The Role and Value of Innovation in the Pulp and Paper Industry

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A Brief Outline of Our Project and the Structure of the Final Report

This report presents the deliverables of the 2004-2006 grant we received from the Center for Paper Business and Industry Studies. The title of the grant was: "The Role and Value of Innovation in the Pulp and Paper Industry."

Our project was motivated by the fact that the global pulp and paper industry had been undergoing a significant transformation since the late-1980s due to rapidly changing international markets, globalization, greater competition faced by incumbents in many markets, overcapacity, among others. Motivated by observations from the industry and some preliminary investigations conducted by us based on visits to pulp and paper mills in the U.S. and Europe, our goals were to identify the specific types of activities that firms in the pulp and paper industry were engaging in to improve their performance, productivity and competitive position.

We consider several broad strategies that firms can adopt to improve their performance and productivity.

- Firms can make investments in modernization. Depending on the availability of data, our goal is to gather information on specific areas of firms' operations and examine what sorts of investments the firms have made in each area. A firm that is very active in making improvements in its production process and engaging in modernization investments should observe better productivity compared to a firm that does not.

- Firms can also pursue pure innovation strategies such as increased R&D expenditures and patents. R&D expenditures are an input to obtaining output such as patents. If the path of innovation is successful, firms would reap gains in performance and productivity.
- Firms can engaging in mergers and acquisitions (M&As) to generate synergies and improve efficiency.
- Firms can also make changes in their organizational structure, improve supply-chains and better management.

In reality, a firm can pursue all (or any combination) of these activities simultaneously to improve its performance and productivity and gain in its competitive position relative to its rivals.

Our research methodology involves using firm-level data available from various sources:

(1) We gathered firm-specific information on capital-stock, sales, employment, R&D, investment, among other variables from the Compustat database,

(2) We filled in gaps in the data on some of the variables like R&D from company annual reports and 10K financial statement filings made to the SEC,.

(3) We gathered information on the number of M&As (total as well as domestic versus foreign) and deal values from the Thompson's Financial database.

(4) We compiled information on the number of patents awarded to the U.S. and foreign firms in our sample from the U.S. and European Patent offices.

(5) We compiled information on transactions made by each firm in different areas of the production process from the publication *Pulp and Paper*. We label these transactions as "targeted investments" to modernize and upgrade the firm's capabilities. The four broad areas where we observe such transactions are: (a) mechanical, (b) chemicals, (c) monitoring devices and (d) information technology. We discuss the data collection procedures, note the pros and cons, and present summary statistics for each data source,.

After compiling all of the data, we conduct two types of statistical analysis: (1) time-series with firm-specific data; and (2) cross-firm analysis where we use 8-to-10 year averages and examine differences across firms. Some of the issues we examine relate to, for example:

- Do new investments help improve productivity?
- Do targeted investments in the mechanical, chemicals, monitoring devices and information technology categories improve productivity? If yes, which area(s) provide a greater boost to productivity?
- Do the traditional measures of innovation – R&D expenditures and patent counts – help explain differences in productivity across firms?
- Do mergers and acquisitions help explain differences in productivity across firms?

In terms of drawing inferences, we use two types of analysis. First, we present correlations among the key variables in our data to explore some patterns. We are careful to note that these correlations are unconditional raw correlations and do not control for other factors that may affect the relationship between a pair of variables. Second, we conduct a more formal statistical analysis by presenting results from regressions. One important advantage is that in this format we are more explicitly able to control for several of the control variables when examining a relationship of interest. For example, when examining the relationship between targeted investments a firm makes to modernize and upgrade its production processes, we are able to control for the total number of mergers and acquisitions a firm engaged in, firm's capital-labor ratio and measures of innovation like patents. If, for example, we are to examine the extent to which mergers and acquisitions may have contributed to productivity and performance, our regression models explicitly control for important control variables such as patents, capital-labor ratio and other forms of investments. Overall, the regression analysis we conduct presents a more encompassing view of the factors that contribute to firms' gains in productivity.

The report is structured as follows. We have written the report as containing two distinct papers that we will aim to get published in interdisciplinary journals that focus on the broad areas of business strategy, economics and innovation. There are two main reasons why we choose to present the final report as two distinct papers:

(1) The range of issues we explore is quite diverse. While all of the data and information we use are firm-level, examination of some of the issues primarily involves time-series analysis while others mainly rely on cross-firm analysis. Therefore, the first paper

contains a fair amount of firm-level time-series analysis and some cross-firm results. The second paper only contains cross-firm analysis using data on the targeted investments.

(2) The data on the targeted investments made by each firm were somewhat unique and required detailed description of how we compiled it, careful evaluation of the pros and cons, separate samples of firms as we had a difficult time putting together a comprehensive dataset containing all of the data for each firm. All of this required a different look at the issues and analysis.

We felt that putting all of this together into one integrated report would not be very meaningful. Separating the two types of analysis also provides us with a clear opportunity to get some papers published.

The first paper is titled: "Innovation and Productivity Growth in the Pulp and Paper Industry: Firm-Level Empirical Evidence." This paper begins by noting that there have been significant changes in the global pulp and paper industry over the last decade such as global overcapacity, increased global competition, development of new overseas suppliers, emergence of new markets and the expansion of international markets. The main goal of this paper is to analyze the role of innovation and its impact on firm productivity in this industry as firms adjust to the new market environment. The paper presents a time-series analysis that covers 24 firms from the period from 1995-2004. We analyze the impact of innovation by examining the role played by research and development expenditures and the number of patents per firm. We use the capital labor ratio as an additional explanatory variable. Unlike in many other industries, the capital stock also embodies some elements of innovation since it captures two unique elements of capital in this industry. New technology is ubiquitously available to those firms willing to make the investment (since equipment suppliers are the innovators). However, given how long-lived the existing capital equipment is, even if new technologies are available, not all firms will adopt the new technologies. There is evidence that some firms were undertaking cost-saving innovations and consolidation through mergers and acquisitions (M&As) as ways to improve the bottom line, hence we also control for M&As in our analysis.

Our results indicate that the capital-labor ratio has a largely positive and significant impact on firm productivity in the industry. There is a great deal of heterogeneity across firms in the impact of capital stock on productivity. Our patent variable is significant in the full sample and in the sub-sample of larger firms (with sales above the median average sales for the sample). Our analysis suggests that the incremental, productivity-enhancing innovations that firms in this industry conduct in-house are probably not patentable and are thus not captured by the patent data. Ideally, firm level R&D data that provides details of different types of R&D activities as well as a breakdown of the capital investment into different technology categories would be very useful in refining our analysis.

The second paper is titled: "Targeted Investments in Modernization and Gains in Productivity: Evidence from the Global Paper Industry." The primary focus of this paper is to examine the impact of firms' targeted investments in modernization and upgrading on productivity. Due to various data constraints, the specific measure of productivity we use is *labor productivity*. In contrast to much of the existing literature which focuses on the impact of R&D and patents on firms' performance and productivity, we examine data on actual investment transactions in four main areas: (i) mechanical, (ii) chemicals, (iii) monitoring devices and (iv) information technology.

The econometric approach we take in this paper is a cross-firm (or cross-section) analysis. All the data we use are at the firm-level and measured as 8-to-10 year averages per firm. From a sample of global pulp and paper firms, we find that investments in modernization deliver a boost to firms' (labor) productivity and the estimated quantitative effects are greater than the impact of the standard innovation variables such as patents and R&D. These results are obtained after controlling for other important firm-specific variables such as capital-intensity and mergers and acquisitions. As expected, firms with a capital-labor ratio have higher productivity. We find that mergers and acquisitions have little or no impact on productivity.

Two messages emerge from our findings. First, firms and managers need to be very focused on strategies related to targeted investments in modernization and various forms of incremental innovations. These appear to be the main channels via which firms can enhance their productivity in the longer-run. Second, managers need to realize that improvements in productivity will typically be small. While small gains may not seem important on a year-to-year basis, they can compound to form meaningful differences in performance and productivity across firms in the longer-run.

Our next step is to refine these papers and develop them into journal quality articles. Given the nature of the topic and the range of issues covered, our aim will be to focus on interdisciplinary journals that cover the broad areas of management strategy, economics and innovation.

Innovation and Productivity Growth in the Pulp and Paper Industry: Firm-Level Empirical Evidence

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Abstract

There have been significant changes in the global pulp and paper industry over the last decade such as global overcapacity, increased global competition, development of new overseas suppliers, emergence of new markets and the expansion of international markets. The main goal of this paper is to analyze the role of innovation and its impact on firm productivity in this industry as firms adjust to the new market environment. This is a time series analysis that covers 24 firms from the period from 1995-2004. We analyze the impact of innovation by examining the role played by research and development expenditures and the number of patents per firm. We use the capital labor ratio as an additional explanatory variable. Unlike in many other industries, the capital stock also embodies some elements of innovation since it captures some unique aspects of capital in this industry. New technology is ubiquitously available to those firms willing to make the investment (since equipment suppliers are the innovators). However, given how long-lived the existing capital equipment is, even if new technologies are available, not all firms will adopt the new technologies. There is also evidence that some firms were undertaking cost-saving innovations and consolidation through mergers and acquisitions (M&As) in order to improve the bottom line; hence we also control for M&As in our analysis. Our results indicate that the capital labor ratio has a largely positive and significant impact on firm productivity in the industry. There is a great deal of heterogeneity across firms in the impact of capital stock on productivity. Our patent variable is significant in the full sample and in the sub-sample of larger firms (with sales above the median average sales for the sample). Our analysis suggests that the incremental, productivity-enhancing innovations that firms in this industry conduct in-house are probably not patentable and are thus not captured by the patent data. Ideally, firm level R&D data that provides details of different types of R&D activities as well as a breakdown of the capital investment into different technology categories would be very useful in refining our analysis.

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1. Introduction

There have been significant changes in the global pulp and paper industry over the last decade. These changes include global overcapacity, increased global competition, development of new overseas suppliers, emergence of new markets and the expansion of international markets. The result has been a fundamental transformation in the US pulp and paper industry. Some of the changes in the industry include: (i) Increased focus on innovation and attaining cost-efficiencies in areas such as waste reduction and energy conservation; (ii) Changes in managing production and striving for a better balance between demand and supply; this is in sharp contrast to the earlier strategy, where mills produced close to full capacity even during periods of declining demand. (iii) Transformation of the industry structure due to mergers and acquisitions (M&As) and plant closings; and (iv) Greater integration of the US industry into global markets and consequent increases in volatility in prices and returns due to export market fluctuations.

The main goal of this paper is to analyze the impact of innovations on firm productivity as firms adjust to the new market environment. We have time-series data that covers 24 firms from the period from 1995-2004. Given the data limitations, our proxy for firm productivity is the real output per employee. We use the ratio of research and development (R&D) expenditures to sales and the number of patents per firm as proxies for innovation. We use the capital labor ratio as an additional explanatory variable in light of the fact that the capital stock also embodies some elements of innovation that occurs in this industry through the equipment suppliers.[1] During this period, firms have also been undertaking consolidation through mergers and plant closings. Our visits to selected mills in Europe and the US as part of our on-going research in the pulp and paper industry highlighted the rather intricate and complementary strategies being pursued by some firms related to cost-saving innovations and consolidation through M&As as ways to improve the bottom line. Hence, we consider it important to control for the impact of mergers and acquisitions while studying firm productivity. This also enables us to conduct a comparative analysis of innovation versus consolidation and to attempt to quantify their relative impacts.

The rest of this paper is organized as follows: Section 2 contains an overview of the pulp and paper industry. Section 3 reviews the related literature, and section 4 discuses the data and develops the empirical model. Section 5 presents the results and section 6 concludes with a discussion of the policy implications.

2. An Overview of the Pulp and Paper Industry:[2]

The paper and forest products industry is among the largest and oldest US industries, with annual shipments of about $260 billion. About 85% of this industry's revenues come from the paper and paperboard segment. It also employed approximately 1.1 million

[1] Note the detailed discussion in section 4 of the paper regarding the unique characteristics of capital in this industry.

[2] This section draws extensively from the Standard and Poor's Industry Surveys, April 2005.

people in 2004 in the US. The US is the biggest consumer in the worldwide paper market. The domestic industry's share of the worldwide market is more than 25%. However, majority of its revenue is derived from sales in the US market.

The US market is highly competitive since most paper products are considered as commodities; hence, there can be a good deal of price volatility. The global economic downturn of the late-1980s and early-1990s significantly changed the competitive landscape for the pulp and paper industry. Ince (1999), for example, notes that prices and capacity utilization became much more volatile during the 1990s due to increased globalization of markets and the effects of changing export demand for US products.[3]

High supply and low demand combined to produce very low prices and returns. During this period, the industry suffered from excess production that was in part induced by the combination of highly capital-intensive production, excess capacity developed in the 1970s, and the inflexibility of contracts related to input procurement, transportation and labor.[4] A new paper machine costs several hundred million dollars and has a long life span of over 30 years. In general, given the high capital-intensity, it makes economic

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[3] Figures 2-4 in Ince vividly display these features.

[4] It is common knowledge that there is global overcapacity (Ince, 1999; Douglas, 2001). The origins of this overcapacity are due in part to events in the 1970s. As noted by Kates (2002), in the late-1970s producers took advantage of high demand and prices and heavily invested in new capacity. Given the longevity of the paper machines, these machines are still active today and contributing to global overcapacity and production. Ghosal (2003) describes evidence on the inflexibility of contracts in earlier years.

sense to run the paper machine close to full utilization to recoup the fixed costs.[5] At low levels of utilization and production, the average cost of production is high due to higher average fixed costs and the firm is more likely to make losses, given that prices are typically determined in broader global markets. Hence, even during periods of low demand, producers traditionally tried to recoup their fixed costs by maintaining high production. As Douglas (2001) notes, paper mills have historically seen maximum tonnage as their primary goal and have run the machines at high operating rates.

There is evidence that some firms in the industry responded to the market events of the early-1990s by embarking on strategies to correct the problems that have led to low prices and dismal earnings. Smaller manufacturers sought to escape the volatile pricing of commodity markets by differentiating their products through value-added grades of paper, while big players in this industry started rapidly shifting to more profitable product lines and focusing on core products to achieve better economies of scale and higher overall profitability.

In recent years the industry has become better at controlling capacity and keeping production in line with demand. According to the American Forest and Paper Association (AF&PA), in 2004 the US paper and paperboard capacity was relatively stable at 100 million tons. However, this strategy has also resulted in a reduction in capital expenditures. While capital spending in the 1980s was 250% of industry depreciation levels, it declined in early 1990s to 100% of depreciation; in 2003 it was below the 75%

[5] The P&P industry has one of the highest capital-intensities in the US manufacturing sector.

level needed to maintain facilities. Standard and Poor (S&P) project that this will increase in the coming years as firms slowly add capacity.

There is considerable variation in firm size in this industry. International Paper at the top of the list generated revenues of $25,500 million in 2004, while Packaging Corporation of America ranked 10th had revenues of $1,890 million. The market is also highly fragmented. International Paper for example has only about 11% of the nation's paper, paperboard, and pulp capacity and 4% of the global capacity. Some firms are integrated paper mills while others are not. Typically most firms produce variety of related products. Table 1 indicates the largest US paper and forest products companies, classified by revenues generated in 2004; it gives us an indication of not only how large the industry is, but also the substantial heterogeneity among the firms' sales. Graph 1 indicates the production in the US during 1995-2005 by various product categories, while Table 2 indicates the projected capacity changes over the period 2005-2007. The total production in 2005 is 46,194 thousand short tons of paper, 53,085 thousand short tons of paperboard, and 67,401 thousand short tons of wood pulp. The estimates for 2007 forecast a decline in all three categories, with the corresponding figures for 2007 being 97,478 thousand short tons of paper, 52,309 thousand short tons of paperboard, and 66,323 thousand short tons of wood pulp.

The fast changing international markets have had a big influence on the US paper industry. Factors such as reduction in trade barriers, economic growth, and the demographics in many foreign countries have made them attractive export markets. Many developing regions have a low per capita consumption of paper and paper products as compared to developed regions of the world. For example, according to Pulp and Paper International, per capita consumption of paper and paperboard in Asia, Latin America and Africa was 31.4 kg., 35.2 kg., and 6.4kg. respectively while the corresponding figure for the US was 300.8 kg.

Russia and China have become large export markets. China has significantly expanded its paper and packaging capacity and is now a large importer of pulp and recovered paper.[6] Some of the US's key trading partners have also made significant investments in paper manufacturing, thus reducing imports from the US. The new global competitors are largely from Europe and the Far East. A Food and Agricultural Organization (FAO) survey indicates that global capacity is expected to increase at a compound average growth rate of 0.95% during 2004-2008. It is estimated that elsewhere in Asia (excluding China) capacity may grow by about 0.43% annually while in Central and South America capacity may expand at a faster pace than the global average.

Table 3 summarizes the export and imports by product category in the pulp and paper industry over the period 1995-2005. US imports of all categories have increased over this period, except for newsprint. Since the mid-1990s, paper and paperboard exports which accounted for 8% of the total US paper and paperboard production

[6] China is estimated to add 7 million metric tons of capacity between 2004 and 2005 with recycled containerboard, boxboard and newsprint capacity estimated to have the largest gains. (S&P Industry Survey, April 2005).

increased to 10%. US export of waste paper shows a dramatic increase, with demand from China being a major driver.

Among the factors that will continue to impact industry profitability are capacity, industry consolidation, narrow vs. extensive product offerings, dependence on recycled materials, environmental regulations, increasing use of electronic communications, global competition and the changing global marketplace. For examples, mergers and acquisitions (M&As) have become a major growth strategy, allowing firms to increase their size and market share, and realign their product mix without increasing overall capacity in the industry (since they acquired existing firms). There has also been a shift towards engineered wood products as environmental regulations restrict the harvesting of old growth trees.

What does all this mean in terms of industry profitability and its relationship to innovation? Global capacity expansion has serious implications for the US industry. In this industry, innovation in machinery and equipment is done largely at the level of the paper machine manufacturers and not by the individual firms themselves. New capacity expansion abroad implies that the foreign competitors will have access to state-of-the-art machinery and equipment which reduce their actual manufacturing costs. The average life span of machinery in this industry is more than 30 years, and most US firms are operating with older equipment and possibly at higher costs. Hence innovation that results in cost cutting becomes critically important for US firms to remain competitive, both domestically and globally.

3. Literature Review:

The main goal of this paper is to analyze how innovation in the pulp and paper industry impacts firm productivity. We draw upon several strands of the literature such as the research on firm productivity, innovation, and mergers and acquisitions to develop the framework for our analysis.

Innovation:

Economic theory has long recognized the significance of innovations and provides sophisticated models of economic decision making under various forms of technological progress. Gort and Klepper (1982, p.634) state that innovations, learning-by-doing, and ongoing improvements not only reinforce the barriers to entry by new firms but also compress the profit margins of less efficient producers who are unable to imitate the leaders. Eventually, the less efficient firms are forced out of the market, and the fittest survive.

Several papers build on the above theme and provide additional insights: e.g., Klepper and Graddy (1990), Jovanovic and MacDonald (1994), Audretsch (1995) and Klepper and Simons (2000). These models assume: (1) a distribution of production efficiencies across incumbent firms, (2) improvements in production efficiency levels due to learning-by-doing and imitation, and (3) a low probability of successful innovations.

Each time period gives rise to innovation opportunities to lower unit production cost, and innovators enjoy greater profit margins than imitators due to their innovative activities. These improvements in production efficiency result in downward pressure on prices. As a consequence, inefficient firms exit from the industry or are acquired by the more efficient firms. The probability of exit is lower for successful innovators. Overall, these theories provide a solid basis for understanding changes in profitability and market shares among incumbent firms.[7]

Several characteristics of the pulp and paper industry make innovation a critical component of firm strategy. First, equipment manufacturers through supplier alliances spearhead most of the process-related technological innovation. Hence, the state of the art equipment and technology is available to both incumbent firms and new entrants all over the world. This implies that paper machines are not likely to be the key source of differences in competitive advantage across firms. [8] In spite of the state of the art technology being readily accessible to all firms, there are large differences in the vintage of machines being used, and in firm performance. The vintage varies not only across firms, but also within firms and even within mills, with newer machines providing higher-speeds, greater capacity, and energy and materials savings. When we consider firms that have access to the same machines, we do not necessarily find that the competitive positions of these firms in the global markets are the same.

[7] Ghosal (2003) provides a review of the theory and empirical evidence.

[8] See Nair-Reichert (2002) for more details. Also see Aiginger and Pfaffermayr (1997) pp. 251.

Second, our discussions with various industry managers revealed that firms might not have substantial power to differentiate their products from that of their competitors and obtain high prices. (We are mainly concerned about the commodity markets and coated and uncoated paper, and not niche paper types.) The main reason is that the underlying technologies to make different types of paper are common knowledge. If a firm developed a specific new type of paper, this will be relatively easy to imitate at least among the dominant firms in the industry.

In short, after controlling for machine vintage effects, it appears that neither paper machines (the key form of capital in this industry) nor a strategy of product differentiation is likely to be the key to gaining competitive advantage over one's rivals. Our discussions indicate that innovations that deliver steady gains in cost-efficiencies in the dimensions of, for example, waste reduction and energy savings are crucial to maintaining and enhancing competitive advantage. The significance of such innovations was highlighted in a CPBIS sponsored study (Ghosal, 2003).

Our discussions with select industry experts revealed that cost-efficiency gains from innovations could be as high as 3% per year, with waste reduction accounting for about 0.5-0.75% per year and energy saving about 2% per year. The mills in Europe and the US we visited suggested that through productivity enhancing innovation alone, they are effectively increasing production capacity by about 1.5-2% per year, setting aside improvements due to new capital investments. This may seem a small annual increase, but the cumulative impact can be large and firms that are successful at this type of innovation will substantially more competitive than their rivals. For example, from the early 1980s to the current period, this would amount to about 40-50% increase in production with the same capital investment made in the early 1980s.[9] Finally, research and development expenditures, as traditionally measured, are typically very low in the pulp and paper industry – accounting for much less than 1% as a fraction of sales revenues. However, some of the mills we visited indicated that maybe 1-2% of their revenues go toward innovation activities and that up to one-third of their technical personnel devote significant time to these innovations. Overall, our initial research confirms the strategic importance of innovations that include chemicals, mixing, pulping and other process improvements and energy savings, and de-bottlenecking.

Apart from our observations, some of the writings in the literature confirm this. Bjorkman, Paun, and Jacobs Young (1997, p.80), for example, note that for the first half of the 1990s, most investments by US and Canadian firms were typically not for new production capacity but for incremental increases in production efficiency, especially environmental improvements.[10] Nilsson et al. (1995) indicates that wood for pulping represents 21% of the total material and energy costs in this industry, while the corresponding numbers for energy, wood pulp and chemicals are 17%, 15% and 6% respectively. Some examples of the incremental energy savings measures include firing

[9] The cumulative productivity graphs in Ghosal (2003) vividly display this aspect.

[10] Environmental regulation appears to be an important driver of the changes that have occurred. For example, the bleaching technologies noted in Norberg-Bohm and Rossi (1998).

the recovery boiler at higher solid content, improving the efficiency of paper drying by reducing overall heat loss, using less air and higher heat extraction from each unit of steam used for drying. In the area of waste reduction for example, using fresher wood chips results in less chemicals and processing and reduces pollution, leading to a lower unit cost (for production and cleanup) and higher paper quality.

Next, we briefly discuss why it is so important to separate the effects of innovations on firm profitable from the effects of M&As in our analysis.

The Role of Mergers and Acquisitions

The 1990s have seen a spate of M&As in the pulp and paper industry, with one of the main drivers being the desire of acquiring firms to improve their bottom line.[11] Douglas (2001) notes that the wave of M&As is an effort to combat poor financial performance by the North American paper industry and increased competition from low-cost producers. Lehman Brothers analyst James Flicker noted (October, 1998) that the US paper industry must restructure, consolidate and close inefficient mills to remain globally competitive; market fragmentation and excess capacity are serious problems. The industry's hope is that through consolidation, paper manufacturers can shut down less efficient mills, manage capacity more efficiently, reduce labor, marketing, sales and engineering costs and improve returns by creating a better balance between supply and demand. Anecdotal

[11] Data on M&As shows that the total number of mergers in the industry was significantly greater during the 1990s as compared to 1980s.

evidence also suggests that innovating firms are often the more efficient firms that seek to acquire the less efficient non-innovators. Hence, any study that attempts to analyze the impact of innovation on firm profitability must necessarily take into account the other main strategy that firms were simultaneously pursuing in order to improve profits and productivity, namely M&As.

While mergers can be horizontal, vertical or conglomerate, our primary focus will be on horizontal mergers as these are more representative of what occurred in the pulp and paper industry in the 1990s and consistent with the industry's objectives of reducing overcapacity, modernizing some mills and bringing better balance between demand and supply. A horizontal merger involves firms operating and competing in the same product market. Forming a larger firm may have the benefits of economies of scale, achieving market power, economies of scope and combining complementary capabilities. The economics literature examines the price and output effects arising from horizontal mergers assuming different forms of competition among the competitors based on quantity (Cournot) and price (Bertrand).[12] Deneckere and Davidson (1985), for example, analyze price effects in a differentiated products model, concluding that mergers generally raise prices. Farrell and Shapiro (1990) show that mergers raise prices in the Cournot model as well as when a dominant firm acquires a fringe firm. Shy (1995, Ch.8) provides an overview of merger theory.

12 See, for example, Salant, Switzer and Reynolds (1983), Baye, Crocker and Jiandong (1996), Hay and Werden (1993), Kamien and Zang (1990), Perry and Porter (1985) and Farrell and Shapiro (1990).

In the context of horizontal mergers, we also note that in the post-acquisition period an acquiring firm may choose to shut down the target. The background for this is the analysis of decision-making by a multiplant monopoly or dominant firm (Shy, 1995). A multiplant monopolist, for example, will make optimal decisions by choosing to operate only the relatively efficient plants and shut down the inefficient ones. By doing so it saves the variable and fixed costs of operating the plant. This insight is applied in the context of horizontal mergers. Consider a market area over which the potential acquiring firm operates along with the potential target firm. Assume that the acquiring firm is more efficient than the target. By letting the target firm continuing to operate independently and supply output to the market, the more efficient firm is confronted with lower prices and margins. One strategy is to acquire the target firm and shut it down. While there is a shorter-run cost of acquiring the inefficient firm, the longer-run benefits are potentially lower supply in the market, and higher prices and profit margins.[13]

[13] In contrast, vertical mergers may arise from technological economies, for example, due to reduced search, transportation, or communication costs; transactions costs economies because of the inability to contract all contingencies reliably with input suppliers in the absence of vertical mergers; and market imperfections such as downstream moral hazard problems, the need to price discriminate between elastic and inelastic downstream demands, etc. See Williamson (1975); Arrow (1975); Greenhut and Ohta (1976); Perry (1980, 1989); Salop and Scheffman, (1983); Crocker, (1983); Grossman and Hart (1986). The finance and management literature also provides several efficiency hypotheses regarding causes of M&As (Weston, et. al. 2001) such as inefficient management of the target firm, diversification, financial synergies, strategic realignment and under-valuation of the target firm by the market.

In the academic literature, empirical research on the economic effects of horizontal mergers is rather limited.[14] There are also relatively few economic studies on the US pulp and paper industry, in part because of the difficulty in quantifying the benefits of M&As. Examples include Ohanian (1993, 1994), Smith (1997), Caves and Christensen (1997).[15] Pesendorfer (1997) examines the M&As in the paper and paperboard industry of the mid-1980s and concludes that the efficiency of the majority of the acquiring firms increased following acquisition.

The impetus for the horizontal mergers in the 1990s comes from the major players in the industry, who are attempting to reduce overcapacity, shut down or modernize older and inefficient mills, obtain control over output and better manage production over cyclical fluctuations in local and global markets. Kates (2002) notes that 62,400 jobs have disappeared in paper, pulp, paperboard, containers and converted paper. Paper mills account for 50% of these losses.

Factors influencing globalization of the paper and pulp industry such as globalization of production and marketing activities, the increased importance of markets in the Asia-Pacific and Latin American regions, new global sources of inputs and the considerable efforts towards reducing trade barriers are also important drivers of M&As.

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[14] Exceptions include Kim and Singhal (1993) and Knapp (1990) on airline mergers. Kim and Singhal find substantial price increases in airline routes when they compare price changes in routes affected by a merger to routes not affected by a merger. Hall (1988) analyzed the effect of mergers on R&D.

[15] Ohanian (1993, 1994) provides historical studies of the industry from 1900-1940. Smith (1997) examines environmental aspects while Caves and Christensen (1997) find that short-run price competition is highly sensitive to capacity utilization.

Increased globalization has resulted in consolidation in the industry in many ways: inefficient firms are no longer competitive and exit the market, domestic firms merge to achieve cost efficiencies and counter foreign competition in the US and overseas markets, and cross-border mergers occur to exploit these new global opportunities.

While there is a good deal of anecdotal evidence and limited research evidence as noted in the preceding paragraphs, we do not as yet have a clear sense of the firm strategies underlying the spate of M&As and plant closings in the 1990s. There is also very little evidence regarding the relative impacts of innovation and M&As on firm productivity, and how each of these strategies moderates the influence of the other. In order to fully understand how innovation affects firm productivity, we need to have a clearer understanding regarding the role of M&As in this industry and hence we will control for the impact of mergers and acquisitions in our analysis.

4. Data and Methodology

In this section we discuss the research methodology, operationalization of the key variables and the main characteristics of the data.

Research Methodology:

The principle objectives of our research will be to quantify the impact of innovation and study its links to firm productivity after controlling for M&As. We do so using several approaches. First we present descriptive statistics that indicate the mean values of the variables and changes in their values/growth over the period of study, 1995-2004. Then we present results from our regression analysis, where we focus on firm productivity as the dependant variable. Firm productivity is proxied by the ratio of real sales to the number of employees (in thousands) in a firm. Real sales in obtained by deflating the nominal sales by the appropriate industry deflator. The dependant variables in the model include one-period lagged firm productivity, the capital labor ratio, proxies for innovation, and the number of mergers and acquisitions per firm. We present regression results for both the 10-year average firm level data as well as the annual firm level data (time-series).

There is a large literature on measuring innovation intensity. We use two of the most commonly used measures in the literature, namely the R&D to sales ratio and the number of patents per firm. While the next subsection discusses the data sources, we want to point out the advantages and disadvantages associated with each of these proxies for innovation.

In the literature, a firm's innovation can be quantified both in terms of the inputs into innovation process, as well as the outputs. Among the input measures that can be calculated using firm level data are R&D expenditures as a percentage of sales, number of R&D personnel, and R&D dollars per R&D worker. Our mill visits also revealed that quantification for this industry may be somewhat complex as many workers, in their day-to-day operations, are engaged actively in process improvements (or cost-saving activities). Many of the mills we visited mentioned they have incentive schemes where a worker or groups of workers could be rewarded if they proposed, and the company subsequently implemented, cost-saving innovations. At this stage, we do not have access to skilled R&D labor data. It is also important to note that a lot of the cost saving innovation may be on account of efforts to optimize the output from the existing equipment, reduce drying times, minimize use of costly chemicals, etc. It is not clear how comprehensively the R&D data from COMPUSTAT captures such activities that may not involve a large outlay but definitely contribute to improving the bottom line. The data on R&D expenditures also has several missing observations. Access to detailed firm level R&D data would greatly improve the quality and usefulness of our analysis, thus biasing the true level of innovative activity.

The use of patent count data as a proxy for innovation has been criticized on the several grounds. First, they measure the output of innovation rather than the process itself. However, this is true of all static measures of innovation that present snapshots at particular points in time in the creative process. Patent counts may also potentially be a downwardly biased measure of innovation: for example, firms may apply for patents only if they believe that the benefits of patent protection outweigh the costs, certain areas may not have adequate patent protection, inventions may be protected by other methods such as trade secrets etc. These issues can be quite significant at the firm level and may create heterogeneity in firm patenting behavior.

Motivated by some of the unique characteristics of capital in this industry, we also use the capital labor ratio as another dependant variable. The capital labor ratio is calculated as the ratio of (nominal) capital stock to the number of employees (in thousands). The capital stock has not been deflated because the capital stock being the cumulative capital employed in the firm can be of different vintages and we were unable to find a suitable deflator. Unlike in many other industries, here the capital stock embodies some elements of innovation since it captures some unique of aspects of capital in this industry. First, process innovation is embodied in plant and machinery as global equipment suppliers are the innovators, and hence, the newer machines are available to all firms that are prepared to make the investment. Second, as discussed earlier, the life span of the pulp and paper machines often extend well over 30 years. So despite newer equipment being readily available, firms may chose not to adopt the new technologies or may chose to selectively retrofit their existing equipment. Hence we use the capital labor ratio as another explanatory variable, and consider it to be an important determinant of firm productivity. Ideally, it would be useful to have details of the capital of different vintage available within a firm, but given the longevity of the machines and the fact that our data is only from 1995 onwards, we do not have access to this information.

Our basic regression model is as follows:

$$Prod_{it} = \alpha + \beta_1 Prod_{it-1} + \beta_2 KL_{it} + \beta_3 Innov_{it} + \beta_4 M\,\&\,A_{it} + e_{it} \qquad (1)$$

where

i indexes the firms in our sample, and t indexes time,

Prod is the firm productivity or the ratio of real sales to the number of employees (in thousands),

KL is the capital labor ratio, or the capital available per thousand employees,

Innov is a measure of innovation, proxied by R&D to sales ratio, and the number of patents per firm, *M&A* is the number of mergers and acquisitions per firms,

and *e* is the error term.

We use different variations of this model and analyze differences between large and small firms (as determined by whether their real sales are above or below the median real sales of $1586 million for our sample). Ideally, this regression should be run in logarithmic form. But we have a large number of missing data and hence we are running the regressions in levels.

Data

Our main goal was to obtain a consistent set of firm level data for our analysis. We started by obtaining the names of the 50 largest firms in the industry from the North American Pulp and Paper Factbook. We then tried to obtain the data for all the variables discussed in the regression model above. Based on data availability, our final sample has 24 firms.

We collected firm-specific time series data from two main sources. First, are the Compustat North America and Global Vantage databases which provide firm level information on sales, investment, R&D, wages, employment and similar variables. Some of these data were incomplete and we have tried to fill in the gaps from 10K statements and other firm publications. However, the biggest challenge has been the incompleteness of the data for crucial variables such as R&D.

We collected data on two of our measures of innovation, namely R&D expenditures and the number of patents from a variety of sources. The patent data was obtained from the US Patent Office database and the European Patent Office databases. These two databases cover the majority of the patents awarded globally. We conducted an extensive search for the patents awarded each year to each firm. During this process, we found that firms often obtained patents in the names of their overseas subsidiary, so our first task was to identify the subsidiaries for each of the firms in our sample. Then we searched the patent data bases for the patents awarded to each firm and its subsidiaries. Finally, we combined all the patents issued to a firm and its subsidiaries, since the COMPUSTAT data is at the overall firm level.

The R&D expenses were much more difficult to obtain on a consistent basis. Our first attempt was to collect R&D data from COMPUSTAT. Unfortunately not all firms have reported their R&D expenditures separately. R&D expenses were often reported combined with other expenses, possibly because R&D is often a prime target during periods of cost cutting. So we looked at publications that had R&D data for major firms in each industry group. We also tried to fill in the gaps by examining the 10K, annual reports and profit and loss statements of the firms in our study. Despite all these efforts, we still had fairly big gaps in our data, so we emailed firms asking for the information. Unfortunately, the response has been minimal.

In addition, we also tried to examine the economic performance of these firms, and the changes that have occurred through merger and acquisition (M&A) activities. M&A activities have been widespread in the industry during this period; they can be a source of technology acquisition, and can act as a means of constraining capacity, thus affecting economic performance substantially. Hence it is important to control for them in our analysis.

The Thompson's Financial database provided us with the Mergers and Acquisitions data. The database is in text form and had to be converted using XML programming into a format suitable for our purposes. The difficulty and complexity of working with this database resulted in a very time-intensive effort and also involved extensive consultations with the database provider. For example, the M&A data is often at the subsidiary level rather than the firm level. Hence, we had to collect information about each firm's subsidiaries, obtain M&A data on each firm and its subsidiaries, and combine the data to get the overall firm level M&A activity, in order to make this data compatible with the COMPUSTAT data on firm performance. Compiling all this data and integrating them in a useable format has given us a unique database and adds significant value to our project.

5. Results

We now turn to a discussion of the results of our analysis. We begin by examining the descriptive statistics, and then present the regression results.

Descriptive Statistics

Tables 4, 5 and 6a deal with the 10-year average data for all the 24 firms in our sample over the period 1995-2004. We report results for the full sample and also for 2 sub samples divided according to 10-year average real sales below (Group 1) or above (Group 2) the median real sales of approximately $1586 million. From the analysis below, it is evident that there is considerable heterogeneity among the firms in our sample along various dimensions.

Table 4 below indicates the real sales and productivity. We have used real values to account for inflation over this period and make the data comparable over time. The real values are obtained by deflating the nominal values with the appropriate price deflators. The average annual real sales over the period 1995-2004 are $3610.36 million and the growth of real sales is approximately 7.06% for the full sample. In Group 1 the corresponding figures are $675.53 million and 6.72% while in Group 2 the figures are $6492.78 million and 7.4% respectively. There is considerable variation among the firms in our sample with average annual real sales ranging from $210.2 million to $15,599.84 million.

Table 4 also report firm productivity. The average labor productivity per employee over the 10-year period was $160,050, while the growth in labor productivity was 4.4%. For Group 1, the 10-year average labor productivity was $147,783 while the corresponding figure for group 2 was $171,959. However, there was no significant difference among the 2 groups in the growth in labor productivity, with both groups experiencing approximately a 4.4% growth.

Table 5 indicates that the average level of capital stock over this period for all the 24 firms was $7024.08 million, and the rate of investment was 7.2%. The rate of investment over this period varied a good deal among firms, ranging from as low as approximately 3.36% to about 31.53%. Part of this variability can be attributed to mergers and acquisitions, with the capital stock of the merged firm possibly increasing substantially in the post-merger year. In Group 1, the average level of capital stock over this period was $2057.04 million, and the rate of investment was 8.4%. In Group 2, the average level of capital stock over this period was $11,815.29 million, and the rate of investment was 5.94%. The change in the rate of investment was marginally negative over the 10-year period with the figure for the full sample being -0.42%, and the corresponding figures for Group 1 and Group 2 being -0.56% and -0.28% respectively.

We also find a good deal of variability in R&D and patenting activity among the firms in our sample as seen in Table 6a. The average R&D expense as a percentage of sales for the 10 year period was 0.82%, with the range extending from 0.08% to 1.9%. However, this number suffers from the fact that data availability was limited in many instances. The R&D to sales number was larger for Group 1 at 1.05% as compared to 0.71% for Group 2. The firms in our sample had a total of 19791 patents over this period, with group 1 accounting for 411 patents and group 2 for 19380 patents.

In Table 6b we see that of the 24 firms in our sample, 10 firms had patents ranging from 0 to 15 over the period 1995-2004. There were 7 firms each with patents in the range 16 to 100, 3 firm with patents in the range 101-1000, and 4 firms with over a 1000 patents each. One firm accounted for 14,867 patents out of a total of 19,791.

Table 7 compares R&D as a percentage of sales for paper and pulp firms and firms in other industries for the years 2001 and 2004. We find a declining trend among majority of the paper firms listed in Table 7. In our sample for example, Kimberly-Clark has the highest R&D as a percentage of sales, which stands at 2.28% for 2001 and 1.85% for 2004. Mead Westvaco’s figures were 1.12% and 0.90% for 2001 and 2004 respectively; while International Paper invested 0.36% in 2001 and 0.27% in 2004. If we compare this to R&D investments in other industries such as the medical products industry or the computer and software industry, we find substantial differences. Intel’s investment in R&D as a percentage of sales was 14.3% in 2001 and 13.97% in 2004; the corresponding figures for Microsoft were 17.31% and 21.12% respectively. In the medical products industry, Johnson and Johnson invested 10.88% of their sales revenue in R&D in 2001 and 10.99% in 2004, while Proctor and Gamble invested 4.51% in 2001 and 3.51% in 2004. The pulp and paper industry’s investment in R&D as a percentage of sales is much lower than in many other industries.

Table 8 summarizes the M&A activity for the 24 firms in our sample. During the period 1995-2004, the firms in our sample entered into 388 M&As, 218 of which were domestic and 170 were cross-border (involving a foreign party) M&As. Thus the average number of M&As per year over this period was 39, with approximately 22 domestic M&As and 17 cross-border M&As per year on average. The variability regarding M&A activity among the firms for which we had data is indicated by the fact that the total number of M&As per firm (for the firms we had data for) for this period ranged from 9 to 49; the total number of domestic M&As per firm varied from 1 to 23 while the total number of cross-border M&As varied from 1 to 34. There was also a good deal of variability in M&A activities between Group1 and Group 2. The firms in Group 1 entered into a total of 127 M&As, 91 of which were domestic and 36 were cross-border M&As. In Group 2, there were a total of 261 M&As, of which 127 were domestic and 134 were cross-border M&As, suggesting that the larger firms as a group were involved in more cross border M&A activity than the smaller firms in the industry.

Table 9 presents the key descriptive statistics for 1995 and 2004, the beginning and ending years of our sample. Real sales increased from $2663.28 million in 1995 to $5022.46 million in 2004; the firms in Group 1 and Group 2 also experienced increases in real sales. Labor productivity increased from $140,043 in 1995 to $198,511 in 2004. For the firms in Group 1, labor productivity increased from $126,141 in 1995 to $175,782 in 2004, while for the firms in group 2 the corresponding numbers were $157,034 and $215,042. R&D as a percentage of sales for the full sample was 0.93% in 1995 and declined to 0.67% in 2004. In Group 1, R&D as a percentage of sales was 1.19% in 1995 and 1.12% in 2004; in Group 2 the corresponding numbers were 0.68% and 0.57%, indicating that although investment in R&D as a percentage of sales declined for both groups from 1995 to 2004, that smaller firms as a group invested a greater percent of their sales revenue in R&D. However, patenting activity by way of the absolute number of patents was much larger in Group 2, where firms were larger in size relative to Group 1.

Regression results

The regression results are presented in Tables 10 to 13. We run different variants of the basic regression equation (1) in Section 4 including grouping by firm size, by year and analysis by individual firm. It is important to note that there are several missing data points, and that we are seriously constrained by data availability in performing our analysis.

We tried to use R&D as one of the proxies for innovation, but there were so many missing values that for the purposes of this regression, we report the results only for the regressions using the number of patents as a proxy for innovation. The capital labor ratio is important since it embodies some of the innovation that takes place in the industry at the level of the suppliers of plant and machinery. The number of mergers and acquisitions and the one-period lagged labor productivity are included as control variables. In all the tables, Model 1 represents the case where the full sample is used; Model 2 contains only firms whose 10-year average real sales is less than the 10-year average median real sales of the sample, ($1586 million); Model 3 contains only firms whose 10-year average real sales is greater than the 10-year average median real sales of the sample ($1586 million).

Table 10 presents the results using the 10-year averaged data. Of the variables of interest to us, the capital labor ratio is highly significant and positive in models 1 and 2; the coefficient estimate for the full sample suggests that a $1000 increase in the capital available per worker increases labor productivity by $250. The number of patents also has a positive and significant impact on firm productivity in Models 1 and 3.

Tables 11 to 13 present the time-series regression results. Table 11 presents the results for all the 24 firms in our sample using annual data. Focusing on our variables of interest, the capital labor ratio is positive in all cases and highly significant in models 2 and 3 models. A $1000 increase in the capital available per employee increases labor productivity per employee in the full model by $60. In the case of firms whose sales are below the median, labor productivity per employee increases by the $110 as the capital available per employee increases by $1000, while for firms whose real sales are above the median real sales, labor productivity increases by $190 per employee. M&As are negative and significant in both models 1 and 3. This is not surprising given that we have used same period M&As in the model and that M&As impose initial adjustment costs on the acquirer as the acquirer seeks to integrate the acquired firm into its own operations.

Given the considerable heterogeneity among the firms in our sample, we decided that it would be worthwhile to examine individual firms where the data availability permits us to do so (a total of 11 firms). The results are presented in Table 12. Again, the capital ratio is positive and significant in 6 out of 11 cases and negative and significant in 1 case. The values of the estimated coefficients vary great deal across firms ranging from 0.03 to -3.06. The patent variable is positive and significant in 4 out of 11 cases and negative and significant in 1 case. Again, the size of the estimated coefficients varies substantially across firm, ranging from -1.99 to 4.71. These results should be interpreted with caution given our small sample size. The M&A variable was negative and significant in 3 out of 11 cases and insignificant in all other cases.

We also examine the impact of innovation on firm productivity across time. Table 13 presents the results of the year-wise regression analysis. The lagged labor productivity is positive as expected, and is significant during 9 out of the 10 years in our study. One of our main variables of interest, the capital labor ratio was positive and significant during 1995, 1999, 2000, 2002 and 2004 and negative and significant during 2001. Again, it is important to remember that with a spate of M&As, there was a good deal of changes in the capital stock during this period. The M&A variable itself was significant and negative only in 1998 and insignificant in all the other years.

6. Conclusions

Our analysis focuses on the role of innovation and its impact on firm productivity in the pulp and paper industry. We study the period from 1995-2004. We examine innovation in this industry by using the number of patents as a proxy for innovation. Unlike in many other industries, the capital stock in this industry also embodies some elements of innovation since innovation in plant and machinery is done by the global suppliers and not by the pulp and paper firms. On one hand, this implies that innovations on the equipment side are freely available to all who are willing to make the investment. On the other hand, these machines last as long as 30 years, so even if new technology is available, not all firms will move to the new technologies.

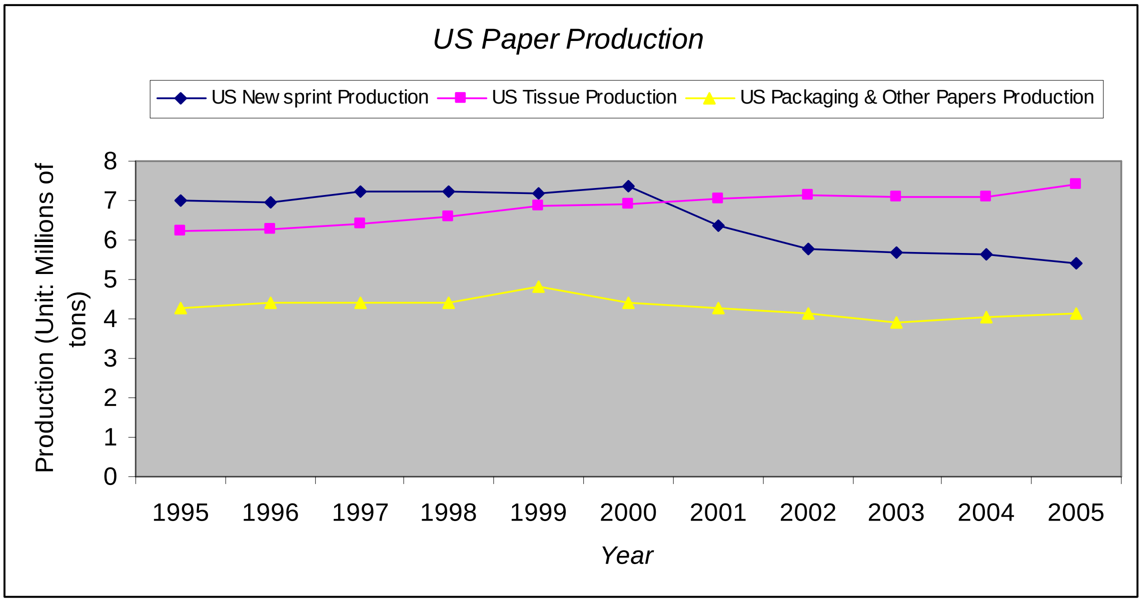
Our results suggest that the capital labor ratio has on average a positive and significant impact on firm productivity in the industry. There is a great deal of heterogeneity across firms in the magnitude of the impact of capital stock on productivity. Ideally, if we could have data on the types of capital investments made by firms, it would enable us to better understand how the capital labor ratio impacts firm productivity. Our patent variable is significant in the full sample and in the sub-sample of larger firms (with sales above the median average sales for the sample). As discussed earlier, we had not reported the regression results using the R&D variable because of the large missing data problem. Our analysis suggests that the incremental, productivity-enhancing innovations that firms in this industry conduct in-house are probably not patentable and are thus not captured by the patent data. Ideally, firm level R&D data that provides details of different types of R&D activities as well as a breakdown of the capital investment into different technology categories would be very useful in refining our analysis.

Table 1

Largest US Paper and Forest Product Companies Ranked by Revenue: 2004

Company	Revenues (Mil. $)
International Paper	25,500
Weyerhaeuser	20,170
Georgia-Pacific	19,656
Smurfit-Stone Container	8,291
MeadWestvaco	8,227
Kimberly-Clark	5,343
Temple-Inland	4,750
Bowater	3,190
Greif Brothers	2,209
Packaging Corporation of America	1,890

Graph 1: Paper Production in the USA (1995-2005)



- Source: American Forest & Paper Association

Table 2. Projected Paper & Pulp Capacity Changes

Categories \ Year	2005	2006	2007
Paper & Paperboard, total	99,279	97,269	97,478
Paper, total	46,194	45,334	45,169
Printing & Writing	27,458	27,033	26,791
Uncoated free sheet	13,558	13,248	12,924
Uncoated Mechanical	2,242	2,262	2,286
Coated free sheet	5,132	5,001	5,052
Coated mechanical	4,991	5,052	5,073
Newsprint	5,758	5,623	5,549
Tissue	8,275	8,232	8,409
Paperboard, total	53,085	51,935	52,309
Containerboard	36,755	35,996	36,335
Linearboard	25,438	24,907	25,241
Corrugating medium	11,317	11,089	11,094
Boxboard	11,239	10,860	10,872
Total, all grades woodpulp	67,401	66,499	66,323
Chemical	56,138	55,462	55,400
Bleached softwood	15,410	15,157	15,074
Bleached hardwood	16,939	16,671	16,389
Unbleached	23,135	23,081	23,384
Semichemical	4,261	4,126	4,126
Mechanical	6,126	6,074	6,074
Dissolving	876	837	723

- In thousands of short tons
- Source: Pulp & Paper Week

Table 3. US Imports and Exports of Paper, Pulp, and Forest Products*

	Imports			
Year	Wood Pulp & Wastepaper	Newsprint	Other Paper&Board	Wood Chips
1995	5.179	7.34	8.314	0.513
1996	5.551	7.784	6.634	0.753
1997	7.09	7.881	7.794	0.382
1998	6.495	7.807	9.248	0.804
1999	7.086	7.491	10.996	0.316
2000	7.835	7.541	11.729	0.329
2001	7.676	6.822	11.691	0.174
2002	7.659	6.905	12.528	0.146
2003	7.09	6.995	13.069	0.416
2004	7.283	6.463	14.682	0.961
2005	7.308	5.927	14.511	0.905

	Exports					
Year	Wood Pulp & Other	Wastepaper	Linearboard	Other Paper&Board	Pulpwood (1,000 CU Meters)	Wood Chips
1995	7.338	6.448	3.224	7.72	2.253	5.651
1996	6.624	5.888	2.995	9.127	2.337	5.248
1997	7.126	7.705	3.222	9.94	2.446	5.689
1998	6.167	10.395	3.494	8.75	2.644	6.067
1999	6.11	8.286	3.302	8.519	2.462	6.784
2000	6.618	10.56	3.331	9.178	2.567	5.686
2001	6.468	10.533	2.942	8.562	2.695	4.257
2002	6.503	11.404	2.976	8.588	2.209	3.039
2003	6.051	13.905	3.064	8.803	0.996	2.488
2004	6.404	14.136	3.121	9.549	1.608	2.723
2005	6.613	16.009	3.346	10.088	0.738	2.673

- Source: American Forest & Paper Association
- * measured in millions of short tons, except in the case of pulpwood

Table 4: Mean Real Sales and Labor Productivity: 1995-2004

Variable	**Full Sample**	**Firms with Real Sales ≤ $1586 mil.**	**Firms with Real Sales >$1586 mil.**
Real Sales, Mil. $	3610.36	675.53	6492.78
Growth in Sales %	7.06%	6.72%	7.4%
Labor Productivity (per 1000 employees)	160.05	147.78	171.96
Growth in Labor Productivity	4.41%	4.43%	4.4%

*Real values are obtained by deflating nominal values with the appropriate deflator.
* $1586 is the value of median real sales

Table 5: Mean Capital Investment: 1995-2004

Variable	**Full Sample**	**Firms with Real Sales ≤ $1586 mil.**	**Firms with Real Sales >$1586 mil.**
Level of Capital Stock, Mil. $	7024.08	2057.04	11815.29
Level of Investment, Mil. $	366.43	171.60	564.86
Rate of Investment	7.2%	8.45%	5.94%
Change in Rate of Investment	-0.42%	-0.56%	-0.28%

Table 6a: Mean R&D to Sales Ratio and Total Patents: 1995-2004

Variable	**Full Sample**	**Firms with Real Sales ≤ $1586 mil.**	**Firms with Real Sales >$1586 mil.**
R&D to Sales Ratio	0.82%	1.05%	0.71%
Total Patents	19791	411	19380

Table 6b: R&D Expenditures and Patents: 1995-2004

Variable	Value
Ration R&D/Sales: RDS (%)	0.82%
Total Number of Patents: PAT	19791
Maximum number of patents by a firm	14867
Minimum number of patents by a firm	0
# of firms in the patent range 0-15	10
# of firms in the patent range 16-25	4
# of firms in the patent range 26-50	0
# of firms in the patent range 51-100	3
# of firms in the patent range 101-200	1
# of firms in the patent range 201-1000	2
# of firms in the patent range above 1000	4

Table 7: Comparison between R&D in P&P firms and Other Firms

Name	R&D to Sales % 2004	R&D to Sales % 2001
Intel	13.97	14.3
Microsoft	21.12	17.31
Johnson & Johnson	10.99	10.88
Proctor & Gamble	3.51	4.51
Kimberly-Clark	1.85	2.28
International Paper	0.27	0.36
Weyerhaeuser	0.24	0.38
Smurfit-Stone	0.11	0.07
MeadWestvaco	0.90	1.21
Stora Enso	0.66	0.68
UPM Kymmene	0. 47	0. 44
Fibermark	0.82	0.91
Sonoco	0.49	0.57

Table 8: Mergers and Acquisitions: 1995-2004

Variable	Full Sample	Firms with Real Sales ≤ $1586 mil.	Firms with Real Sales >$1586 mil.
Total M&As	388	127	261
Domestic M&As	218	91	127
Foreign M&As	170	36	134

Table 9: Mean Real Sales, Labor Productivity and Investment: 1995 and 2004

Variable	Full Sample		Firms with Real Sales ≤ $1586 mil.		Firms with Real Sales >$1586 mil.	
Year	1995	2004	1995	2004	1995	2004
Real Sales, M$	2663.28	5022.46	594.43	806.11	5191.89	8184.72
Growth in Sales %	2.04%	8.58%	-0.34%	8.94%	4.68%	8.30%
Labor Productivity (per 1000 employees)	140.04	198.51	126.14	175.78	157.03	215.04
Growth in Labor Productivity	-2.12%	9.74%	-0.80%	11.54%	-3.59%	8.44%
Level of Capital Stock	4607.93	10,143.82	1669.70	1876.52	7839.99	15,655.36
Level of Investment	410.90	349.28	211.63	50.84	654.45	573.11
Rate of Investment	11.15%	3.55%	11.74%	3.22%	10.5%	3.8%
Change in Rate of Investment	2.84%	-1.31%	2.24%	-2.42%	3.49%	-0.48%
R&D to Sales Ratio	0.93%	0.67%	1.19%	1.12%	0.68%	0.57%
Total Patents	739	3567	11	86	728	3481
Total M&As	45	37	10	12	35	25
Domestic M&As	27	19	8	8	19	11
Foreign M&As	18	18	2	4	16	14

Table 10: Firm Productivity and Innovation

Dependant Variable: Firm Productivity

Variable	Model 1 Full Sample	Model 2 Real Sales ≤ Median	Model 3 Real Sales > Median
Intercept	127.10* (23.82)	131.44 (91.22)	148.90** (66.25)
Capital labor ratio	0.25* (0.08)	0.25* (0.06)	0.36 (0.31)
# of patents	0.003** (0.0015)	-0.005 (0.13)	0.003** (0.001)
# M&As	-0.61 (0.67)	-2.78 (5,98)	-1.29 (1.15)
R^2	0.45	0.67	0.58
Number of Observations	22	10	12

1. Robust standard errors in parentheses.
2. * significant at 1%; ** significant at 5%; *** significant at 10%.
3. Firm productivity is the defined as real sales (ie., nominal sales deflated by the appropriate deflator) in millions of dollars per thousand employees.
4. The capital labor ratio is the defined as the capital stock in millions of dollars per thousand employees.

Table 11: Firm Productivity and Innovation: Annual Data

Dependant Variable: Firm Productivity

Variable	**Model 1 Full Sample**	**Model 2 Real Sales ≤ Median**	**Model 3 Real Sales > Median**
Intercept	28.06** (11.11)	40.69** (19.41)	6.90 (11.04)
One-period lagged firm productivity	0.82* (0.07)	0.59* (0.14)	0.85* (0.08)
Capital labor ratio	0.06 (0.04)	0.11* (0.04)	0.19* (0.057)
# of patents	0.005*** (0.003)	0.70 (0.49)	0.006** (0.002)
# M&As	-2.06** (0.94)	-0.17 (3.49)	-1.68*** (1.02)
R^2	0.76	0.76	0.80
Number of Observations	150	67	83

1. Robust standard errors in parentheses.
2. * significant at 1%; ** significant at 5%; *** significant at 10%.
3. Firm productivity is the defined as real sales (ie., nominal sales deflated by the appropriate deflator) in millions of dollars per thousand employees.
4. The capital labor ratio is the defined as the capital stock in millions of dollars per thousand employees.

Table 12: Regression Results for Individual Firms

Dependant Variable: Firm Productivity

Part A

Variables	Firm #6	Firm #7	Firm #8	Firm #9	Firm #10
Intercept	77.50* (6.04)	50.69 (64.09)	151.16* (58.28)	116.10 (86.41)	-105.07* (37.59)
One-period lagged firm productivity	-0.09 (0.06)	0.94* (0.27)	-0.56 (0.48)	-0.33 (0.50)	0.31 (0.19)
Capital labor ratio	0.66* (0.08)	0.18 (0.30)	0.72 (0.96)	0.97*** (0.51)	1.66* (0.58)
# of patents	4.14* (1.07)	-1.99 (2.89)	2.46 (6.85)	0.37* (0.14)	4.71* (0.68)
# M&As	0.78 (0.52)	-23.70* (4.37)	11.52 (16.63)	11.39 (15.46)	1.69 (13.33)
R^2	0.99	0.96	0.36	0.84	0.97
Number of Observations	7	8	10	7	8

1. Robust standard errors in parentheses.
2. * significant at 1%; ** significant at 5%; *** significant at 10%.
3. Firm productivity is the defined as real sales (ie., nominal sales deflated by the appropriate deflator) in millions of dollars per thousand employees.
4. The capital labor ratio is the defined as the capital stock in millions of dollars per thousand employees.

Table 12: Part B

Dependant Variable: Firm Productivity

Variable	Firm#11	Firm#12	Firm #14	Firm #15
Intercept	72.19 (57.51)	53.10 (80.74)	181.47* (17.95)	98.52** (47.72)
One-period lagged firm productivity	0.90* (0.18)	-0.12 (0.51)	-0.57* (0.08)	-0.22 (0.37)
Capital labor ratio	0.03 (0.27)	1.75 (1.08)	0.36* (0.09)	0.78* (0.20)
# of patents	-0.31 (0.24)	-0.016*** (0.009)	1.14* (0.11)	-0.82 (1.73)
# M&As	-5.43* (1.16)	0.41 (1.25)	0.62 (0.86)	-10.88 (8.38)
R^2	0.98	0.57	0.96	0.84
Number of Observations	8	9	8	10

1. Robust standard errors in parentheses.
2. * significant at 1%; ** significant at 5%; *** significant at 10%.
3. Firm productivity is the defined as real sales (ie., nominal sales deflated by the appropriate deflator) in millions of dollars per thousand employees.
4. The capital labor ratio is the defined as the capital stock in millions of dollars per thousand employees.

Table 12: Part C

Dependant Variable: Firm Productivity

Variable	**Firm #19**	**Firm #20**
Intercept	-11.89 (23.26)	750.00* (253.91)
One-period lagged firm productivity	1.00* (0.21)	-2.33*** (1.19)
Capital labor ratio	0.56** (0.23)	-3.06* (0.97)
# of patents	0.13 (1.5)	4.30 (11.07)
# M&As	-18.34** (8.34)	-2.89 (3.66)
R^2	0.71	0.74
Number of Observations	9	9

1. Robust standard errors in parentheses.
2. * significant at 1%; ** significant at 5%; *** significant at 10%.
3. Firm productivity is the defined as real sales (ie., nominal sales deflated by the appropriate deflator) in millions of dollars per thousand employees.
4. The capital labor ratio is the defined as the capital stock in millions of dollars per thousand employees.

Table 13: Regression Analysis by Year

Dependant Variable: Firm Productivity

Part A

Variable	**1995**	**1996**	**1997**	**1998**	**1999**
Intercept	-1.70 (17.86)	28.20** (12.40)	34.85 (49.94)	60.43* (18.13)	51.14** (20.90)
One-period lagged firm productivity	0.82* (0.07)	0.79* (0.10)	0.82 (0.56)	0.87* (0.13)	0.56* (0.15)
Capital labor ratio	0.15* (0.05)	-0.04 (0.06)	-0.01 (0.30)	-0.13 (0.11)	0.24*** (0.13)
# of patents	0.05*** (0.03)	0.04*** (0.02)	0.05 (0.05)	0.004 (0.01)	0.02** (0.01)
# M&As	1.52 (2.81)	-1.06 (4.0)	-3.34 (3.16)	-14.94* (1.58)	-2.85 (2.91)
R^2	0.82	0.73	0.75	0.90	0.88
Number of Observations	15	14	13	14	12

1. Robust standard errors in parentheses.
2. * significant at 1%; ** significant at 5%; *** significant at 10%.
3. Firm productivity is the defined as real sales (ie., nominal sales deflated by the appropriate deflator) in millions of dollars per thousand employees.
4. The capital labor ratio is the defined as the capital stock in millions of dollars per thousand employees.

Table 13: Part B

Dependant Variable: Firm Productivity

Variable	**2000**	**2001**	**2002**	**2003**	**2004**
Intercept	41.64 (33.26)	47.29 (28.77)	-7.27 (22.05)	44.26** (19.36)	9.79 (12.8)
One-period lagged firm productivity	0.65* (0.22)	0.81* (0.21)	1.11* (0.16)	0.79* (0.17)	0.89* (0.10)
Capital labor ratio	0.18* (0.05)	-0.15** (0.06)	0.06** (0.02)	0.08 (0.06)	0.19* (0.04)
# of patents	-0.017*** (0.01)	0.004 (0.004)	0.0003 (0.003)	0.001 (0.003)	0.07 (0.04)
# M&As	-1.86 (1.88)	-4.29 (2.72)	-2.52 (2.43)	-4.30 (3.85)	-1.06 (0.95)
R^2	0.94	0.79	0.89	0.93	0.99
Number of Observations	16	17	18	16	15

1. Robust standard errors in parentheses.
2. * significant at 1%; ** significant at 5%; *** significant at 10%.
3. Firm productivity is the defined as real sales (ie., nominal sales deflated by the appropriate deflator) in millions of dollars per thousand employees.
4. The capital labor ratio is the defined as the capital stock in millions of dollars per thousand employees.

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Targeted Investments in Modernization and Gains in Productivity: Evidence from Firms in the Global Paper Industry

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Abstract
The primary focus of this paper is to examine the impact of firms' targeted investments in modernization on productivity. In contrast to much of the existing literature which focuses on the impact of R&D and patents on firms' performance and productivity, we examine data on actual investment transactions in four main areas of operations: (i) mechanical, (ii) chemicals, (iii) monitoring devices and (iv) information technology. From a sample of global pulp and paper firms, we find that the investments in modernization deliver a boost to firms' productivity and the estimated quantitative effects are greater than the impact of standard innovation variables such as patents and R&D. These results are obtained after controlling for other firm-specific variables such as capital-intensity and mergers and acquisitions. Two messages emerge from our findings. First, firms need to be very focused on strategies related to targeted investments in modernization and various forms of incremental innovations. Second, firms need to realize that improvements in productivity will typically be small. While small gains may not seem important on a year-to-year basis, they can compound to form meaningful differences in performance and productivity across firms in the longer-run. While this paper focuses on the pulp and paper industry, our broad framework and methodology is general and can be applied to understanding firms' business strategies related to enhancing performance and productivity in a variety of industries.

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1. Introduction

Improving productivity is at the core of a firm's business strategy. Higher productivity is likely to improve profitability and enhance a firm's competitive position relative to its rivals. There are alternative strategies a firm can pursue to improve its productivity. These include: (1) pursuing a path of pure innovation captured by variables such as R&D expenditures and patents granted; (2) engage in targeted investments that modernize and upgrade production capabilities; (3) engage in mergers and acquisitions to reap economies of scale and scope and generate other synergies; and (4) make changes to its organizational structure, better management and improve its supply-chains. While a firm can potentially pursue all of these strategies, which one is likely to be more successful, or viable, depends, in part, on market conditions and the industry the firm operates in.

Our focus in this paper is on the global pulp and paper industry. A defining characteristic of this industry is that the basic technology used for producing paper is quite old and well known. While recent decades have seen changes in the sophistication of equipment and machines and the incorporation of digital devices and information technology, this is not an industry where a firm can typically expect to make a breakthrough innovation to distance itself from its rivals.[16] In our sample of pulp and paper firms from North America, Europe and other regions, the "typical" firm has an R&D intensity of about 0.5% and the number of patents granted is low at about 2 per year. These numbers are underwhelming; R&D and patents, at least as conventionally measured, seem unlikely to be the major avenues for productivity gains. In this sense,

[16] See Ghosal and Nair-Reichert (2007) for some details about the nature of technologies in this industry.

firms in this industry are more likely to be able to achieve gains in productivity via strategies of modernization and upgrading of production processes, incremental innovations that arise from learning-by-doing and possibly mergers and acquisitions.

The global pulp and paper industry has undergone significant changes since the late-1980s.[17] The global economic downturn in the late-1980s and early-1990s produced downward pressure on prices of paper products and sharp compression in firms' profitability. Firms were saddled with significant overcapacity due to low demand. Changing environmental standards forced firms in many countries to make new and costly investments to reduce pollution in order to meet the new regulatory standards. More open global markets and reduced ocean-freight rates allowed firms to enter new markets and compete. The overall effect was that firms in the pulp and paper industry faced a new economic environment and increased competitive pressure. To survive in this new environment, they had to carefully think through their business strategies in order to stay competitive and improve their bottom-line.

As we examine the behavior of the firms in the pulp and paper industry, we find that many engaged in a significant number of M&As, presumably with the objective of consolidating their position in the market, potentially reaping economies of scale and scope, and weeding out competitors as evidenced by post-merger plant closings.[18] To

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[17] See Ince (1999), Douglas (2001), Engel (1997), Ghosal (2003), Ghosal and Nair-Reichert (2007), Kates (2002), McNutt (2002), Nair-Reichert (2002) and Suhonen (2001). Ohanian (1993, 1994) presents a historical perspective of some of the changes in this industry.

[18] See Kates (2002) for plant closings. Pesendorfer (2003) examines M&As in the U.S. pulp and paper and evaluates the effects on firms' investment decisions, costs, and consumers. Among his findings are that the merged firms are likely to scrap capacity subsequent to an acquisition.

improve their competitive position, many firms also engaged in investments that modernized their production facilities, improved innovation outcomes, implemented changes in the supply-chain and their organizational structure.[19] In a broad sense, the firms appear to have adopted a two-pronged strategy of improving efficiency via modernization and incremental innovations, and engaging in M&As.

The objective of this paper is to examine in detail the outcomes of some of these strategies. Some of the questions we seek to answer are:

- Did the strategies to modernize and update production processes improve the performance and productivity of the firms?
- Did M&As improve productivity?
- Which strategy worked better?

This paper contributes to our understanding of business strategies pursued by firms in the global pulp and paper industry by developing a framework within which we conceptualize the evaluation of productivity gains and compile an extensive dataset from myriad sources to quantify the impacts.

Our main findings are that targeted investments in modernization and upgrading of the production processes pay off in terms of higher firm-level productivity. The estimated quantitative impact on productivity of these targeted investments is greater than the gains obtained by pursing a path of more innovation as measured by R&D expenditures and patents.[20] M&As appear to have little or no effect on productivity. In

[19] See Bjorkman, et al. (1997), Ghosal (2003) and Nilsson et al. (1995) for some details about the pulp and paper firms. The role of various types of innovations have been formally discussed by Audretsch (1995), Gort and Klepper (1982) and Winter (1984).

general, the gains in productivity via modernization and upgrading investments are not large. While the year-to-year gains are somewhat modest, the important point to note is that these modest gains can compound over time to form meaningful differences across firms. Therefore, managers of firms need to stay focused and emphasize the incremental gains in productivity to maintain or enhance their competitive position in the longer-run.

While the issues we discuss and our framework and data are for the firms in the pulp and paper industry, the conceptual framework we outline is general enough to be applied to examining business strategies related to productivity and innovation at the firm-level in almost any industry.

The paper is organized as follows. Section 2 provides information about the industry. In section 3 we discuss the production process and technologies, outline our categorization of targeted investments in the key areas and provide details about the extensive dataset we compiled. Sections 4 and 5 describe the framework for examining firm-level differences in productivity and the firm-level data from the Compustat and Thompson's Financial databases. The results of our regression analysis are presented in sections 6 and 7. Implications and concluding remarks appear in section 9.

2. Industry Basics

We begin by providing a brief outline of the industry and the production processes. Paper is manufactured from wood, a natural and renewable raw material. Pulp – the basic ingredient for the manufacture of paper and board – is produced from fresh

[20] For various facets of the standard literature on R&D and patents and empirical findings, see Audretsch (1995), Cohen and Levin (1989), Griliches (1984), Sutton (1997) and Winter (1984).

wood, woodchips from sawmills, recovered paper, sometimes from textiles, agricultural by-products and industrial crops.

The use of recycled fiber has been growing steadily since the 1980s. Between 40-50% of all paper used in North America is recovered for recycling and reuse. The recycling rate is higher in several European countries. (The recycling rate is calculated on the basis of recovered paper used in recycling compared to total paper consumption.)

The process of making paper has not fundamentally changed since its discovery. But, modern papermaking has evolved into a complex industry. The important steps in the production process are:

1. Forestry. Trees used for paper-making are usually grown and harvested like a crop. To meet future demand, forest products firms and private landowners plant millions of new seedlings every year.

2. Debarking, Chipping and/or Recycling. To begin the process, logs are first passed through a debarker, where the bark is removed. Next, the debarked logs are passed through chippers where the wood is cut into 1" pieces. The wood chips are then pressure-cooked in a digester with a mixture of water and chemicals. Used paper is an important source of paper fiber. The recycled paper is shredded and mixed with water.

3. Pulp Preparation. The pulp is washed, refined, cleaned and sometimes bleached, then turned to slush in the beater. Color dyes, coatings and other additives are mixed in, and the pulp slush is pumped onto a moving wire screen. Computerized sensors and state-of-the-art control equipment monitor each stage of the process.

4. Paper Formation. As the pulp travels down the screen, water is drained away and recycled. The resulting crude paper sheet, or web, is squeezed between large rollers to remove most of the remaining water and ensure smoothness and uniform thickness. The semi-dry web is then run through heated dryer rollers to remove the remaining water.

5. Paper Finishing. The finished paper is wound into large rolls, which can be 30 feet or more in width and weigh close to 25 tons. A slitter cuts the paper into smaller rolls and the paper is ready for use. Papermaking is a highly capital-intensive industry and, in many firms, there are over $100,000 in equipment for each employee. The largest paper-making machines can be over 32 feet wide, 550 feet long and produce over 1,000 miles of paper a day.

3. Production Process and Targeted Investments: Categorization and Data

To develop our framework for analysis, we gathered information about the production process from various industry publications. In addition, both of us had visited pulp and paper mills in the U.S. and Northern Europe to get a first-hand look at the processes. Using this information, we classified the overall process into 15 key stages itemized in **Table 1**.

Next, as we looked through the important areas of operations of the pulp and paper firms, we created 4 broad categories in which we could observe important changes. These relate to (1) mechanical, (2) chemical, (3) monitoring devices and (4) information technology. We also created a fifth category “other” for those areas that do not fit into the four main categories noted above. Since each of the four main categories involve distinct processes and technologies, we classify them as “targeted investment” categories. The five categories are listed in columns 1 of **Table 2**.

Our insight is that by tracking firms’ investments in equipment and machinery, chemicals and chemicals processes, monitoring devices and information technology, we obtain a broad sketch of the transactions the firms engage in. The main premise is that these targeted investments allow firms to improve their productivity and competitive position relative to their rivals. The more active a firm is in making these improvements and upgrades, the more likely it is that the firm will improve its performance and productivity.

The pulp and paper industry is highly capital-intensive and uses machinery and equipment of various degrees of complexity in almost all of the processes outlined in table 1. As firms think of improving their performance and production efficiency, they can make new investments to modernize their production processes. Given the highly capital-intensive nature of production, a significant fraction of these investments are likely to fall under the “mechanical” category – related to investments in equipment and machinery. Chemicals constitute an important input into the paper-making process as they are used for processing woodchips, treating pulp, washing the pulp, coating paper, to name a few. Refinements in chemical inputs and chemical processes can lead to better paper, better coatings and may also reduce pollutants, leading to potentially lower environmental clean-up costs. Investments in monitoring devices and information technology have constituted important investments by many firms. Monitoring devices can help managers of firms exercise better control and timely intervention to check for problems in the production line, and help monitor quality of the outputs in the intermediate stages as well as the final product. Investments in information technology have become critical in various areas such as enterprise management, supply-chain management and integration of the monitoring devices into a centralized command structure.

Our next task was to gather information and gain insights into the transactions in each of the four key targeted investment categories (noted in table 2) for the major firms in the global pulp and paper industry, and then provide a comparison of how the efforts to modernize and improve efficiency varied across the different firms. Unfortunately, due to confidentiality restrictions and lack of reliable and consistent firm-level data available in the public domain, this proved to be a far more difficult task than we had expected.

3.1. Compiling the Data

We examined information from a large number of pulp and paper industry resources. The publication *Pulp and Paper* was the only source that provided semblance of a consistent data source. For each of the targeted investment categories noted in table 2, we collected information from *Pulp and Paper's* "Orders and Deliveries" section over the time-period 1996-2003. The time period for our data collection was restricted by the following: (1) at the time we started collecting the data, 2003 was the most recent year for which we could obtain complete data; and (2) the years before 1996 contained relatively sketchy data.

Included in the Orders and Deliveries information were names of buyers and suppliers, and some specifics of the transactions such as purchase of a new pulping or debarking unit, purchase or refurbishing of the paper mill, coating systems, calendaring machine, among many others. Table 2 (column 2) provides information on the range of transactions that were obtained by us. In terms of having a complete dataset, we have information on a total of 25 firms (buyers), including most of the major global firms. On the supplier side – that is, suppliers of equipment, machinery, chemicals, monitoring devices and information technology – our information contains names of over 20 firms (globally). We then developed a system of classification outlined in tables 1 and 2. We obtained information on firm-specific transactions under each of the 15 different processes noted in table 1, and then further classified them by the five targeted investment categories described in table 2.

Before describing the features of these data, we provide a quick look at how we went about compiling the information. The buyer-seller transactions data were not available in machine-readable form. We had to first copy the relevant pages from the monthly issues of *Pulp and Paper* over the eight-year period, 1996-2003. Next we scanned the information, and then sorted, cleaned and systematized the information in machine readable form. After the data were in this more usable form, we then went through a painstaking process of examining each transaction, obtaining additional information on many of them from secondary sources such as the firms' websites, industry reports, among others, and then arranged them into the classification scheme outlined in tables 1 and 2. Across all the processes and categories under our two-tier (tables 1 and 2) classification system, we have a total of 462 buyer-seller transactions for the period 1996-2003 for 25 U.S. and foreign firms.

3.2. Pros and Cons of our "Orders and Deliveries" Targeted Investments Data

As we noted above, the *Pulp and Paper* publication is the only source we could find that reported such buyer-supplier transactions on a consistent basis. The other sources we were able to find were either very limited in scope and/or did not offer data on a consistent basis. The *Pulp and Paper* publication compiled information on the buyer-seller transactions as part of their own research as well as transactions reported to them by the firms on a voluntary basis.

There are two important shortcomings of the data. First, the data are not comprehensive in the sense that they do not contain data and information on all the transactions undertaken by a given firm over the 1996-2003 period. This deficiency is clearly a limitation, but there was no other source we could find that would allow us to obtain a complete set of transactions. Further, there were some firms for which we recorded zero or 1 transactions for the 8-year period. We tried to figure out the reason for the low counts, including contacting *Pulp and Paper*, and in some cases the firms, to see if we could fill in the gaps. This did not prove successful. Our requests made to the firms did not break this deadlock as they either did not have these data stored and available for distribution or there were issues related to confidentiality due to which the firms were not in a position to share the data with us. Much later, when we presented our initial findings at the TAPPI conference (Atlanta, Nov. 2006), the participants who were industry consultants and employees of paper firms mentioned that some firms do not make an effort to systematically store these types of data. To get a better feel for the missing data, we attempted to spot any obvious patterns, such as more or less missing transactions for U.S. versus foreign firms or smaller versus large firms. We were hard-pressed to identify any clear patterns in this dimension. Given these problems, we decided to drop these firms (with unrealistically low transactions over the eight-year period) from our sample. Dropping these resulted in a final set of <u>19 U.S. and foreign firms</u>.

The second shortcoming is that while we were able to observe the transactions, we were not able to assess how large or small they were in monetary terms. It is clear that there are significant direct and indirect costs for transactions like machine rebuilds; the indirect costs arise due to work disruption, loss of output and other factors. But many of the transactions were related to upgrades in various stages of the production process, installation of monitoring devices, quality control devices, information technology adoption, among others. While these are clearly very important for the firms' attempts to modernize and upgrade production process with a view to improving their performance and competitive position, it would have been better if we also had a monetary sum to attach to these transactions. We return to this specific issue in our concluding remarks.

On the positive side, the information on the buyer-seller transactions for the categories listed in tables 1 and 2 are high quality and informative. To provide the reader with a glimpse of the richness of the data, below we present several examples to indicate the level of detail. Below we conceal some of the information including the "buying" company names and locations for confidentiality. Since the selling firms typically sell to many buyers, we do not conceal these names.

- [company name] has ordered a new complete Valmet uncoated free-sheet paper machine as part of a major expansion at its [mill name]. The new machine has a wire width of 380 in., a trim of 354 in., and is designed to run at 4,500 fpm and produce 910 tpd of office, offset printing, forms, and envelope papers containing varying amounts of virgin and recycled fiber.

- [company name] has installed a new Gardner Systems steam system with Blow-Thru controls on its paper machine dryer section. As a result of this installation, the machine has achieved higher production on heavier grades and has recorded steam savings that have averaged 15,000 pph.

- [company name] has ordered an enterprise software license agreement and long-term maintenance agreement form 3C Software for Impact:ECS, an enterprise cost management system. The implementation of Impact:ECS will being in Oct. 2002, at [company name] Fine Papers division in [location].

- [company name] purchased Industrial IT quality control and web imaging for coater machine.

- [company name] has named BetzDearborn the primary supplier of specialty chemicals at its [locations] paper mills. The three-year agreement covers chemicals used for water treatment and process systems.

- For its bleached kraft mill in [location], [company name] has ordered a two-line thickness screening system by Acrowood to install prior to its 10 batch digesters. Each of the two screening lines will include a disc scalper, two Model 50144 DiamondRoll primary thickness screens placed one after the other, a Model 7222 air density separator to process the overs before they are sent into a Model 3672 chip cracker, and a Model 90108 DiamondRoll fines screen fit with the raised roll feature to process fines.

- [company name] has nearly finished putting its 525-tpd recycled paperboard mill under full automation with new process control technology. The PlantWeb digital plant architecture from Emerson Process Management is superceding a Honeywell TDC3000 distributed control system.

- [company name] has ordered the world's largest basis weight actuator system from ABB Industrial Systems Inc. The [location] mill will install a Beloit Concept IV-MH headbox with dilution control provided by 277 zone AccuRay Smart Weight profiler-dilution actuators on paper machine No. 64. The project also includes the addition of Smart CD to the existing AccuRay 1180M system and measurement platform. [company name] has chosen Beloit for the management of its paper machine upgrade, including the integration and staging of the AccuRay profilers and Smart CD.

- [company name] has selected Brown & Root Engineering and Construction to provide construction services for environmental improvement projects at its [location] pulp and paper mills. The projects will convert the mills’ bleaching sequences to elemental chlorine-free (ECF) and assure compliance with the EPA’s cluster rules and [state] regulations.

- [company name] [location] mill has ordered a whitewater filtration system from AES Engineered Systems. The equipment includes AES's 4045 gravity strainer and multiple 14 station barrel pressure filter. [company name] will use the new equipment for straining and filtering whitewater from the mill's saveall clean leg for reuse on paper machine showers.

- [company name] has purchased its fifth digital break recording system from Papertech. The latest installation—a 12-camera system—is at [company name] [location] mill. Other installations include [company name]'s [locations] mills.

- [company name] has selected Rockwell Automation to implement a comprehensive power demand management system at its [location] paper mill. The Rockwell Automation Power and Energy Management Solution (PEMS) is designed to help eliminate plant-crippling power blackouts caused by fluctuations in power supply levels.

- [company name] has begun installation of Quantum Technologies' HiYield polysulfide pulping process at its [location] mill.

- [company name] has retained Sapient, a business and technology consultancy, to develop a proprietary, enterprise-wide solution for managing internal costs and providing customers online interactive design and project management tools. The system will provide performance measurement, operational, and order visibility capabilities.

- [company name] [locations] mills have agreed to receive their supply of precipitated calcium carbonate (PCC) from ECC/ Faxe LLC, a joint venture between English China Clays (ECC) and Faxe Paper Pigments. The new PCC plants will be located adjacent to the two paper mills and will produce PCC for both filling and coating applications.

These examples demonstrate the richness of the Orders and Deliveries transactions data from *Pulp and Paper* and allow us to take a close look at the operations of the firms.

In summary, while the incompleteness and lack of monetary values are shortcomings, we feel that the richness of the available data offered an unique opportunity to conduct research into the firms' efforts to modernize the production processes and business operations in order to improve their production efficiency and competitive position.

3.3. Targeted Investment Categories: Data Characteristics

Our examination of the orders and deliveries transactions data over the 1996-2003 period reveals wide variation in activity across the different U.S. and foreign firms in our sample. Our base data are compiled by the 15 process categories in table 1 and the 5 targeted investments categories in table 2. For example, suppose we look at the process category # 3 "pulping" in table 1. In the pulping process, there are a variety of investments that can be made related to mechanical equipment, chemicals, monitoring devices, information technology, among others. That is, the 5 targeted investments categories in table 2. Thus, we can think of classifications like 3A, 3B, 3C, 3D and 3E, with the numeric-ID corresponding to table 1 and the alphabetical-ID corresponding to table 2. Since our main interest is in the targeted investment categories in table 2, and since presenting all the data would be rather tedious, in **Table 3** we present a summary by the targeted investment categories. The following observations emerge from table 3.

First, as we look at the last column "Total" we note that there is significant variation across firms in the total number of transactions over the 1996-2003 period. The mean number of transactions are about 24 with the 25th and 75th percentile values being 13 and 34 transactions, respectively. The total number of transactions range from a low of only 4 to a high of 63. We observe five firms (#s 6, 14, 16, 18, 19) with roughly 40 or more transactions for the 8-year period. In contrast, there are four firms with less than 10 transactions for the same 8-year period.

Second, if we look at the row labeled "Mean" and examine the numbers corresponding to the columns, we note that the mechanical category (col. A) has the highest mean number of transactions at about 16. Information technology and monitoring devices are next at about 4.5 and 2.5 transactions. Thus, transactions (investments) in the mechanical category were the most important. The overall importance of the transactions in the mechanical category is not surprising given the highly complicated nature of the machinery being used in the pulp and paper production process and the frequent need to engage in maintenance, upgrading and modernization.

Third, if we examine the data within any category – mechanical, chemical, etc. – we see considerable variation across firms in the number of transactions. We took a closer look at the specific transactions in the mechanical category and found that there is significant variation across the firms in the extent of investment activity in the machine build/rebuild category. While many of the firms in our sample have little/no activity in this category, there are some firms with significant investments in this category over our sample period. Pulping is an important activity and the 1996-2003 period saw some firms engage in significant investments in this part of the production process whereas other firms made little or no investments and improvements. Finally, the processes related to draining water, squeezing and drying saw many firms incur significant investments.

Fourth, and this is not evident from the data presented in table 3, many of the recorded transactions were simultaneously in the categories of "monitoring devices" and "information technology", as well as some that occurred in combination with "mechanical". In part, this is due to the fact that installation of monitoring devices of various types (see table 2) – such as digital cameras and quality control devices – also involved investments in software and other information technology areas to provide a centralized control structure.

3.4. Targeted Investment Categories: Correlations

In **Table 4** we report the Spearman rank-order[21] correlations between the five targeted investment categories. Transactions in the chemical area are not correlated with the other areas. This is probably not surprising given the relatively low number of transactions we recorded in the chemicals category. Transactions in the mechanical category are highly correlated with both monitoring devices and information technology. Finally, transactions in the monitoring devices category are highly correlated with information technology transactions. The latter observation reflects the fact that in many of the transactions we recorded, investments in monitoring devices went hand-in-hand with investments in software and other information technology areas. The strong correlation between mechanical and monitoring devices and information technology makes sense in that firms that installed newer equipment and production process often also installed the latest supporting devices and software for better control of intermediate and final products and the ability to intervene to correct for problems from their centralized control areas.

4. Firm-level Analysis

Our central objective is to link information on firm-level transactions in the various targeted investment categories to some measure of firm-level performance. To focus our thoughts on this, consider the following general expression:

$$(1)\ \text{Performance} = f\,(\text{Modernization Investments}; \text{Innovation Activity}; \text{Control Variables}).$$

[21] In Spearman's correlations, each variable under consideration is ordered by rank from low to high and then the rank-order correlation is computed.

All the variables in (1) are measured at the firm-level. We expect modernization and upgrading, as well as innovative activity, to deliver gains in performance. For measures of firm-level performance, we considered two candidates:

(1) Profitability. This is an obvious choice. But, as we note below, we encountered considerable difficulties in obtaining consistent and comparable data for the U.S. and foreign firms in our sample.

(2) Productivity. This is a meaningful measure of performance in the sense that firms that are more active in modernization investments, improving their production processes and engaging in innovative activity, should experience productivity gains compared to the firms that are less active. While there are several choices, we use "labor productivity" as our measure. The Compustat dataset did not allow us to calculate more sophisticated measures such as multi-factor productivity due to the lack of availability of data on materials usage, among other variables.[22]

Regarding the control variables, we considered three we felt were most important for our firm-level analysis:

(1) Mergers and Acquisitions (M&As). M&A activity was widespread in the industry during our sample period and M&As can significantly affect firms' productivity with the effects varying considerably in the shorter versus longer-run. M&As can be a source of technology acquisition (or, more generally, productivity gains), be motivated by reaping economies of scale and scope, act as a means of constraining capacity, among others, and, therefore, can significantly

[22] See Ghosal (2003) for details on computing multi-factor productivity measures.

affect the performance of firms. Further, integration of newly-acquired firms can take time and drain the acquiring company of many resources. Acquiring firms may well see sharp drops in short-run productivity. If the takeover and reorganization is successful, the acquiring firms may see gains in productivity over time. Some of the shorter versus longer run effects also depend on the pre-M&A differences in productivity between the acquiring firms and the target. In short, M&As are *ex-ante* an important control variable, although the sign of the relationship is uncertain due to the shorter and longer run issues noted above.

(2) R&D Expenditures and Patents. Firms' R&D expenditures and the number of patents granted are two commonly used measures of innovative activity. R&D can be thought of as an input measure of innovative activity whereas patents an output measure. Firms that have higher R&D and have more patents granted are expected to be more innovative and efficient compared to those that have lower propensities. We consider both of these not only as control variables, but also to examine whether innovative activity – in the sense of more R&D and patents – delivers gains in productivity. This question is interesting for a traditional industry like pulp and paper as firms in this industry typically have very low R&D intensities and, in general, have low patent counts.

(3) Capital-intensity. If we use labor productivity (that is, the ratio of total output to total labor) as our measure of performance, then capital-intensity, or the firm's capital-labor ratio, is an important control variable. This is because for a given amount of labor, firms that have a higher capital-stock will also produce more output resulting in higher labor productivity.

5. Firm-level Data

5.1. Sources

We collected firm-specific time-series data from several sources for the 10-year period 1995-2004. First, *Compustat North America* and *Global Vantage Database* provided firm-level information on sales, investment, capital-stock R&D expenditures, wages and other variables for the U.S. and foreign pulp and paper firms. Some of the data were incomplete and we attempted to fill the gaps from company 10K financial statements and other company publications such as annual reports. Data on R&D expenditures were much more difficult to obtain on a consistent basis. Our first attempt was to obtain the R&D data from Compustat. Unfortunately not all firms reported their R&D expenditures. Next, we examined various publications that had R&D data for major firms in each industry group. We also tried to fill in the gaps by examining the company 10K statements, annual reports and profit and loss statements of the firms in our study. When this did not succeed, we sent inquiries to the firms requesting R&D data. The response, unfortunately, was disappointing. Despite all these efforts, we still have fairly big gaps in our R&D data. Finally, we were unable to obtain meaningful data on firm-level earnings (or profits). The data presented in the Compustat contained large unexplained jumps in the data for several of the important firms in our sample. We examined ancillary data sources, including firms' 10K statements and annual reports but were unable to make sense of the large jumps. It almost seemed that the data definitions had changed or there was some change in reporting standards. Since we could not identify the cause, we decided to focus on productivity (described above) as our measure of performance.[23]

Second, we used the *U.S. Patent Office* and the *European Patent Office* databases by searching for patents awarded each year to each U.S. and foreign firm in our sample. These two databases cover the majority of the patents awarded globally. We combined all the patents issued to a firm and its subsidiaries.

Overall, while we were able to get a reasonably complete dataset on the number of patents granted to firms in the pulp and paper industry, the data on R&D expenditures are somewhat incomplete (i.e., have missing observations).

Third, the *Thompson Financial* database provided us with the Mergers and Acquisitions data. The database is in text form and had to be converted using XML programming into a format suitable for our purposes. The difficulty and complexity of working with this database resulted in a very time-intensive effort and also involved extensive consultations with the database provider. The M&A data are often at the subsidiary-level rather than the parent-firm-level. Therefore, we had to collect information about each firm's subsidiaries, obtain M&A data on each firm and its subsidiaries, and combine the data to get the overall firm-level M&A activity in order to make this data compatible with the Compustat database we described above.

Compiling all of the above data and integrating them in a useable format has given us a unique database. This adds significant value to our project. To the best of our knowledge these data are being systematically compiled for the first time.

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[23] The firms for which there were large jumps in the data were significant players in the market and dropping them from the sample would make little sense.

5.2. Summary Statistics

Table 5 presents information on the data sources and some description. **Table 6** presents the summary statistics for selected firm-level variables for our final set of 19 firms that we use for our regression analysis. The 19 firms are those for which we have complete data from the *Pulp and Paper* targeted investment categories (table 2) as well as firm-level data from the Compustat, Thompson Financial, and U.S. and European patent offices. Some observations that emerge from table 6 are as follows.

- For the typical firm in our sample, the average level of capital stock over this period was \$8,682 million per year. The range, as defined by the spread between the 25th and 75th percentile, is \$2,533 million to \$14,392 million. This shows that the firms in our sample vary considerably in size, as defined by their stock of capital.
- The rate of (new) investment is defined as the ratio (INV_t / CAP_{t-1}), which is current year total investment in plant, equipment and machinery divided by the previous year's stock of capital. This ratio gives us the net (or new) investment in the current year. For the typical company in our sample, the mean rate of new investment was 6.3% per year over the 10-year period. The rate of investment over this period varied a good deal among firms, ranging from 4.8% (25th percentile) to 7.6% (75th percentile). A part of the variability in investment and capital stock can be attributed to M&As with the investment of the merged firm increasing substantially in the post-merger year.

- The mean growth in sales shows fairly large differences across the firms with the 25th percentile value being 3.8% per year for the 10-year period versus the 75th percentile value of 9.9% per year.
- Productivity is a key variable in our analysis. For the typical firm in our sample, the mean level of labor-productivity is $166.56 thousand dollars per employee. The gap between firms seems quite important as it ranges from $147.7 thousand dollars per employee (25th percentile) to $202.15 thousand dollars per employee (75th percentile). While this may not seem such a striking difference, modest differences in productivity being sustained over time can mean marked differences in the competitive position of firms in the longer-run.
- The mean value of R&D intensity, as measured by the ratio of R&D expenditures to sales, is about 0.6%. This is quite low. Even at the 75th percentile value of 0.7%, the R&D intensity seems fairly low.[24]
- The typical firm in our sample had a total of 1,024 patents granted. In contrast to the R&D data, what is striking about the patent data are the dramatic differences between firms. At the 25th percentile value, the firm has a total of 6 patents for the 10 year period, whereas at the 75th percentile value the firm has 254 patents. As we examined the underlying data about company specifics and patents, some of these differences are arising due to the different range of products being

[24] As a comparison, for the year 2004, Proctor and Gamble had an R&D intensity of about 4% and Microsoft Corp. of about 21%.

manufactured by the firms in our sample. Even so, the differences between the range of R&D intensities and the patent counts seems quite striking.[25]

- In terms of the total number of M&As over the 10-year sample period, the range is between 10 (25th percentile) to 19 (75th percentile). As we look at the disaggregation by domestic versus foreign mergers, we observe that the range is quite large for both types. One reason why the range is larger for the disaggregated components (domestic and foreign) as opposed to the totals is that some firms show more activity in the foreign M&As category versus the domestic and vice versa.

Overall, the data on our final set of firms shows fairly significant variation across the firms and this is encouraging from the viewpoint of our proposed regression analysis to estimate the linkages between modernization and upgrading investments, innovative activity and productivity.

5.3. Correlations between Firm-Specific Variables

For selected variables of interest, we examined the Spearman rank-order correlations between the firm-level data we compiled from the Compustat, Thompson's Financial and the U.S. and European Patent offices. The correlations are unconditional pairwise-correlations and do not control for the influences of other variables – this is in contrast to the regression analysis where we have other control variables.

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[25] While table 6 presents data on the final set of firms we use for our regression analysis, our complete dataset contained quite a few more firms. As we looked closer at the patents data we found that of the 51 firms we have data for, 34 firms had patents ranging from 0 to 15 over the period 1995-2004. Of these, 11 had no patents. There were 10 firms each with a total of more than 100 patents during this time period. And one firm accounted for 6483 patents out of a total of 11935.

- Productivity shows a strong positive correlation with: (a) firm-size (as measured by capital-stock or sales) with the correlations being in the 0.5 to 0.6 range; and (b) capital-intensity as measured by the capital-labor ratio, with the correlation being about 0.7.[26] The latter is expected as, for a given amount of labor, the higher is the capital-stock, the higher will be the firm's production. The former is interesting in the sense that there is no unambiguous *ex-ante* prediction from theory between firm-size and productivity. But in our sample of pulp and paper firms, there appears to be a fairly strong positive correlation.

- Total number of patents granted over the 10-year sample period is: (a) positively correlated with firm-size as measured by sales or capital stock with the correlation being about 0.5; (b) positively correlated with firm-level R&D intensity with a correlation of 0.4; and (c) weakly correlated with labor productivity with a correlation of 0.3. All of these correlations are generally in the expected directions. Larger firms typically have more resources to devote to innovative activities and therefore the link to larger number of patents is not unexpected.

- M&As, total, domestic and foreign, are: (a) negatively correlated with capital-intensity with the correlations ranging from about -0.4 to -0.7; and (b) negatively

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[26] For (K/L), which we use in our cross-firm productivity analysis, our data on K is nominal and L (the number of employees) is, of course, real. This causes an error in the (K/L) data as both K and L should be in real values. We did not convert K to real as we did not have data on a capital price deflator. On the plus side, if we reasonably assumed that firms in the industry faced roughly similar capital costs (at least in Europe, Canada and the U.S.) on the assumption that they are drawing on the same international capital markets to finance their physical capital purchases, then the deflator would be roughly common for all firms. In this sense, while the numbers on K are inflated due to using nominal values, using a common deflator across all firms would scale-down the K values uniformly across all firms. Thus, the ranking of mean (K/L) values across firms would not change. Of course, if capital price data are available at the firm level, they can be used to obtain the correct real values of K and construct (K/L) accordingly.

correlated with productivity with correlations ranging from -0.2 to -0.5. Foreign M&As are positively correlated with firm-size, R&D and patents with the correlation being in the range 0.4 to 0.6.

5.4. Correlations between Targeted Investments and Firm-Specific Variables

These correlations are reported in **Table 7**. The correlations are unconditional pairwise-correlations and do not control for the influences of other variables. The following observations emerge:

- Firm-size, as measured by capital-stock, is positively correlated with the transactions in all of our targeted investment categories noted in table 2. This indicates that larger firms on average are more active in making new investments related to upgrading, maintenance and modernization.
- Productivity has a meaningful positive correlation with transactions in the mechanical, monitoring devices and information technology categories. This is encouraging as it indicates that attempts to upgrade production processes and engage in modernization is likely to be paying off in higher labor productivity.
- Total patent counts, like productivity, have a positive correlation with transactions in the mechanical, monitoring devices and information technology categories.
- R&D is generally negatively correlated with the transactions in our targeted investment categories. This, in part, may reflect the fact that the R&D data were particularly unreliable and had missing observations for many firms.
- Sales growth is not correlated with any of the targeted investment categories. This is somewhat disappointing as one would have liked to see that improvements in

production processes and efficiency would lead to improved market position and sales growth.

While the correlations in table 7 are unconditional correlations, they show some interesting relationships between the targeted investment variables and the firm-specific variables. Our regression analysis will shed a bit more formal light on this issue.

6. Regression Analysis: Baseline Results

Earlier, in expression (1), we had outlined our general approach. In this section we establish a set of baseline regression results which do not include the targeted investment categories data. The baseline regression we estimate is given by:

$$(2)\ \mathrm{Productivity}_i = \alpha_0 + \alpha_1 (K/L)_i + \alpha_2 \mathrm{Patents}_i + \alpha_3 (M\,\&\,A)_i + e_i,$$

where “i” denotes firm, e_i is the regression error term, productivity is the mean labor productivity for the 10-year period 1995-2004, (K/L) is the mean capital-labor ratio for the 10-year period, and Patents and M&A are the total number of patents and mergers and acquisitions over the 10-year period.[27] While the complete specification includes all

[27] Empirical specifications with labor productivity as the dependent variable and capital-intensity as the explanatory variable are estimated in log-linear form as the underlying production function – such as a standard Cobb-Douglas production function - is non-linear in levels. We do not estimate specification (2) – and later a modified specification (3) – in log-linear form as some of the firm-level variables related to patents, mergers and the disaggregated components of the technology categories have zero values. Our sample size is already small to begin with and we do not have the option of dropping these firms (the one with the zero values for the variables) from our sample in order to estimate specification (2) in logarithmic form. Since estimating a specification where some of the variables are measured in logarithms and others in levels is not particularly meaningful, we estimate specification (2) in levels.

of the above variables, we also present results with subsets of the variables. These results are presented in **Table 8**. The key observations that emerge are:

- As expected, a firm with higher capital-labor ratio has higher labor productivity with the estimated coefficients being highly statistically significant in all the specifications.
- Firms with a larger number of patents show greater labor productivity. The estimated coefficients are highly significant. This result is in the expected direction.
- The number of M&As a firm engaged in – one of our control variables – appears not to be important in explaining differences in labor productivity across firms. We included this control variable because firms that are more active in M&As may face uncertain shorter and longer-run outcomes due to the uncertainties of integrating the new acquisitions. Our data do not reveal a significant relationship in either direction.
- The regression adjusted-R^2s are around 0.5 implying that only about one-half of the labor productivity differences across firms are explained by the variables included in the estimated specification.

In an ancillary regression we included R&D intensity as a control variable. To include R&D, we had to drop several firms from our set of 19 due to the lack of R&D data. R&D turned out to be insignificant in all the estimated specifications. This is likely due to the data problems we noted earlier. Given this result, we do not focus on R&D in our subsequent analysis.

7. Regression Analysis: Incorporating the Targeted Investment Categories

In this section we augment the baseline specification (2) to include our targeted investment categories variables. The central objective is to examine the linkages between the firms' transactions in the various targeted investments and performance, which in our case is productivity. The augmented regression takes the form:

$$\text{(3)} \quad \text{Productivity}_i = \alpha_0 + \alpha_1 (K/L)_i + \alpha_2 \text{Patents}_i + \alpha_3 (M\&A)_i + \alpha_4 (\text{Targeted Investments})_i + \upsilon_i ,$$

where υ_i is the regression error term and "targeted investments" refers to mechanical, chemical, monitoring devices and information technology classifications described in table 2. We first use the total number of transactions across all categories to get a broad picture. Then we re-estimate (3) by using the individual targeted investment categories to provide a comparison of the effects of the transactions in the different categories.

The estimates appear in **Table 9**. First, we examine the estimates presented in columns A-D; in these columns, we include the total number of M&As as the control variable. The observations that emerge from table 9 (columns A-D) can be summarized as follows:

- The estimate of the total number of targeted investment transactions (column A) is positive and significant, indicating that firms that engaged in a larger number of transactions typically had higher labor productivity.

- When we disaggregate the total into the mechanical and digital[28] components, we find that the estimates of both categories are highly significant indicating that these transactions individually played an important role in enhancing productivity. The point estimate of the digital transactions is greater than the mechanical category, but, as we evaluate later, the estimated quantitative effect of the digital category is only slightly larger than mechanical.
- The estimate of the chemicals category while positive, is statistically insignificant. This is probably not too surprising given that we do not observe many transactions in the chemicals category for our sample of firms.
- If we compare column F in table 8 to column A in table 9, the latter has an adjusted-R^2 that is 0.2048 greater. Thus, adding the total number of targeted investment transactions increases the (degrees of freedom adjusted) explanatory power by 20% - a fairly large increase.
- Given our small sample, we have some concerns about the degrees of freedom. Since the M&A effects were statistically insignificant, we re-estimated specification (3) by excluding the M&A control variable. These estimates are presented in columns E-H of table 9. Our broad inferences remain intact.

To summarize, the targeted investment transactions aimed at modernization and upgrading of the production processes and other aspects of firm operations do seem to be an important factor explaining productivity differences across firms in the pulp and paper industry. In particular, firms that engaged in a larger number of transactions in the

[28] As we note in the table, the "digital" category is the sum of the "monitoring devices" and "information technology" categories.

monitoring devices and information technology areas seem to have experienced a noticeable boost in productivity.

7.1. Assessing the Quantitative Impacts

In table 9 we presented the estimates from the regression analysis. While these estimates inform us of the sign (direction) and statistical significance of the relationship, they do not provide a clear picture of the implied quantitative effects.

To take a look at the quantitative effects, in **Table 10** we present numbers where the point estimates from table 9 are multiplied by one-standard-deviation of the relevant variable. This is a useful way of gauging the quantitative effects in the sense that if we think of a one-standard-deviation increase in the number of transactions in, say, the digital category, this would tell us by how much would productivity change by within our sample of firms. Considering a one-standard-deviation difference is reasonable as this number is arising from the distribution of observed numbers from within the set of firms we consider.

The estimates of the quantitative effects presented in table 10 indicate that the largest increase in (labor) productivity comes from increase in the firm's capital-labor ratio. This is expected as, *ceteris paribus*, a higher capital-to-labor ratio is at the core of the firm's ability to produce more. Given the units of measuring productivity, the quantitative estimates in table 10 show that a firm that has a one-standard-deviation higher (K/L) has approximately $28,000 higher (labor) productivity.

The next largest set of increases in productivity come from the number of transactions a firm engaged in the mechanical and digital categories, with transactions in the digital category providing a bigger quantitative boost to productivity. Given the units of measuring productivity, the quantitative estimates in table 10 show that a firm that has a one-standard-deviation larger number of transactions in the mechanical and digital categories has approximately $15,000 and $19,000 higher (labor) productivity, respectively.

The chemicals category does not provide a boost given that the point estimate from table 9 is statistically insignificant. As noted in table 9, the point estimate of M&As was also statistically insignificant, implying that M&As do not impact productivity in our sample of firms. Finally, we used patents as a measure of pure innovation output and our quantitative estimate in table 10 shows that the gains to productivity from higher patenting is positive, but somewhat low – lower than that provided by the transactions in the mechanical and digital technology categories.

8. Some Implications of our Findings

Our study was motivated by the changing landscape in the pulp and paper industry as well as our observations from trips to various pulp and paper mills where we obtained an in-depth understanding of the economic realities and how the firms were responding to improve their competitive position. In a white-paper written for CPBIS (Ghosal, 2003), it was noted that various kinds of "incremental" innovations, modernization investments, among others, appeared to be the mainstay of how the pulp and paper firms viewed themselves as staying competitive in the short-run as well as gaining on their competitors in the longer-run.[29] Breakthrough innovations that characterize some industries are not the most important factors that drive the changing competitive position and performance of firms in this industry. In contrast, firms that succeed in implementing even small gains in productivity on a year-to-year basis via investments in upgrading and modernization, as well as making changes to the supply-chain, would in the medium-to-longer run gain relative to those firms who were not successful at implementing such strategies.

The results in this paper, linking productivity differences across firms to modernization investments and upgrading in various categories, as well as examining the link to patents, appear to strongly reinforce this message. Patents, for example, help explain differences in productivity across firms, but the quantitative effect is not very large. In contrast, the estimated impact of investments in the mechanical, monitoring devices and information technology categories on productivity is positive and larger than those observed for patents. Based on our results, R&D expenditures do not make a meaningful contribution to productivity. The clear message is that firms need to stay focused and actively implement modernization investments in all stages of the production process to ensure that they achieve gains in productivity. Further, while these investments may only produce relatively small gains in productivity on a year-to-year basis, it is important to recognize that these small gains can compound over time to form larger differences in productivity across firms in the longer-run. To provide an illustrative display, consider two firms A and B starting off at our sample mean level of productivity of $166,562 (see table 6). Now assume that firm A implements various modernization

[29] Norberg-Bohm et al. (1998) present insights on specific aspects of incremental innovations in this industry.

investments and other strategies and experiences an annual average growth in productivity of 1.5% while firm B achieves 0.8%. **Figure 1** plots the time-paths of the evolution of productivity starting at year 1 when both are equal. **Figure 2** plots the percentage gap in productivity between firms A and B. In year 1 the productivity gap is zero by construction. The productivity gap increases to 6.43% in year 10. Clearly, the relatively small annual difference compounds to form a meaningful productivity gap between the two competitors in the longer-run.[30]

9. Concluding Remarks

The primary contributions of this paper can be viewed as follows. First, we develop a framework within which we conceptualize firms' operations and strategies to boost productivity. We did not emphasize much of the standard literature that focuses on R&D expenditures and patent counts to gauge firms' innovation activities and link these to the measures of performance. While R&D and patents are useful measures in many industries, in general they are unlikely to be good measures for firms in the pulp and paper industry. This is because firms in this industry typically have a rather low R&D intensity, as measured by the ratio of R&D expenditures to sales, and most firms do not hold a large number of patents. Our prior, therefore, was that R&D and patents were unlikely to be the key channels. Our empirical results confirm this insight. We found that patents had a relatively small positive contribution towards firm-level productivity and our experiments with R&D revealed that it was not a factor in boosting productivity. Our visits to various pulp and paper mills convinced us that examining investments made by

[30] Ghosal (2003) presents some industry-level multi-factor productivity graphs to display this aspect.

firms related to modernization and upgrading would be more useful in gaining insights. In short, the framework we adopted was more expansive, allowing alternative channels to affect firm-level productivity.

Second, we compiled an extensive dataset from diverse sources. These were described in detail in sections 3 and 5. As far as we are aware, there is no other study of firms in this industry which has put together such a diverse amount of data and information to analyze issues related to investments, innovation, M&As and productivity.

In combination, we feel that our framework and the data we have collected can serve as a useful starting point for future research on productivity and performance issues not only for firms in the pulp and paper industry, but also provide a model for research for other industries.

We noted several shortcomings of our data. Our hope is that future research can fill the gaps in the data and provide a more comprehensive picture. There are two areas in particular where additional data and insights would add value to this line of research. The first one relates to quantifying the monetary value of the investments in the mechanical, chemicals, monitoring devices and information technology categories. Despite our best efforts, we were unable to put together a complete dataset in this dimension. If one is able to attach monetary values, then one could provide useful insights on prioritizing the different areas of investments and modernization. The second one relates to obtaining a consistent database for firm-level profits. This is a key measure of firms' bottom-line and would serve as an important complement to examining productivity differentials across firms. Due to the reasons noted in section 5.1, we were unable to compile a consistent and comparable data on U.S. and foreign firms in the pulp and paper industry.

Apart from the path we pursued in this paper, another area of promise would be to examine the organizational and management changes the firms in the pulp and paper industry made in response to the competitive challenges. Following up on visits to pulp and paper mills, Ghosal (2003) presents an observation-based analysis which indicates that firms made dramatic modifications to their organizational structure and supply-chain to achieve gains in productivity. An examination of organizational and management changes in combination with our data-driven analysis will provide a more encompassing picture of business strategies pursued by firms in the pulp and paper industry.

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Table 1
Production Process

Process Number	Process Description
1	Debarking
2	Chipping
3	Pulping (pressure-cooking)
4	Washing
5	Refining
6	Cleaning
7	Bleaching
8	Dying
9	Coating
10	Pumping
11	Draining Water
12	Squeezing (removing water)
13	Drying
14	Calendaring
15	Slitting

Table 2 **Targeted Investment Categories**	
Category	Comments
Mechanical	Transactions in this category include major machine rebuilds and a variety of other investments, upgrades and modernization of physical equipment related to the processes described in table 1. The recorded transactions in this category include a wide range such as press section rebuilds, installation of fibreflow drum pulper, coating systems, new recovery boiler, paper winders, screening systems to remove plastics and contaminants, replacement of chip-and-saw heads with turnknife chipping heads, covers for supercalender, gravity strainers and showers, steam systems with blow-thru controls on paper machine dryer sections, pre-evaporation systems to capture blow steam from mill pulping process, chip thickness screening equipment, sludge dewatering equipment, among many others.
Chemical	Includes transactions related to dyes, pigments, water treatment chemicals, among others. Some examples include high yield polysulfide pulping processes and precipitated calcium carbonate for coating and filling. Chemicals are an important component of the process categories 3-9 in table 1.
Monitoring Devices	Included in this category are transactions related to digital cameras and a variety of other devices designed to monitor the production line. Examples include devices that monitor fluid leaks in the production line, paper jams, paper quality, paper reflection, paper-coat weight, curl and moisture on the coater, digital break recording systems, devronizer systems and on-line measurement of kappa and dissolved lignin.
Information Technology	Transactions in this group included purchase and installation of new software and integration investments with digital devices and other aspects of production. Examples include integrated quality control systems to provide regulatory control for paper machines, order fulfillment systems, wood procurement systems, transportation management and plantwide information systems.
Other	Miscellaneous transactions not covered in the above categories. Examples include construction services for environmental improvements, contracts to manage wastewater treatment facility, injury prevention initiatives and initiatives to reduce water consumption.

1. For some of our analysis we will combine “Monitoring Devices” and “Information Technology” into one category labeled “Digital” as several of the transactions we recorded contained elements of both.

Table 3
Targeted Investments: Data Summary
Time period: 1995-2003

Firm ID	Mechanical	Chemical	Monitoring Devices	Information Technology	Other	Total
1	9	0	3	5	0	17
2	16	1	1	2	0	20
3	2	0	1	1	0	4
4	11	0	2	3	0	16
5	5	1	1	1	0	8
6	44	1	5	10	3	63
7	16	1	3	5	0	25
8	8	1	3	3	0	15
9	10	0	2	4	0	16
10	13	1	2	5	3	24
11	3	0	0	1	1	5
12	22	0	3	4	0	29
13	4	1	1	1	0	7
14	33	0	3	5	2	43
15	17	0	1	2	1	21
16	31	0	3	8	0	42
17	4	0	3	5	0	12
18	26	0	6	13	2	47
19	31	0	2	5	1	39
Mean	16.05	0.37	2.36	4.37	0.68	23.84
Std. Deviation	12.05	0.49	1.46	3.18	1.06	16.19
25^{th} Percentile	6.50	0.00	1.00	2.00	0.00	13.50
50^{th} Percentile	13.00	0.00	2.00	4.00	0.00	20.00
75^{th} Percentile	24.00	1.00	3.00	5.00	1.00	34.00

1. The table presents summary statistics for our final set of 19 firms that we use for our regression analysis.
2. The numbers represent the totals over the sample period. For example, for firm #6, the total number of recorded transactions was 63, with 44 of those being in the “mechanical” category, 10 in the “information technology” category, etc.

Table 4
Correlation between Targeted Investment Categories

	Mechanical	Chemical	Monitoring Devices	Information Technology	Other	Total
Mechanical	1.000	_	_	_	_	_
Chemical	-0.069	1.000	_	_	_	_
Monitoring Devices	0.558	-0.072	1.000	_	_	_
Information Technology	0.700	-0.142	0.871	1.000	_	_
Other	0.507	-0.011	0.178	0.414	1.000	_
Total	0.969	-0.059	0.691	0.825	0.543	1.000

1. The reported numbers are the Spearman rank-order correlation coefficients.

Table 5
Description of Firm-Specific Variables

Variable Name	Variable Description
Capital Stock	Source: Compustat. Net book value of physical capital: sum of plant, equipment and machinery. This is measured in nominal (current) dollars (in millions) as no price deflator for physical capital was available.
New Investment	Source: Compustat. Ratio of "net current year expenditures on plant, equipment and machinery" to previous year's "net capital stock". This gives us the rate of new investment in the current year.
Capital-labor ratio: (K/L)	Source: Compustat. Ratio of "net current year capital stock" to "current year employment". This measures the capital-intensity. Capital stock is measured in $ millions and # employees is measured in thousands.
Total Sales	Source: Compustat. Real sales or the ratio of "current dollar value of total sales" to "industry product price deflator". Since we did not have access to firm-specific product prices, we could not use an industry deflator. "Sales Growth" is the percentage annual growth of real sales. Sales is measured in $ millions.
Productivity	Source: Compustat. Ratio of "real sales" to "employment". This gives us the labor productivity as measured by sales per worker. Sales is measured in $ millions and employees in thousands. Since no output (or production) data were available, we did not construct an output based productivity measure. "Productivity Growth" is the percentage annual growth of productivity.
R&D	Source: Compustat and other publications. Ratio of "current dollar expenditures on research and development" to "current dollar value of sales". This gives us the R&D intensity.
Patents	Source: U.S. and European Patent Offices. Total number of patents granted.
M&A: Total	Source: Thompson's Financial. Total number of M&As, domestic and foreign.
M&A: Domestic	Source: Thompson's Financial. Number of M&As where the target was domestic or within the country.
M&A: Foreign	Source: Thompson's Financial. Number of M&As where the target was foreign or outside the country.

1. All raw data are at an annual frequency for the years 1995-2004.

Table 6
Firm-Specific Variables: Summary Statistics

	Mean	Std. Deviation	25th Percentile	50th Percentile	75th Percentile
1. Capital Stock (Nominal $ millions)	8,682.694	8,480.563	2,533.352	5,538.300	14,392.262
2. New Investment (Percent)	0.063	0.022	0.048	0.057	0.076
3. (K/L) ($ '000 per worker)	135.721	64.751	82.969	146.604	175.411
4. Total Sales (Real $ millions)	5,511.040	5,561.422	1,260.080	2,732.206	9,587.847
5. Sales Growth (Percent)	0.067	0.046	0.038	0.0695	0.099
6. Productivity ($'000 per worker)	166.562	39.577	147.704	162.504	202.150
7. R&D (Percent)	0.006	0.005	0.003	0.004	0.007
8. Patents (Total number)	1,024.211	3,384.972	6.000	20.000	254.500
9. M&A: Total (Total number)	16.632	13.635	10.000	14.000	19.000
10. M&A: Domestic (Total number)	9.158	6.817	1.500	11.000	13.000
11. M&A: Foreign (Total number)	7.474	9.330	1.000	4.000	9.000

1. The table presents summary statistics for selected firm-level variables for our final set of 19 firms we use for our regression analysis.
2. For variables in rows 1-7 above, the raw data are at an annual frequency. For each variable we computed the 10-year (1995-2004) **mean**. We get 19 mean values corresponding to the 19 firms. The numbers above are the cross-firm summary statistics corresponding to these mean values. E.g., the 10-year mean rate of new investment (row 2) across the 19 firms was 6.3% with a standard deviation of 2.2%.
3. For variables in rows 8-11, the raw data are at an annual frequency. For each variable we computed the 10-year **total**. The numbers reported are the cross-firm summary statistics corresponding to these totals. E.g., the total number of M&As (row 9) averaged 16.63 with a s.d. of 13.63.
4. The sales and capital-stock numbers are not comparable as the former in real dollars and the latter in nominal (see table 5).

Table 7
Correlation between Targeted Investment Categories and Selected Firm-Specific Variables

	Orders and Deliveries Investment Categories				
	Mechanical	Chemical	Monitoring Devices	Information Technology	Total
Capital Stock	0.387	0.259	0.654	0.725	0.508
Sales Growth	-0.004	0.139	0.105	0.061	0.035
Productivity	0.270	0.119	0.363	0.549	0.347
R&D	-0.309	0.454	-0.299	-0.293	-0.319
Patents	0.273	0.149	0.569	0.459	0.356

1. The data on the targeted investment categories are as noted in table 3. And the data on the firm-specific variables are as noted in tables 5 and 6.
2. The reported numbers are the Spearman rank-order correlation coefficients.

Table 8
Regression Results I
Dependent Variable: Productivity

	A	**B**	**C**	**D**	**E**	**F**
1. Intercept	103.6123* (11.292)	99.0880* (17.976)	105.2461* (18.540)	99.6184* (15.277)	99.1355* (10.896)	104.4400* (17.948)
2. (K/L)	0.4638* (0.070)	0.4799* (0.082)	0.4579* (0.079)	0.4779* (0.077)	0.4839* (0.067)	0.4693* (0.008)
3. Patents	–	–	–	–	0.0017* (0.0008)	0.0020* (0.0009)
4. M&A: Total	–	0.1406 (0.346)	–	–	–	-0.1568 (0.389)
5. M&A: Domestic	–	–	-0.0919 (0.873)	–	–	–
6. M&A: Foreign	–	–	–	0.2776 (0.474)	–	–
# Observations Adjusted-R^2	19 0.5509	19 0.5247	19 0.5230	19 0.5270	19 0.5456	19 0.5171

1. Heteroscedasticity-consistent standard-errors are in parentheses. An asterisk * denotes statistical significance at least at the 10% level.
2. In ancillary specifications we experimented with using firm-level R&D as an alternative measure of innovative activity. None of the R&D coefficients were significant, hence we do not report them here.

Table 9
Regression Results II
Dependent Variable: Productivity

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
1. Intercept	87.4466* (14.934)	91.2353* (15.219)	81.8564* (14.360)	103.2551* (17.155)	75.1274* (10.349)	79.1913* (10.692)	75.7428* (8.814)	97.9323 (9.421)
2. (K/L)	0.4334* (0.068)	0.4428* (0.075)	0.4315* (0.066)	0.4577* (0.089)	0.4801* (0.056)	0.4884* (0.062)	0.4527* (0.050)	0.4766 (0.075)
3. Patents	0.0028* (0.0007)	0.0031* (0.0009)	0.0017* (0.0005)	0.0016* (0.0004)	0.0019* (0.0005)	0.0021* (0.0006)	0.0013* (0.0004)	0.0013 (0.001)
4. M&A: Total	-0.4988 (0.380)	-0.4926 (0.425)	-0.2264 (0.316)	-0.1969 (0.384)	–	–	–	–
5. O&D: Total	**1.0761*** (0.259)	–	–	–	**1.0180*** (0.294)	–	–	–
6. O&D: Mechanical	–	**1.2640*** (0.459)	–	–	–	**1.1770*** (0.481)	–	–
7. O&D: Digital	–	–	**4.1845*** (0.786)	–	–	–	**4.1671*** (0.795)	–
8. O&D: Chemical	–	–	–	**7.5215** (13.938)	–	–	–	**7.0459** (13.963)
# Observations Adjusted-R^2	19 0.7219	19 0.6626	19 0.7782	19 0.4923	19 0.7228	19 0.6681	19 0.7892	19 0.5233

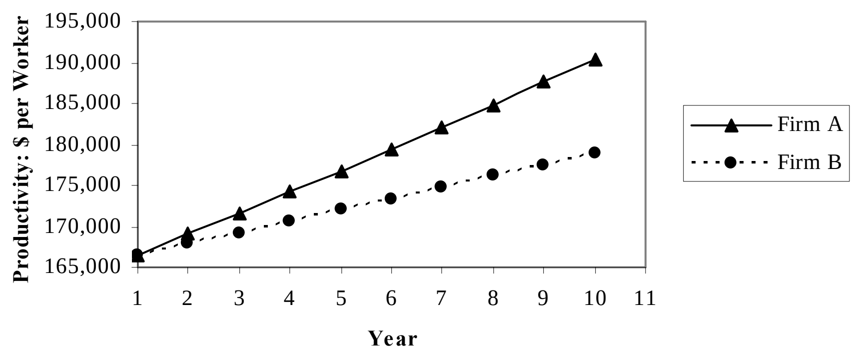
1. The “O&D: Digital” category in row 5 is the sum of the “Monitoring Devices” and “Information Technology” categories noted in table 2. We created “Digital” for our regression analysis as several of the transactions we recorded contained elements of both.
2. Columns E-H repeat the regressions presented in columns A-D, but exclude the “M&A: Total” variable. Since “M&A: Total” was insignificant in columns A-D, we dropped this to conserve degrees of freedom.
3. Heteroscedasticity-consistent standard-errors are in parentheses. An asterisk * denotes statistical significance at least at the 10% level.
4. As in table 8, in ancillary specifications we experimented with using firm-level R&D as an alternative measure of innovative activity. None of the R&D coefficients were significant, hence we do not report them here.

Table 10
Dependent Variable: Productivity
Estimated Quantitative Effects

	A	B	C	D
1. Intercept	87.4466* (14.934)	91.2353* (15.219)	81.8564* (14.360)	103.2551* (17.155)
2. (K/L)	28.07* (0.068)	28.67* (0.075)	27.94* (0.066)	29.64* (0.089)
3. Patents	9.48* (0.0007)	10.49* (0.0009)	5.75* (0.0005)	5.42* (0.0004)
4. M&A: Total	-6.79 (0.380)	-6.71 (0.425)	-3.08 (0.316)	-2.68 (0.384)
5. O&D: Total	**17.42*** (0.259)	–	–	–
6. O&D: Mechanical	–	**15.23*** (0.459)	–	–
7. O&D: Digital	–	–	**19.12*** (0.786)	–
8. O&D: Chemical	–	–	–	**3.68** (13.938)
# Observations Adjusted-R^2	19 0.7219	19 0.6626	19 0.7782	19 0.4923

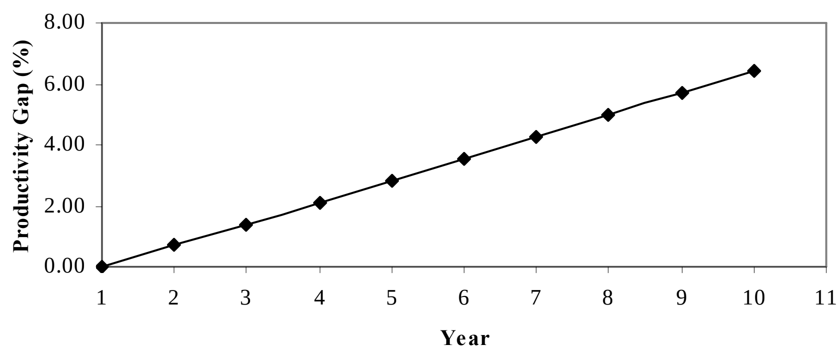
1. The numbers presented in this table are the coefficient estimates presented in table 9 (columns A-D) multiplied by one-standard deviation of the relevant variable. The standard deviations of the relevant variables are given in tables 2 and 6. For the "digital" category we created by summing monitoring devices and information technology, the standard deviation is 4.57. As an example of our computations, the point-estimate of (K/L) from column A in table 9 is 0.4334. From table 6, the standard-deviation of (K/L) is 64.75. Multiplying these two numbers gives us 28.07 – which is the number reported in column A of this table. We carry out a similar exercise for all the included variables.
2. The standard errors, significance levels and adjusted-R^2 are the same as in table 9 – we repeat them here for convenience. An asterisk * denotes that the estimate is significant at least at the 10% level.
3. The estimate of the intercept is the same as in table 9 – but this is not important for the procedure for computing the quantitative effects of the explanatory variables.

Figure 1. Hypothetical Productivity Paths



Note: We assume that both firms start off in year 1 at our sample average productivity of $166,562 per worker. Subsequently, firm A experiences a 1.5% productivity improvement per year whereas firm B has 0.8% per year.

Figure 2. Productivity Gap between Firm A and Firm B



Note: In the starting year 1 there is no gap by construction. By year 10, firm A has a 6.43% higher productivity than firm B.