment rate, and population density. Supply side variables include the average rent, the commercial energy price, and the gas price.

In Tables II-D and II-E I report estimation results for each industry. For every specification the regression is run with and without the number of establishments per capita in the previous period. This variable captures a competition effect in the entry decision. In both industries, this variable has a negative and significant coefficient, implying that an additional incumbent establishment decreases the net turnover rate. The net turnover rate decreases either when the number of entrants decreases or when the number of exiting establishments increases. Either case can be interpreted as tougher competition.

Other than the constant term, three other variables show significant effects. First, (a growth rate of) the disposable income per capita has a significantly negative coefficient. Conditioning on the income per capita, the disposable income per capita changes by an income tax. The negative coefficient means higher income taxes decrease the net turnover rate. This can be attributed to lower demand for printing caused by higher income taxes.

The other two significant variables are the energy price growth rate and the gas price growth rate. Both variables are the supply side variables and are expected to have negative effects. Although the gas price growth shows a negative effect, the energy price growth rate shows a positive effect. A possible cause is that the energy price growth may capture strong economy where higher demand for energy drives its price to increase.

Signs and significance of coefficients are robust to both the year dummy variables and the random effect. The random effect controls for unobserved variables that affect differences in the net turnover rate across states. The number of observation is not high enough to include the year dummy variables and the random effect at the same time.

The focus of this paper is to compare the effect of the number of establishment per capita in the previous period between the two industries. The quick printing industry represents an established industry, while the digital printing industry represents a young industry. Since they are in the same printing industry, my comparison is less contaminated by unobserved intrinsic differences across industries.

When the two coefficients are compared, the digital printing industry seems to have a bigger competition effect. The absolute value is 0.095 in the digital printing industry, while it is 0.003 in the quick printing industry. However, the two industries have very different numbers of establishments so this difference should be accounted for in comparison.

For this purpose, I use a percentage change in the net turnover rate with respect to adding one more establishment given all other things constant. This is simply done by dividing the coefficients by the mean of the net turnover rates of each industry. This number is 0.55 in the digital printing industry and 1.88 in the quick printing industry. In other words, when there is one more establishment per capita, the net turnover rate decreases by 55 percent in the digital printing industry, while it decreases by 188 percent in the quick printing industry. This means that the competition effect is more than three times larger in the quick printing industry, and is consistent with an intuition that it is harder for a potential entrant to enter a more established market.

In Table II-F I report results when the same regressions are run when the number of establishment per capita is adjusted by the size (number) of employees. The number of establishment per capita in the previous period captures the competition effect at an establishment level. When this number is adjusted by the employee size, it captures changes in supply capacity, more precisely changes in the number of employees hired, and this does not necessarily have the same type of the competition effect. This is like a difference between adding another firm and increasing given firms' capacities (number of employees) in an oligopolistic model.

Table II-F shows that signs and significance of all variables do not change in the digital printing industry, while significance goes away except for the employee size adjusted number of establishment per capita in the quick printing industry. The employee size adjusted number of establishment per capita is negative and significant in both industries, and its absolute value is 0.013 in the digital printing industry and 0.0002 in the quick printing industry. When these values are divided by the mean net turnover rates, it becomes 0.075 in the digital printing industry, while it becomes 0.125 in the quick printing industry. In other words, when an additional employee is hired, the net turnover rate decreases by 7.5 percent in the digital printing industry, while it decreases by 12.5 percent in the quick printing industry. Now, the difference between the two industries shrinks so significantly that the effect is only 1.5 times larger in the quick printing industry.

To account for any correlation between the two industries, the seemingly unrelated regression is run with the same specification and results are reported in Table II-G. A new variable is the first variable y_{other} and it captures the effect of having another establishment in one industry on the net turnover rate in the other industry. This variable is negative and significant in both industries, suggesting that there is business stealing effect between the two industries. The competition effect is still negative and significant. Moreover, the difference becomes larger so that the effect is about four times larger in the quick printing industry (59 percent in the digital printing industry vs. 250 percent in the quick printing industry.)

4 Conclusions

This paper compares the competition effect between the mature industry and the young industry. The quick printing and the digital printing industries are chosen to represent each type of industry, respectively. The selection is done within the same industry to minimize unobserved differences other than being mature and young. The competition effect is defined as the effect of having one more establishment on the next period's net turnover rate.

The competition effect is negative and significant in both industries, but the effect is much larger in the quick printing industry. This confirms the intuition that it is harder for a potential entrant to enter a more mature industry. This also supports a common practice in the firm entry literature that the number of firms in the previous period is used to capture the competition effect.

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Table II-A- Summary Statistics

		1998	1999	2000	2001	2002
Quick Printers per capita	mean	29.07	27.62	25.73	25.74	28.11
	std	9.55	9.03	8.03	6.68	7.16
Digital Printers per capita	mean	1.59	1.56	1.67	2.05	2.42
	std	1.22	1.00	1.05	1.19	1.70
Income per capita	mean	25.49	26.27	26.51	26.69	26.93
(in thousands dollars)	std	3.90	4.09	4.36	4.26	4.19
Disposable Income per capita	mean	19.15	22.51	22.37	22.90	23.69
(in thousands dollars)	std	2.80	3.10	3.09	3.15	3.28
Unemployment rate (%)	mean	4.77	4.16	3.94	4.58	5.39
	std	1.22	1.05	0.97	0.91	1.04
Average Rent (in dollars)	mean	650.67	666.53	684.40	722.00	759.85
	std	127.15	115.05	120.30	134.20	152.98
Energy Price [y]	mean	4.84	4.77	5.01	5.44	5.33
	std	1.63	1.59	1.82	2.01	2.03
Gas Price [Z]	mean	68.59	64.23	112.54	104.60	88.71
	std	9.13	9.19	5.75	10.06	7.02

[y] In cents per kilowatt-hour.
[Z] In cents per gallon excluding excise taxes.

Source: US Census Data (http://www.census.gov)

Table II-B - Distribution of Firm Size in the Digital Printing Industry

	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6	Size 7	Size 8	Size 9	Skew
1998	3.73	2.06	1.43	0.94	0.35	0.08	0.06	0.00	0.00	1.51
1999	3.86	1.84	1.37	1.04	0.29	0.10	0.02	0.00	0.00	1.66
2000	4.12	1.92	1.35	1.18	0.29	0.08	0.00	0.00	0.00	1.70
2001	5.86	2.55	1.35	1.35	0.35	0.08	0.00	0.00	0.00	1.99
2002	8.24	3.08	1.90	1.47	0.35	0.16	0.00	0.00	0.00	2.19
Mean	5.16	2.29	1.48	1.20	0.33	0.10	0.02	0.00	0.00	
S.D.	1.92	0.52	0.24	0.22	0.03	0.03	0.03	0.00	0.00	

Table II-C - Distribution of Firm Size in the Quick Printing Industry

	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6	Size 7	Size 8	Size 9	Skew
1998	91.92	42.45	16.96	7.04	1.35	0.27	0.08	0.06	0.00	2.11
1999	87.04	40.71	16.96	6.84	1.24	0.39	0.08	0.04	0.00	2.08
2000	80.65	38.73	16.49	7.20	1.45	0.33	0.08	0.06	0.00	2.04
2001	82.31	38.33	16.31	7.24	1.41	0.49	0.08	0.06	0.00	2.08
2002	96.49	38.53	16.96	6.55	1.25	0.29	0.02	0.04	0.00	2.26
Mean	87.68	39.75	16.74	6.97	1.34	0.36	0.07	0.05	0.00	
S.D.	6.60	1.79	0.31	0.28	0.09	0.09	0.03	0.01	0.00	

Table II-D - Net Turnover in the Digital Printing Industry

	Spec1-1	Spec1-2	Spec2-1	Spec2-2	Spec3-1	Spec3-2
n_{t-1}		-0.095		-0.093		-0.095
		(0.033)		(0.033)		(0.033)
pi_grw	2.97	2.096	1.330	1.364	2.297	2.096
	(2.653)	(2.605)	(3.110)	(3.057)	(2.653)	(2.604)
dpi_grw	-1.474	-1.616	-0.151	-0.589	-1.474	-1.616
	(0.751)	(0.739)	(2.326)	(2.292)	(0.751)	(0.739)
p_energy_grw	0.872	0.809	0.795	0.785	0.872	0.809
	(0.339)	(0.333)	(0.362)	(0.355)	(0.339)	(0.333)
gas_grw	-0.313	-0.344	-0.524	-0.455	-0.313	-0.344
	(0.121)	(0.119)	(0.411)	(0.404)	(0.121)	(0.119)
rent_grw	-0.552	-0.207	-0.620	-0.261	-0.552	-0.207
	(0.771)	(0.766)	(0.781)	(0.778)	(0.771)	(0.766)
unemp_grw	0.095	0.085	0.075	0.059	0.095	0.085
	(0.245)	(0.240)	(0.271)	(0.267)	(0.245)	(0.240)
const	0.265	0.426	0.177	0.377	0.265	0.426
	(0.074)	(0.092)	(0.127)	(0.144)	(0.074)	(0.092)
Year Dummies	No	No	Yes	Yes	No	No
Random Effect	No	No	No	No	Yes	Yes
Pr > F (or $\chi 2$)	0.0042	0.0003	0.0197	0.0023	0.0031	0.0002
Adj. R^2	0.065	0.099	0.054	0.086	0.093	0.131
N	200	200	200	200	200	200

pi_grw	Income per Capita growth rate
dpi_grw	Disposable income per capita growth rate
p_energy_grw	Energy price growth rate
gas_grw	Gas price growth rate
rent_grw	Average rent growth rate
unemp_grw	Unemployment rate – growth rate

Table II-E- Net Turnover in the Quick Printing Industry

	Spec1-1	Spec1-2	Spec2-1	Spec2-2	Spec3-1	Spec3-2
n_{t-1}		-0.003		-0.003		-0.003
		(0.001)		(0.001)		(0.001)
pi_grw	0.947	0.951	0.265	0.387	0.947	0.951
	(0.476)	(0.458)	(0.515)	(0.491)	(0.476)	(0.458)
dpi_grw	-0.664	-0.584	0.272	0.190	-0.664	-0.584
	(0.135)	(0.131)	(0.385)	(0.367)	(0.135)	(0.131)
p_energy_grw	-0.096	-0.084	-0.014	0.002	-0.096	-0.084
	(0.061)	(0.059)	(0.060)	(0.057)	(0.061)	(0.059)
gas_grw	-0.141	-0.129	0.064	0.093	-0.141	-0.129
	(0.022)	(0.021)	(0.068)	(0.065)	(0.022)	(0.021)
rent_grw	-0.184	-0.163	-0.203	-0.174	-0.184	-0.163
	(0.138)	(0.133)	(0.129)	(0.123)	(0.138)	(0.133)
unemp_grw	0.044	0.051	-0.038	-0.026	0.044	0.051
	(0.044)	(0.042)	(0.045)	(0.043)	(0.044)	(0.042)
const	0.053	0.134	0.111	0.012	0.053	0.134
	(0.013)	(0.024)	(0.021)	(0.065)	(0.013)	(0.024)
Year Dummies	No	No	Yes	Yes	No	No
Random Effect	No	No	No	No	Yes	Yes
Pr > F (or $\chi 2$)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Adj. R^2	0.273	0.328	0.375	0.432	0.295	0.352
N	200	200	200	200	200	200

Table II-F - Size Adjusted Net Turnover in the Digital and Quick Printing Industries

	Digital Printing			Quick Printing		
	Spec1	Spec2	Spec3	Spec1	Spec2	Spec3
adj_n_{t-1}	-0.013	-0.014	-0.013	-0.000	-0.000	-0.000
	(0.004)	(0.004)	(0.004)	(0.000)	(0.000)	(0.000)
pi_grw	18.650	25.095	18.650	-1.650	-2.149	-1.704
	(7.086)	(7.904)	(7.086)	(0.933)	(1.035)	(0.931)
dpi_grw	-3.383	-12.745	-3.383	0.220	0.967	0.225
	(1.786)	(5.518)	(1.786)	(0.235)	(0.722)	(0.233)
p_energy_grw	2.445	2.565	2.445	0.144	0.116	0.145
	(0.812)	(0.859)	(0.812)	(0.107)	(0.113)	(0.107)
gas_grw	-0.995	-0.102	-0.995	0.026	0.162	0.025
	(0.331)	(0.974)	(0.331)	(0.044)	(0.128)	(0.044)
rent_grw	0.989	1.444	0.989	-0.181	-0.221	-0.168
	(1.853)	(1.866)	(1.853)	(0.244)	(0.246)	(0.245)
unemp_grw	-0.763	-0.494	-0.763	-0.037	-0.096	-0.040
	(0.590)	(0.645)	(0.590)	(0.077)	(0.084)	(0.077)
const	0.406	0.781_	0.406	0.109	-0.014	0.113
	(0.228)	(0.335)	(0.228)	(0.034)	(0.121)	(0.035)
Year Dummies	No	Yes	No	No	Yes	No
Random Effect	No	No	Yes	No	No	Yes
Pr > F (or $\chi 2$)	0.0001	0.0002	0.0000	0.0023	0.0033	0.0017
Adj. R^2	0.115	0.118	0.151	0.079	0.084	0.116
N	200	200	200	200	200	200

Table II-G Seemingly Unrelated Regression

	Digital Printing	Quick Printing
Yother	-0.938	-0.034
	(0.384)	(0.012)
Nt-1	-0.102	-0.004
	(0.032)	(0.001)
pi_grw	2.970	1.029
	(2.568)	(0.447)
dpi_grw	-2.249	-0.629
	(0.766)	(0.129)
p_energy_grw	0.714	-0.054
	(0.328)	(0.058)
gas_grw	-0.478	-0.139
	(0.128)	(0.021)
rent_grw	-0.355	-0.180
	(0.751)	(0.130)
unemp_grw	0.125	0.055
	(0.235)	(0.041)
const	0.487	0.148
	(0.093)	(0.024)
Pr > $\chi 2$	0.0000	0.0000
R2	0.130	0.354
N	200	200

Appendix III

A survey of Digital Press Manufacturers: Critical Paper Requirements (2008)

Howard Vogl,
Visiting Professor, School of Print Media, Rochester Institute of Technology

RIT Printing Industry Center Research Monograph No. PICRM-2008-03

Vogl, H., "A Survey of Digital Press Manufacturers: Critical Paper Requirements", RIT Research Monograph, No. PICRM-2008-03, Rochester Institute of Technology, Printing Industry Center, Rochester, NY (2008). (http://print.rit.edu/pubs/picrm200803.pdf)

CRITICAL PAPER REQUIREMENTS - BASED ON SURVEY OF DIGITAL PRESS MANUFACTURERS

OBJECTIVE

Printer device manufacturers were interviewed (surveyed) to understand:

- The limitations that available paper grades impose on current digital press design and innovation in printing devices
- The limitations that digital press design impose on the use of currently-available papers
- Future trends in digital press design; in digital papers as enabled by technology developments

Based on the survey results, constraints to printer performance and quality were identified, in terms of critical paper property requirements affecting digital printing. Paper quality issues included those listed here and in Table III-A:

- Web transport (web fed printing)
- Sheet transport
- Web breaks (related to paper tensile, elongation)
- Sheet feeding (dimensional stability, two-sidedness, stiffness, curl)
- Linting (charge, surface strength)
- Printability (uniformity, roughness)
- Print-through (bulk)

APPROACH

H. Vogl conducted a telephone survey of five major electrophotographic printer device manufacturers, selected based on prior relationships with RIT. The survey was executed using a pre-written survey template form, which was provided to each participant a′ priori for review and which was used during the actual survey.

RESULTS

H. Vogl determined that dimensional stability, product uniformity, and toner adhesion were the primary parameters considered critically important by all respondents (Table III-B). H. Vogl also points out: "when asked about paper characteristics important to optimal toner application, paper surface resistivity and moisture level were almost universally important. Surface resistivity and moisture level play an important role in toner density and evenness. Since fusing energy is evenly distributed on the substrate surface, unexpected variations in toner density result in less than optimal fusing of toner to substrate. Therefore, optimal toner fusing is, in part, based on substrate uniformity".

Vogl also found that the importance of other specific paper characteristics diverged, partly due to differences in the print hardware technology used. These characteristics included:

- Sheet filler transfer to fuser rollers
- Sheet recycle content
- Sheet moisture level

Parameter	Cause	Result	Transport	Printing	Post Processing
High Moisture Level	Environment, manufacture	Increased conductivity, change in dimensions, wavy edges	Feed problems	Poor toner transfer, misregistration	Jams in finishing
Low Moisture Level	Environment, manufacture	Decreased conductivity, change in dimensions, static buildup, tight edges	Jams	Misregistration	Jams in finishing
	Fusing	Change in dimensions		Misregistration	Jams in finishing
Grain Direction	Substrate	Variance in stiffness	Transport		Toner cracking
Substrate Dimensions	Environment, manufacture, cutting accuracy, fusing	Wrong or inconsistent dimensions	Feed problems	Misregistration	Feed problems, jams in finishing
Surface Smoothness – Too Smooth	Manufacture		Feed problems		Feed problems in finishing
Surface Smoothness – Too Rough	Manufacture			Poor toner transfer	
Porosity	Manufacture		Vacuum feed problems	Toner penetration	Vacuum feed problems
Filler and Formation	Manufacture			Toner transfer and even toner density, filler buildup on fuser roller	
Paper Dust	Cutting	Paper Dust		Dust buildup on fuser roller	

Table III-A – Relationship of Paper Properties to Press Performance (Vogl, 2008; Garno,W., “Advances in Digital Printing”, Tappi Coating Conference, Dallas, TX, 2008)

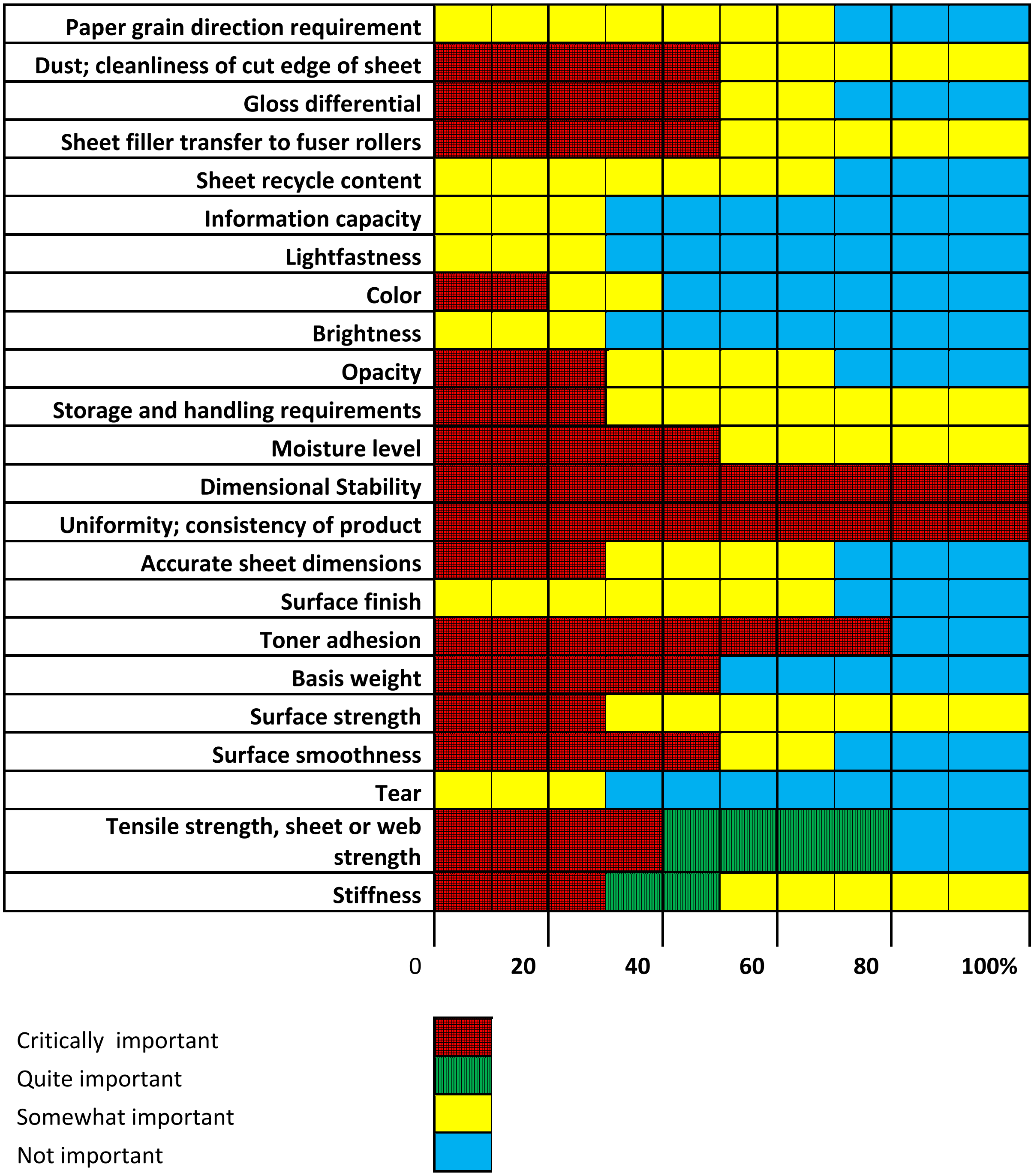

Table III-B – Percent of Responders Indicating Degree of Importance of Specific Paper Characteristics (Vogl, 2008)

Appendix IV

IPST Mill Model – Improved Uniformity Case

Area			Uncoated Freesheet	
			Base Case	Increase Uniformity in Wood Supply
Unit Prices	SW Chips, $/BDMT		68	68
	SW Roundwood, $/cu. m sub		38	38
	Hog fuel, $/BDMT		12	12
	Fuel Oil, $/bbl		70	70
	Purch. Pwr, $/kWh		0.07	0.07
Stock Prep	Furnish		78% fiber (85% BHKP, 15% BSKP); 17% filler; 5% starch	78% fiber (85% BHKP, 15% BSKP); 17% filler; 5% starch
Cooking	Yield		SW: 44 HW: 50	SW: 44 HW:50
	Steam Demand, lb/BDMT	Factor down by 10%	SW: 1650 HW: 1600	SW: 1485 HW: 1440
Screening / Knotting (HW and SW)	Screening Losses, %	Factor down by 50%	0.5	0.25
	Knotter Losses, %	Factor down by 50%	1.0	0.5
Wet End	Machine Breaks, %		3.0	1.0
Dry End	Broke, %		6.2	3.1
Finished Paper Costs	**$/FMT**		**508**	**503 (savings in fiber, energy)**
Uncoated Freesheet Production	**FMT/y**		**298,759**	**315,199 (5.5% increase)**

TABLE IV-A- IPST Mill Model: Improved Uniformity Case