Is There a Productivity Gap Between U.S. and European Pulp and Paper Producers?

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Summary

The broad objectives of this project were: (1) to study innovation and technological change in the pulp and paper industry; and (2) provide a comparison between U.S. and Scandinavian mills with regard to (potential) technological differences between them. I visited a Scandinavian mill in August 2002 and a U.S. mill in February 2003. Some of the key observations are:

> (a) Following the economic downturn of the 1990's, restructuring the supply-chain and process-management were essential to stay competitive. These included changes in, for example, log and chip inventory holdings, restructuring transportation contracts, greater emphasis on de-bottlenecking, offering workers incentives to be more productive, and modernization via use of computers which improved process-management.
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> (b) Incremental innovations are key to survival. This is because new paper machines are very expensive and last long; in the interim period, greater output has to be tweaked from existing machines. Remarkably, both said that gains in output due to incremental innovations, with a given mill, appear to be in the 1.5%-2% per year range.
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> (c) The U.S. mill seemed more focused on buyer-seller relationships. They seemed to argue that price was not often the key determinant. Right quality, consistency of quality, on-time delivery and individual attention were very important. I suspect the Scandinavians do this too, but they did not emphasize this as much; they argued that they had little pricing power and had to rely on quality and cost-efficiency to stay competitive.
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> (d) Based on the US and Scandinavian mill trips, I really could not tell whether one or the other had an advantage. Both had relatively newer machines that were efficient at high production volume and met or exceeded environmental standards. The mills appeared to be efficiently managed, had a high level of computerization and had made significant organizational changes to meet changing market conditions. Both noted that machine vintage effects were significant: if a company had relatively older machines, they would be more inefficient and incorporating newer environmental controls costly.

Apart from these observations based on mill trips, the paper presents a brief overview of the U.S. pulp and paper industry till the mid-1990's, outlines alternate strategies to measure innovation and productivity gains, computes total factor productivity measures for the U.S. industry, and outlines a framework within which we can compare innovation and productivity improvements for U.S. and foreign producers where data are available.

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1. Objectives and an Outline of the Issues

The objective of the white paper was to explore potential technology gaps in the pulp and paper industry between the U.S. and their European/Scandinavian counterparts. In our discussion below, for convenience, we will talk about US versus Scandinavian producers.

There are two ways of looking at the bigger picture. First, think of whether Scandinavian producers are using or have access to **better technology** *per se* as defined traditionally by better machines, production processes, etc. Second, think of the issue more broadly and ask the question whether Scandinavian producers are **more cost-efficient** than US. Better technology, ceteris paribus, should translate to more cost-efficient production. But even without better technology, there could be significant differences in cost-efficiency across producers. These could come from, for example:
(1) incremental innovations or learning-by-doing that tweak extra efficiency/output from existing machines and production processes (see Appendix A for a discussion).
(2) better organization and management of the entire chain of operations from procurement of inputs like timber to final sales and transportation contracts with truck and rail transport carriers;
(3) changes in organizational structure which give workers added incentives to be productive; and
(4) organizing input procurement, production and distribution to be able to better withstand cyclical fluctuations in product and input markets.
In short, one needs to evaluate at least five issues; technology plus the four above.

Looking at the range of research strategies that can be pursued to examine the above questions, there are at least two complimentary approaches:
(1) Build a broad information and data base from ground up. Here we visit similar mills in the US and Scandinavia and interview technical personnel and managerial staff. The objective being to understand the business strategies pursued by the firms, technologies and production processes, organizational structure, incentive systems, and differences in approach to changing market conditions. This information will be helpful in several dimensions; and
(2) It is very important that one be able to quantify (potential) differences in productivity and cost-efficiency. While the level of detail and insights obtained from mill visits will be invaluable, if there are distinct productivity differences between the US and Scandinavian industries, it should show up in more aggregated industry data. For the US industry, one could use data obtained from industry sources or publicly available sources (e.g., COMPUSTAT, Census of Manufactures, or other industry sources) to evaluate productivity and cost-efficiency. At this point I'm not sure about access to foreign data sources.

2. A Look at the US Pulp and Paper Industry.

Paper mills correspond to SIC 2621 of the US 4-digit manufacturing classification. For this level of disaggregation, time series data from the late-1950's to mid-1990's are available from the National

Bureau of Economic Research (Bartlesman and Gray, 1998). In addition to this, I gathered some data on broad industry structure characteristics related to the number of firms, four-firm concentration and distribution of establishments by employment size. Unfortunately, more recent data are not particularly useful since I could not get data on the price deflators for materials, energy, investment, etc, which are key to getting a proper picture of the data. I will try to update this at a later stage. Finally, my search for corresponding data for some of the European countries did not lead to positive results. This summer, when I am likely to be in Germany, I will try to explore whether comparable data can be obtained for other countries.

Regarding broad industry structure characteristics, the four-firm concentration ratio has ranged between 22%-35%. The total number of firms has declined over the years from around 200 in the 1960's and 1970's to closer to 125 by the early-1990's. A firm can have multiple establishments. The industry average number of establishments per firm has increased from about 1.7 in the 1960's and 70's to closer to 2.2 by early-1990's. Regarding the size distribution of establishments as measured by the number of employees, the number of establishments employing less than 500 workers has steadily declined from around mid-250's to closer to 180 in recent years. The number of larger (greater than 500 workers) establishments has remained steady around 90. Overall, looking at the data on concentration, number of firms and establishments till early 1990's, there only appears to be a modest upward trend in concentration.

Figures 1-7 provide a quick look at some aspects of this industry. As expected, real sales (Figure 1) show a distinct upward trend. Noteworthy is the negative trend of both the number of total workers as well as production workers (Figures 2-3).[1] This generally reflects a steady drift towards more capital-intensive (or labor-saving) techniques. While the composite of materials and energy usage (Figure 4) shows a steady upward trend, energy usage (Figure 5) shows a relatively flatter path in the middle-years, but the overall trend is positive. Unlike many other industries where net investment is highly volatile, the net investment series for the paper mills (Figure 6) shows much less year-to-year volatility; the series in Figure 6 includes investments in plant as well as equipment and machinery.[2] Finally, Figure 7 displays the foreign sector. The import-share has generally fluctuated in the 14%-19% range. Unlike the US manufacturing sector as a whole which shows dramatic increase in import-share during the 1980's-90's (see Ghosal, 2002.a), this feature is much less pronounced in the paper mills sector. The implication of this would be that imports as a disciplining factor appears less

[1] Engel (1997) also notes that while employment fluctuates due to cyclical factors, it has failed to return to previous peaks during more recent times.

[2] More traditionally, the three major areas of capital spending in this industry are (i) new paper machines, (ii) environmental, and (iii) paper machine rebuilds (see North American Factbook, 2001). Since, roughly, the 1970's, environmental considerations have driven much of the overall investment patterns. In recent years, there appears to have been a shift in the pattern of new investments. As noted by Engel (1997), while the number of new machine instals and rebuilds have been declining since 1987-88, there is growth in new recycling mills which can be installed on a smaller scale, cost less per ton of output and meet the incremental expansions in demand. These issues can be addressed within the context of a larger study; our aggregated data, however, do not contain the component spending items.

of an issue here than US manufacturing as a whole. Regarding exports, the series appears relatively flat till the late-1980's and then shows a marked increase.

Next we turn to Figures 8-12. The year-to-year sales growth data are plotted in Figure 8. Aside from some sharp fluctuations in the mid-1970's, the pattern of volatility is somewhat muted. The data clearly show the stagnation of markets in the late-1980's-early-1990's; from 1987 till about 1993 is a very flat period in sales growth, coinciding with the well known US and global slowdown. Figure 9 displays the series on real investment in equipment and machinery. Aside from the mid-to-late 1960's and late-1980's to early 90's, the series is rather flat. Later in our discussion we will detail how to measure productivity growth. For the moment think of total factor productivity (TFP) growth simply as the difference between growth of an industry's output minus the growth of inputs (materials, energy, labor and capital). Figure 10 plots two series; for now we only discuss the TFP series. It shows an incredible amount of variation in year-to-year fluctuations in measured productivity. We take this same data and display it differently in Figure 11. We create a productivity index where our first year (1958) is assigned a value 1.00. Then we use the computed TFP growth data from Figure 10 and create a cumulative index "CTFP" – this is the top graph. This shows that productivity was generally stagnant till 1970, with some fluctuations it rose significantly through mid-1980's and then reveals mixed fortunes. The last data that we look at relates to some rough measures of profitability - Figure 18. Profitability shows declines through the late-1960's; a steady upward trend through the mid-to-late 1980's and then a decline.

The above discussion and data were to provide a context. Later we return to several features of the data and try to link these observations to what we learnt from trips to paper mills.

3. Mill Trips: Learning About Organizational Structure, Business Strategies and Innovation.

3.1. A Scandinavian Mill Trip

I visited a paper mill in Scandinavia during August 2002. The integrated pulp and paper mill uses state-of-the-art production processes and their primary focus is on printing and specialty papers.[3] Of their total production of printing papers, about 50% is accounted for by magazine papers and the rest by newsprint and fine papers. I asked them questions regarding their operations, technologies and changes they have made over the last decade. What follows is a brief rendition of what I learnt.

3.1.(i) Changes Over the Last Decade

They indicated that following the economic downturn of late-1980s early-1990s, they had instituted some major changes in how they do business. During the 1990-91 downturn, they had major problems with excess production and pileup of wood inventory. During that period, they were forced to sell even when the market was down and prices were low. All of this was the result of their

[3] A non-integrated mill, for example, could only produce only paper or produce (market) pulp.

relatively inflexible input procurement and transportation contracts,[4] and production. Post-recession, they embarked on a efficiency drive; think of it as a cleansing effect of the recession.[5] An important objective was to avoid selling when price was low. Below I detail some of the items.

(a). They restructured their timber procurement contracts to make it more flexible and hold less stocks of timber logs and chipped wood. Earlier, they were holding stocks of logs and chips worth about 2-3 months of input usage. In the 1990s, they gradually reduced this to about 10 days supply of chips and 4 days of logs for a total of 14 days of input. Overall, much smaller input inventory holdings.

(b). Their contracts with farmers (who along with the government own approx 90% percent of the forests)[6] for logs is quite flexible and allows them to increase/decrease log supply fairly quickly.

(c). Holding smaller inventory of logs and chips implies that the wood is relatively fresh and the fibers have not degraded. This has enormous implications for the subsequent chain of events. First, if the chips are fresh, the pulp fibers need less chemicals and processing. Higher quality paper can be produced at lower cost. If the chips are older, the fibers degrade and need more chemical processing which raises the cost and reduces quality. Second, since less chemicals and processing are required with fresher wood chips, the amount of pollution is lower. This reduces the cost of cleanup. Overall, fresher chips imply lower unit cost (of production and cleanup) and higher quality. In combination, this could have an appreciable effect on profit margins.

(d). They indicated that they can ramp production up or down by a significant percentage in a short time frame; claiming they could increase or decrease production between10-15% within a few days.

(e). They restructured their transportation contracts. Earlier it was longer term and relatively inflexible. Now it is more flexible. They rely on both rail and truck transport; rail tends to be more inflexible. Now they have a core of longer term contracts and the remainder they use whatever flexibility is available in (mainly) truck and (some) rail.

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[4] Inflexible in the sense that their input and transportation contracts were relatively longer term. This afforded them little opportunity to cut costs and scale down production quickly during downturns.

[5] Ince (1999) points to some of these issues as problems for the U.S. industry.

[6] This situation is quite different from the US. Also, since the farmers treat their timber assets as a source of short and long run income, they tend to sell only small amounts of timber and clear-cutting is very difficult.

(f). Summary of items (a)-(e). Dramatic changes in the entire supply chain; inputs, production and transportation. Greater flexibility. Lower costs. Higher quality. Because of this they can avoid selling when market prices are low. Potentially significant impact on longer-run efficiency and profits.

(g). Much greater emphasis on de-bottlenecking and incremental innovations; the right amount at the right time. They noted that by doing this, they are effectively increasing production capacity by about 1.5-2% per year without any new capital investments. They view this as vital to the firm's survival in the longer-run. These incremental innovations and efficiency enhancements, which cover chemicals, mixing and process improvements, are particularly important since new capital investments tend to be quite expensive. (They indicated that the incremental efficiency enhancements seem to save them 5-10% in terms of costs, but it is very hard to verify what exactly they mean by this.)

(h). Significant changes in management-labor relationships. After the 1990-91 downturn, it became clear they had to re-organize. Labor unions in Scandinavia are very strong and initially resisted management's approach to reduce labor component, increase capital-intensity and modernize. However, after a prolonged period of negotiations and impressing on the unions that modernization was vital to their survival, they succeeded in making the changes. From what I could infer, there were minimal/no layoffs, but future growth of the firm would come from growth of capital and technology and not additional labor. Today, they said, they have bottomed out on the labor saving aspect; i.e., in the near term, no further gains are possible in this dimension. To put it differently, capital-and-technological intensity appear to be at their peaks.

(i) In the area of incorporation of computers, there was dramatic evidence. Side by side, in one room they had an older pulp and paper mill that produced uncoated (relatively basic) paper. In the adjoining room, they had their newest machine which produced their flagship products - printing and specialty papers. Around the older machine, there was much greater labor activity - people trying to monitor and fix things - and less computerization. For the newer machine, almost everything - entry of wood chips into the system, pulping, mixing of chemicals, etc - was controlled via computer terminals and cameras. Each stage could be monitored closely via these terminals. Workers in charge of monitoring and adjusting the systems, had a lot of discretionary power to fix the problems. They argued that such decentralization in decision-making was necessary in order to avoid production slowdowns and stoppages. To make this system operational, they had to train their workers to operate and manage this system. They incur significant training costs; they boasted that they may well have the most trained and skilled labor force in the industry. Overall, computerization and technical change was obvious and the human-capital embodied in their workforce seemed high.

(j) In tune with the above, they have instituted better incentive mechanisms for labor. Workers are encouraged to report their ideas about improving productivity and lowering costs to management. They have an elaborate mechanism for determining the merit of these suggestions and appropriately rewarding the workers. These were designed to keep them a step-ahead of their competition and improve worker productivity and morale.

(k). Greater emphasis on in-house energy generation. They argued this was a significant cost-saving. The payback period for going in-house on energy was about 4-5 years and was a bargain in the longer-run.

3.1.(ii) Technology and Production Processes

They indicated that the machines and production processes used by various competitors were relatively common knowledge and it was unlikely to be the case that, on average, this was a major source of advantage across producers in the key countries; i.e., if producers in Sweden, Germany or Finland had access to a certain technology, producers in the US would have access to it as well.[7] If this is true, then one would typically not look at differences in core technologies and production processes to identify differences in efficiency levels and comparative advantage.

3.1.(iii) Environmental Issues

Scandinavia has tough environmental standards. And these high hurdles are getting even higher. In part, they saw some of the changes described above, like using fresher wood chips and less chemicals, as contributing to significant improvements in their environmental efficiency. Rather than fight the system, they decided to go to the other extreme and modernized their plants, restructured the supply chain and exceed the environmental standards. They argued that this has paid significant dividends in their production efficiency, relationship with local communities and federal and local environmental regulators. Portraying the right “environmental image” to the public and regulators was a very important part of their business strategy.

3.1.(iv) An key Theme from my Scandinavian Mill Trip

Incremental innovations and efficiency enhancements; the right amount at the right time! They were not searching for the big-bang technological improvements that would put them ahead of their competitors. But a lot of attention was paid to making the existing machinery and processes work better. How to tweak even small amounts of extra output from the existing machines was viewed as important. The Scandinavians argued that their US counterparts typically did not focus on this during the 1990s. They felt that the US efforts to catch up now may be a too little too late.[8]

The Scandinavians noted that producers in the industry typically have little pricing power. Further, gaining pricing power through product differentiation was difficult as imitating a competitor’s new paper products was generally not difficult. All of this implied that, to be profitable, one had to be

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[7] There are of course differences based on vintage of machinery as well as some differences in the chemicals and processes used in pulping, among others.

[8] In a related context, some of the issues highlighted in section 2.1(a)-(h) are noted in McNutt (2002, p.13) as challenges for the U.S. producers in an increasingly global marketplace for the pulp and paper industry. See, for example, the discussion related to employee training and development, workplace transformation, capital spending efficiencies, global supply chains, among others.

efficient and reduce costs. Hence the extreme focus on incremental innovations and efficiency enhancements.

3.2. A U.S. Mill Trip

I visited an U.S. paper mill in February, 2003. The main products produced by the company were copier paper, business forms, envelopes, writing materials, etc. The mill had two paper machines that make medium and light weight paper. One started early 1980's. The second in early 1990's. The total investment cost was over 1 billion.

At the planning stage, it was recognized that future environmental standards would become more stringent. This was built in during the construction phase and cost approximately 5% of the total investment. If they did not do it then, but had to modify the mills now, the costs would be substantially (3-4 times) higher. They indicated that modifying older mills to incorporate recent environmental standards can be very costly.

With regard to transportation: about 20% rail; 75% truck; 5% smaller vehicles (this is expected to increase to about 10%). They indicated that rail is very inefficient. Truck and other smaller vehicles can deliver on-time at short notice. This is important for establishing good buyer-seller relationships.

3.2.(i) Change in market conditions.

(a) The early-1990's downturn resulted in significant excess supply in the market. This resulted in suppliers looking for newer markets to sell and opened up global markets. Two issues that producers now need to focus on: (1) potentially look for buyers outside their traditional markets; (2) be aware of foreign producers attempting to enter local markets. To protect their local/ traditional markets, there is increased emphasis on buyer-seller relationships, price competition and quality control (high quality as well as consistency of quality across different orders). Since the mid-1990's, need for greater awareness of foreign suppliers who may enter the producer’s market.

(b) Less focus on inventory management (which was traditionally the case). More focus on process and supply management. Much greater emphasis on short-term demand-supply matching.

(c) Since mid-1990's, greater emphasis on innovation and de-bottlenecking to stay competitive and reduce costs. Given the relatively long-lasting and expensive nature of capital (paper mills), improvements in cost-efficiency have to come in the form of incremental innovations. In terms of R&D expenditures as traditionally defined, there is very little. Instead, a lot of it involves tweaking existing processes to extract greater output and increase efficiency. They indicated that close to one-thirds of their technical staff devote significant amounts of time on such incremental process innovations. Two quantitative measures:
(i) they indicated that 1-2% of revenues go towards incremental innovation activities;
(ii) in terms of gains in output of paper, these innovations have resulted in approximately 1.5-2% per year growth in production. This is significant. For example, starting from early 1980's to the current period, this would amount to about 40-50% increase in production with the same capital investment

made in early-80's (noted above).
(d) Their typical input (logs, chips) inventory holding is about 2-3 weeks. Mainly trucked in via independent contractors. They indicated some inflexibility due to the work-schedules of these contractors (who appear to work 4 days/week). They can store logs and chips in climate controlled (moist) conditions to minimize the effects of aging. (At least in terms of my discussions, the Scandinavians did not indicate they had climate controlled input storage.)

(e) Due to increased computerization, worker training and human-capital has increased. Cameras and other electronic devices monitor production processes which the workers can keep track from computer terminals. Workers have leeway in fixing problems as they occur. The particular U.S. mill I visited was non-unionized. Therefore, I could not get a direct comparison with the Scandinavian mill which was unionized. The company provides worker incentives. The focus is more on teamwork rather than individuals. If worker-teams suggest cost-saving innovations which are eventually adopted, workers receive some form of financial rewards.

4. Some Comparisons Between the Scandinavian and US Mill Trips.

(a) Both emphasized incremental innovations as key to survival. Remarkably, both said that gains in output due to incremental innovations, with a given mill, appear to be in the 1.5%-2% per year range. This number was very surprising to me given that it was coming from mills so far apart and in different market environments.

(b) Both emphasized that following the economic downturn of the 1990's, restructuring the supply-chain and process-management were essential to stay competitive. These included changes in, for example, log and chip inventory holdings, restructuring transportation contracts, greater emphasis on de-bottlenecking, offering workers incentives to be more productive and incorporating modernization via computers for better process-management.

(c) The U.S. mill seemed more focused on buyer-seller relationships. They seemed to argue that price was not often the key determinant. Right quality, consistency of quality, on-time delivery and individual attention were very important. I suspect the Scandinavians do this too, but they did not emphasize this as much; they argued that they had little pricing power and had to rely on quality and cost-efficiency to stay competitive.

(d) The Scandinavian mill was unionized and the US mill was not. The former laid enormous emphasis on union-management relationships and how this was critical to their change in fortunes in the 1990's.

(e) Two related issues:
(i) I could not get a proper sense of this, but it may be an issue as it came up briefly during my conversations. Is there any asymmetry between US v. European tax codes (or other things that the Govt may do) that allow Europeans to make modernization investments on a more consistent basis? If so, this would be important in maintaining and enhancing efficiency.
(ii) The US mills are more likely to be constrained by stock price considerations (Wall Street) when

making large investments of the sort required to update to newer mills. The Scandinavians did not seem to consider this as an issue. If so, this could potentially affect the long-run productivity and profitability of the industry.

(f) Based on the US and Scandinavian mills I visited, I really could not tell whether one or the other had an advantage. Both had relatively newer machines that were efficient at high production volume and met or exceeded environmental standards, the plant was clean, appeared to be efficiently managed, had a high level of computerization and had made significant organizational changes to meet changing market conditions.[9]

5. Quantifying Productivity.

As noted before, the mill trips are valuable in gathering broad information about business strategies, organizational structure, propensity to innovate, etc. However, to make this exercise meaningful, in the end we will need to quantify differences in productivity (or cost-efficiency). In the technology literature, researchers have used several alternate approaches to study differences in the levels of technology/innovations and the time-path of these. We list some alternatives below and indicate relevance for the paper industry.

5.1. Factor Productivity Measures.

Firms use some production technology (machines, mixing processes, etc) to convert inputs (e.g., wood chips, chemicals, energy) to output (paper). One way paper production can increase is by increasing usage of inputs. A second reason for paper production to increase would be improvements in productivity or better technology. Below we discuss several ways of measuring factor (or input) productivity.

5.1.(a) Total Factor Productivity (TFP).

Consider the difference between the growth of output and the input-share-weighted growth of inputs. The growth of paper production that is not accounted for by the growth of inputs, is broadly construed as emanating from technological (productivity) improvements. This is a direct measure in the sense that improvements in this index will reflect actual gains in productivity/efficiency. In the literature, this is referred to as the total factor productivity (**TFP**) growth. The technical details for constructing the TFP measures are given in Appendix B. To implement this procedure, we collected industry data on production of paper and use of broad inputs like materials and energy, and labor.

Figure 10 plots the data on the year-to-year TFP numbers: the basic measure TFP and the cyclical capital-utilization adjusted measure TFP-Adj. The two measures appear to relatively closely track

[9] Both noted that if some company had machines of older vintage, they would be more inefficient and incorporating newer environmental controls costly. This indicated that vintage effects were significant.

each other, however there are subtle differences in the exact numbers as we look at the peaks and troughs. A better way to take a look at this data is to construct a cumulative productivity index - **CTFP**. We let this index take a value of 1.00 in the starting year and then we augment the index based on the measured annual TFP growth number. We do this for both TFP and TFP-Adj giving us two cumulative indices: CTFP and CTFP-Adj. Figure 11 plots these data. The differences between the two series become more apparent. The adjusted CTFP-Adj measure shows an overall lower growth over time as well as a distinct flattening out over the 1980's before showing an upward trend in the 1990's. The unadjusted CTFP measure follows a similar profile, but the differences in the 1980's is quite sharp. Looking at the CTFP-Adj graph, one is inclined to say there was a distinct productivity slowdown in the paper mills industry over the 1980's.

At this level of aggregation, and in the absence of more refined data, it is hard to pinpoint a cause of the pattern of the CTFP-Adj series. I tentatively offer an hypothesis.

My mill trips revealed:
1. The industry is highly capital-intensive;
2. New paper machines cost a lot - the US mill trip revealed initial investment costs in the range of $500-$900 million; and
3. Investments in new paper machines are very lumpy and discrete - occurring rather infrequently. If one had data at the firm level, one would find very high investment when the firm is scrapping an old mill and purchasing a new one. After that, maybe for 2-3 decades, the firm will use the same mill and rely only on incremental innovations and modernization (e.g., computerization) to improve efficiency. This purchase of a new mill will, however, translate to better productivity (gains). If Figure 9 (new investment in equipment and machinery) is telling us the right story, the industry as a whole may have gone through a higher than normal purchases of new mills around 1965-66. This then translated to significantly improved productivity index (Figure 11) in the 1970's and early 1980's before the gains appear to flatten out. Figure 9 shows another spike in investment around 1988-91. Again, if the data are revealing the correct picture, this should translate to further gains in productivity with a delay of a few years. Could the upward drift of the CTFP-Adj series starting around 1991-92 reflect the gains from these new investments?

A useful extension of this line of thinking could be to check industry trade publications to see if one can obtain news about scrapping of older mills and purchase of newer mills. Such updating will, of course, happen on a more continuous basis as some company or the other updates to newer mills. But for the industry as a whole to show significant upward productivity movement, we must have greater than normal frequency of updating. This is certainly a line of thinking that I would like to pursue as I gather more information and provide an revised version of the white paper after my mill trip to Germany and maybe another US mill trip later this summer.

<u>Data *versus* Mill Trip?</u> Both the Scandinavian mill and the US mill said that they get productivity gains - roughly, in output holding constant the base capital investment and some other modernization expenditures - of 1.5%-2% per year. Can we come close to this using our TFP computations? For the base TFP measure, the computed average growth over the late-1950's to mid-1990's period was 1.8%. For the corrected cyclical capital-utilization adjusted measure TFP-Adj the average growth

was 1.1%. While not directly comparable, these numbers look quite close to what I seemed to have unearthed from my mill trips. One needs to keep in mind that both the mills I visited had rather new machines and this would lead to higher productivity numbers. For industry as a whole, with firms having different vintages of capital, one would expect lower average productivity growth numbers. I am not sure exactly what to make of my comparison above, but it looks intriguing and worth further investigation.

In principle, gains in productivity from better machines, among other factors, should translate to increased profitability. Figure 18 shows that profitability generally improved from 1970-71 to 1988. But since then it shows a steady negative trend. While this is unsettling, one would need to look at more recent data to see if this trend is reversed. If not, then one would need to closely examine other determinants like foreign competition, input costs and global demand to see if these are imposing greater downward pressure on prices.

5.1.(b). Single-Factor Productivity.

Here one can evaluate, for example, the quantity of paper that can be produced per: (a) labor hour; (b) unit of materials used; and (c) unit of energy used. Labor productivity has been used extensively in the literature. Given that paper mills are highly capital-intensive and the human-capital in this industry is likely to be relatively high due to the need to monitor and operate expensive and sophisticated machinery, we consider the following labor productivity measure: [total output/total production worker hours worked]; this gives us output of paper per production-worker hour worked. The output data are the nominal dollars deflated by the industry-specific output price deflator. Figure 12 plots these data and Figure 15 below displays the annual rate of growth of labor productivity. Figure 15 shows that aside from a few years, the labor productivity growth is positive. This is reflected in Figure 12 which shows a fairly steady rise in labor productivity. The increase over our sample period is quite dramatic.

The two other measures we look at relate to a "composite" of materials and energy (Figures 13 and 16), and only energy (Figures 14 and 17). The materials and energy composite data in Figure 13 shows an initial period of stagnation and marginal decline, followed by a significant positive trend starting around 1971 with some year-to-year fluctuations. The initial decline and stagnation up to about 1970 is quite evident in Figure 16 showing negligible or negative growth rates. The energy productivity measure shows a sharp decline till about 1970, a general upward trend from about 1971-1987 and a sharp drop thereafter. The pattern for energy is somewhat puzzling and does not appear to conform to a systematic interpretation (such as energy prices, business cycle fluctuations, etc) over time.

What inferences can we make for materials-only productivity?[10] First, looking at the period till 1970, the decline in energy productivity (Fig.14) is much greater than the materials and energy

[10] Unfortunately, the dataset does not contain a materials-only price deflator. We have either an energy-only price deflator or a composite materials and energy deflator. Hence the need to make indirect inference.

composite (Fig.13). This implies that materials-only productivity very likely increased during this period. Second, focusing on the period 1987 onward, energy productivity seems to decline, but the materials and energy composite productivity generally increases. The inference we can reach is that the materials-only productivity continued to increase through the late-1980's and early 1990's. Overall, it seems that the materials-only productivity shows a clear upward trend over our sample period. One way to think about this is to say that the amount of paper produced per unit of wood showed steady upward trend over our sample period.

To summarize, labor and materials-only productivity appear to have increased steadily over our sample period. This conforms to our priors. But energy productivity shows mixed trends. I don't have data on this, but it would be interesting to see the engineering specifications of the newer paper machines versus the older one's in terms of their energy requirements as well as the impact of any environmental regulations.

5.2. Other Measures.

5.2.(a). Assessment of Actual Technologies in Use.

Researchers, based on mill trips, questionnaire surveys sent to key industry personnel, among other methods, could evaluate technologies in use and how they have changed over time. This would not only apply to the main capital investment, but also ongoing modernization and other process improvements. I was not able to make much head-way in this dimension.

5.2.(b) Innovation Counts. (E.g., Audretsch, 1995.)

This approach counts the innovations that were commercially introduced. This gives a more direct picture of incorporation of newer technologies. Further, the source, Industrial Arts and Sciences, provides information on new and emerging technologies in myriad production processes, and are grouped by product type. One could examine this source over the last 10-20 years and itemize the new technologies in the paper industry.

5.2.(c). Emerging Technologies.

In the context of the paper and pulp industry, the technologies related to, for example, "black liquor gasification", "impulse drying" and "condensing belt drying" can be treated as relatively new and emerging technologies. Adoption of these, among other processes, would signal efficiency gains. (See http://europa.eu.int/comm/energy_transport/atlas/htmlu/ppintro.html for a description for some of these processes.)

5.2.(d). New Capital Investments.

Typically, new investments will embed newer, more efficient, technologies. In the context of paper machines, these could translate to greater tonnage per day and higher speeds Here the rate of new capital investments could serve as a proxy for efficiency gains. From my Scandinavian mill trip, and the observations related to their older versus newer machines, it was abundantly clear how much more efficient the new machine was. As we noted above, new paper machines are very expensive and last long. Between new purchase and scrapping, there are a lot of incremental investments. These could take the form of modernization (incorporating more computers), environmental related to meet more stringent standards, better coating machines, supercalendering machines, etc. Unfortunately, I was not able to get a clear sense of the significance and magnitude of these secondary investments which are important for continued productivity growth.

5.2.(e) R&D and Patents. (E.g., Cohen and Levin, 1989; Griliches, 1984.)

A traditional approach has been to look at R&D expenditures and patent counts across different producers/countries. The underlying intuition being that greater R&D and patents imply eventual incorporation of newer more efficient technologies. However, anecdotal evidence seems to indicate that R&D and patents are not the major sources of differences across producers in this industry and across the key countries. A cursory look at the US data on R&D in this industry revealed that the intensity was much less than 1%.

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Appendix A: Role of Incremental Innovations

The literature on technology has extensively analyzed the role of both major and incremental innovations. Major innovations play a role in birth of products and dramatic changes in the competitive landscape. Such changes are however very infrequent. Incremental innovations are more frequent. Regarding incremental innovations, learning-by-doing and ongoing improvements, Gort and Klepper (1982, p.634) state that such innovations not only reinforce the barriers to entry but, in addition, compresses the profit margins of the less efficient producers who are unable to imitate the leaders. Eventually, the exit rates rise as the less efficient firms are forced out of the market.

Several papers build on the above theme and provide additional insights; e.g., Klepper and Graddy (1990), Jovanovic and MacDonald (1994) 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 R&D opportunities to lower unit production cost and innovators enjoy greater profit margins than imitators due to their R&D activities. These improvements in production efficiency result in downward pressure on prices. The next step in these models can be thought of an exit from the industry or a process of mergers and acquisitions; the probability of exit is lower for successful innovators. Overall, these theories provide an understanding of changes in profitability and market shares among incumbent producers.

Regarding the pulp and paper industry, anecdotal evidence appears to indicate that there have been relatively little technological change in the U.S. industry over the last decade or two. Whatever change has occurred has primarily been driven by environmental regulation. In the context of bleaching technologies, see Norberg-Bohm and Rossi (1998) for a discussion of how the industry has responded to this challenge. They note (p.237-38) that, due to the nature of EPA's balancing of costs and benefits in regulatory decision making and other factors, most of the technological advances have been relatively incremental and radical transformation is rare. The paper and pulp industry employs myriad technologies ranging from those embedded in physical plant and equipment to those in different pulping processes. The technical life of paper machines, for example, appears to be in the 20-25 year range and investment costs are extremely high making it somewhat difficult to rapidly induct new technologies. In view of this, it may be particularly important to evaluate the role of incremental innovations which lead to gains in cost-efficiency and profitability.[11]

[11] For the first half of the 1990's, Bjorkman, Paun and Jacobs Young (1997, p.80), for example, note that most investments by U.S. and Canadian firms were typically not for new production capacity, but on incremental increases in production efficiency. Much of these investments in turn are for environmental improvements.

Appendix B: Measuring Total Factor Productivity (TFP)

Consider four general factors of production: capital stock, K; labor hours H; materials, M; and energy, E. (In our context, materials can be further disaggregated into wood pulp, chemicals, etc. Labor can be decomposed into relatively skilled versus unskilled labor. How one implements this depends on data availability.) The basic TFP measure is given by:

$$TFP_t = [\Delta q_t - (\gamma_{kt}\Delta k_t + \gamma_{ht}\Delta h_t + \gamma_{mt}\Delta m_t + \gamma_{et}\Delta e_t)] \qquad (1),$$

where q, k, h, m and e are **logarithms** of output and the four inputs, Δ denotes change, and γ the input share. Thus TFP is the difference between growth of output (q) and the input-share-weighted growth of various inputs. Measurement issues are important. While use of various materials inputs and energy is relatively straightforward, measuring capital poses some complications. For example, the Scandinavian producer talked about the adverse effects of low demand during the 1990-91 recession. Here, the firm still had the same number of machines, but they were being utilized at the much lower rate than during normal times. Thus, the total number of machines may remain the same, but their utilization could vary significantly over high and low states of demand.

The variable utilization of capital has received much attention in the literature as this imparts a strong procyclical bias to TFP (see Burnside et al., 1995; Burnside, 1996; Basu, 1996). Various strategies have been adopted to correct TFP of its cyclical input utilization bias: Burnside et al. (1995) use electricity consumption to proxy utilization of capital and obtain a corrected TFP residual; Burnside (1996) uses total energy consumption; and Basu (1996) uses materials inputs; in our context, consumption of wood, for example, could serve as a proxy for the utilization of capital. The basic intuition is that these inputs (materials and energy) do not have a cyclical utilization component like capital and, therefore, are good proxies for the utilization of capital; i.e., assuming capital stock is constant, if the utilization of capital increases, then materials (wood, chemicals, etc) and energy usage will typically increase. Correcting for this gives us a better measure of TFP. There are several ways to obtain an adjusted measure. Below we detail one.

Very briefly, suppose that capital-utilization is proportional to energy (E) consumption. The adjusted TFP measure is given by TFP-Adj:

$$TFP\text{-}Adj_t = [\Delta q_t - (\gamma_{kt}\Delta e_t + \gamma_{ht}\Delta h_t + \gamma_{mt}\Delta m_t + \gamma_{et}\Delta e_t)] \qquad (2).$$

As compared to TFP, in TFP-Adj we replace Δk_t by Δe_t. (Alternately, we could assume that the paper mill's capacity utilization is proportional to wood consumption and replace Δk_t by Δw_t, where w is the logarithm of pulp usage.) The way this measurement is set up, any gains in cost-efficiency will be reflected in higher productivity growth. Once we obtain a TFP-Adj type measure for the US paper industry and their foreign counterpart(s), we would be able to compare the productivity growth over time.[12]

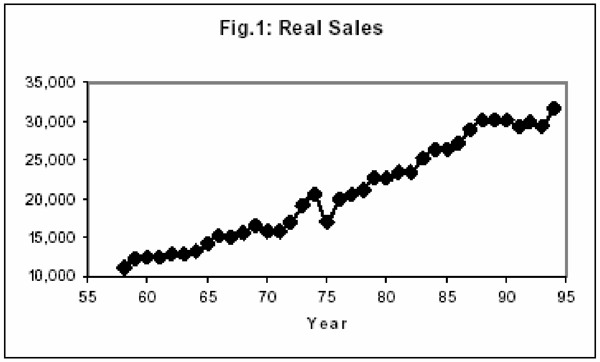
[12] Ghosal (2002.b) presents additional details about measuring TFP using industry data.

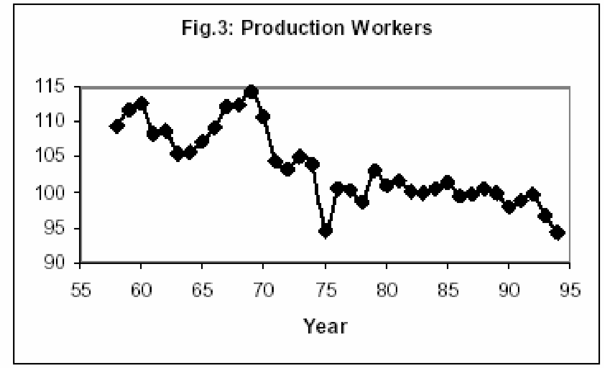
Data for Estimating U.S. Productivity Growth

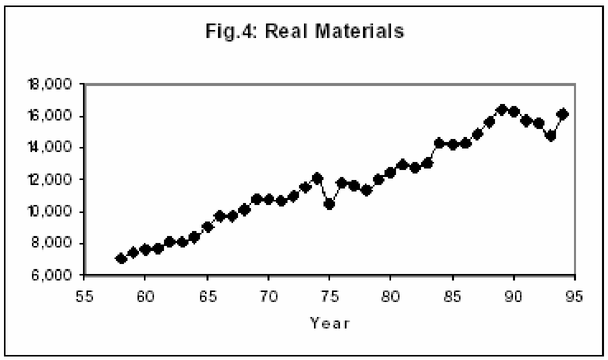
I explored some data sources. For example, for paper mills we have access to the following data:
(i) Production;
(ii) Energy usage and price index;
(iii) Labor hours, wages and number of employees;
(iv) Materials usage and price index;
(v) New capital expenditures on plant and equipment, and total value of fixed assets;
(vi) Environmental expenditures;
(vii) R&D expenditures;
(viii) Several other variables.
The data are typically at an annual frequency and available at least over the last several decades. Given the construction of the measure described in (2), the above data are sufficient to measure TFP-Adj. Where more disaggregated (e.g., firm-level and/or product-line data exists), we can construct more refined measures. In short, examining broad movements in productivity/efficiency for the U.S. industry is quite feasible and can inform us of how the (productivity) fortunes of the U.S. producers have changed over the last couple of decades.

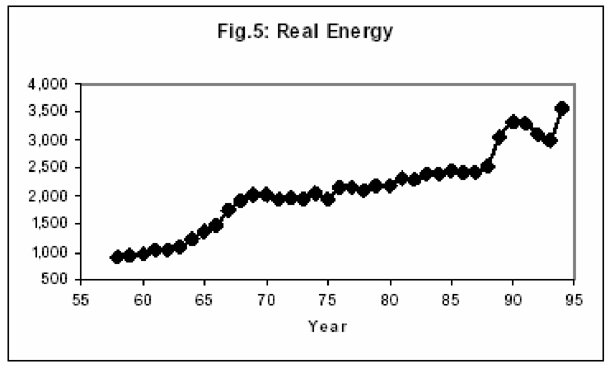
Data for Estimating Foreign Productivity Growth

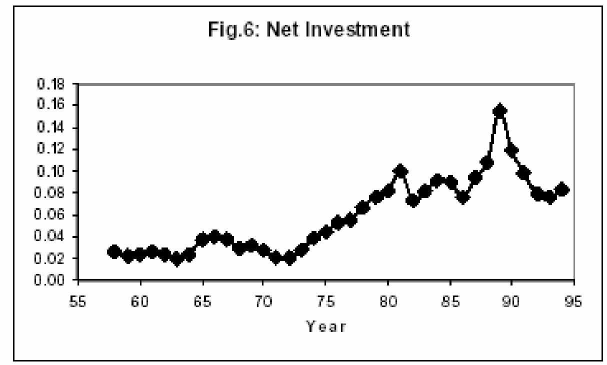
For this exercise to be complete, we will require similar data for foreign industry/producers. Typically, like the U.S. data, we will need data on the Scandinavian countries. Unfortunately, these data were not easily available.

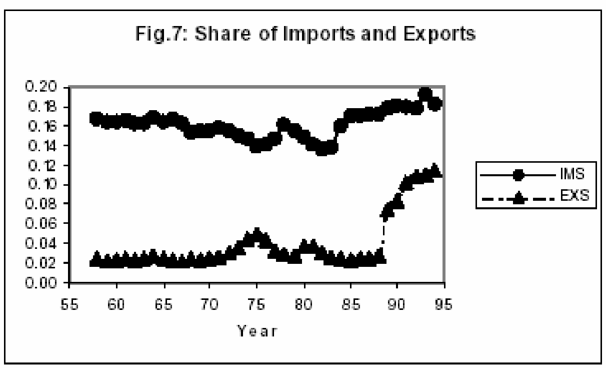












Notes for Figures 1-7: All data are industry-specific for SIC 2621 (paper mills).
Figure 1: Total shipments (or sales) deflated by the industry-specific shipments price deflator.
Figure 2: Total employment.
Figure 3: Total number of production workers.
Figure 4: Total materials consumed deflated by industry-specific materials price deflator.
Figure 5: Total energy consumed deflated by industry-specific energy price deflator.
Figure 6: The ratio of current year total investment divided by beginning-of-year total capital stock.
Figure 7: Import-share (IMS) equals (imports)/(imports+domestic shipments).
Export-share (EXS) is measured as (exports/domestic shipments).

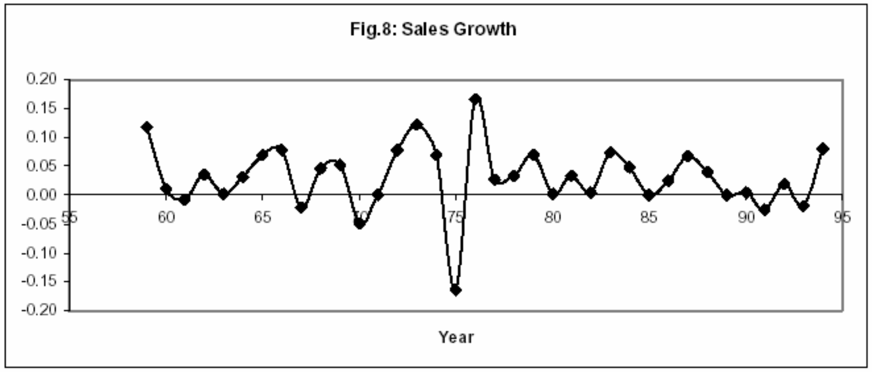


Fig.8: Sales Growth

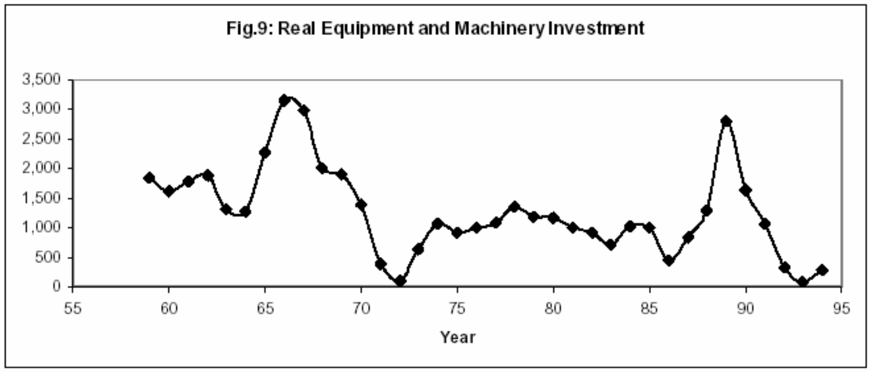


Fig.9: Real Equipment and Machinery Investment

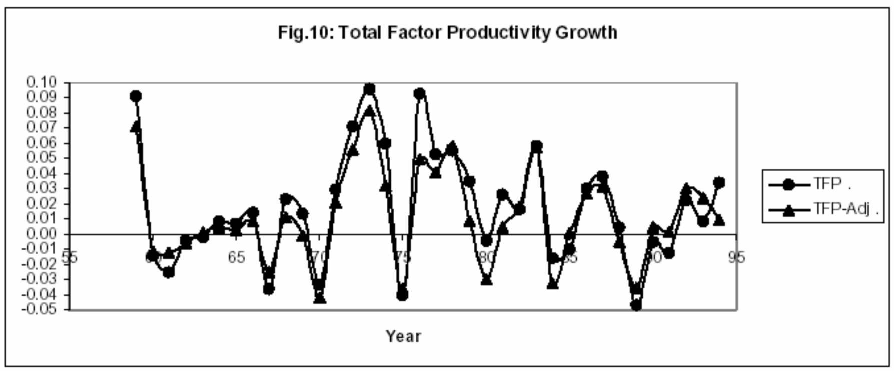


Fig.10: Total Factor Productivity Growth

Notes for Figures 8-10: All data are industry-specific for SIC 2621 (paper mills).
Figure 8: Annual growth rate of real industry shipments (or sales).
Figure 9: Total equipment and machinery investment deflated by industry-specific investment price deflator.
Figure 10: Total factor productivity (TFP) growth; growth of output minus share-weighted growth of inputs. TFP-Adj is a measure with cyclical capital utilization correction.
Some Correlations: (a) TFP Growth*Sales Growth = 0.78; (b) TFP Growth*Equipment Investment = -0.40; (c) Sales Growth*Equipment Investment = -0.02.

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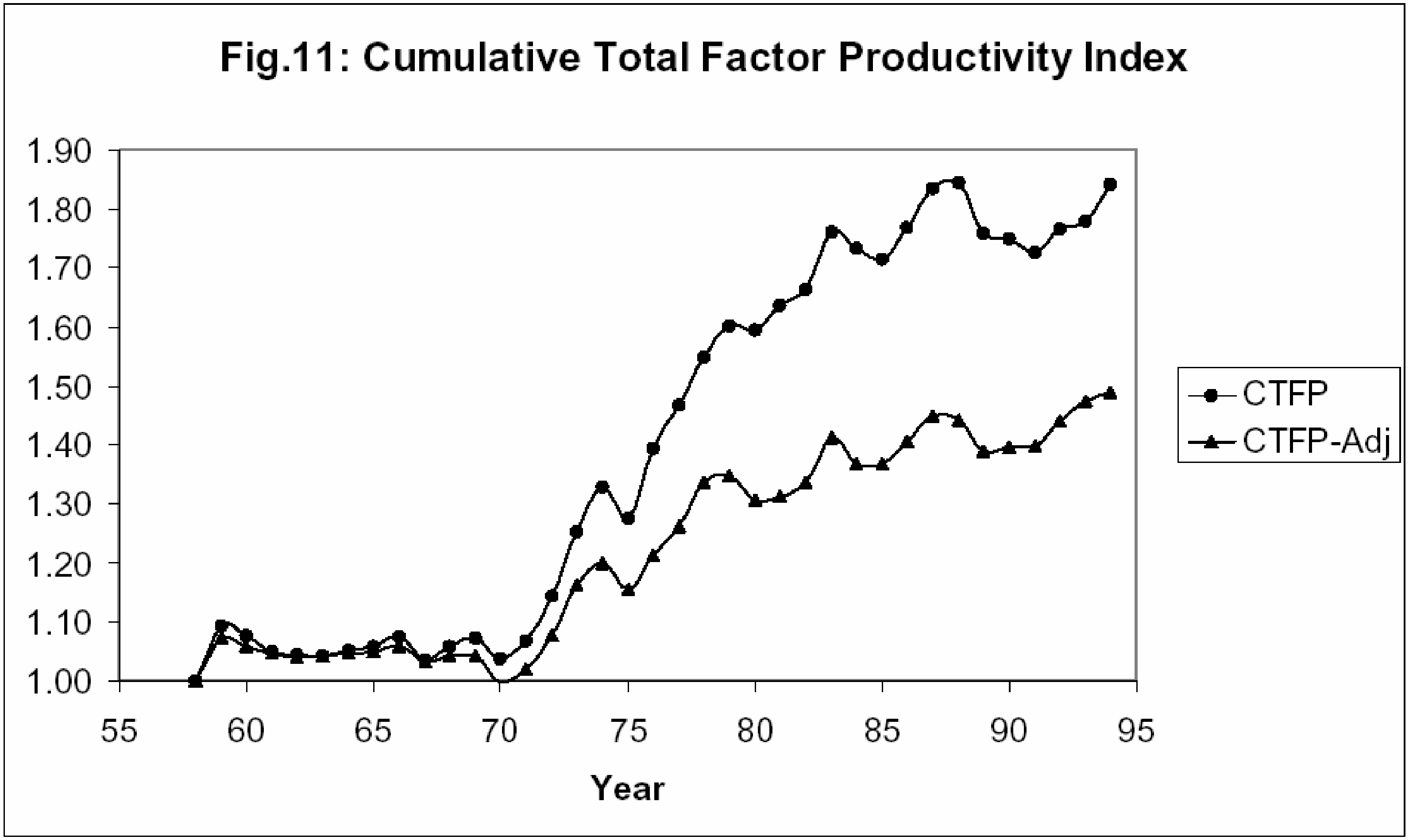
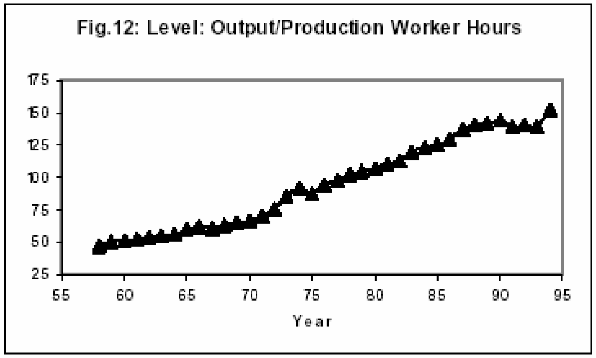
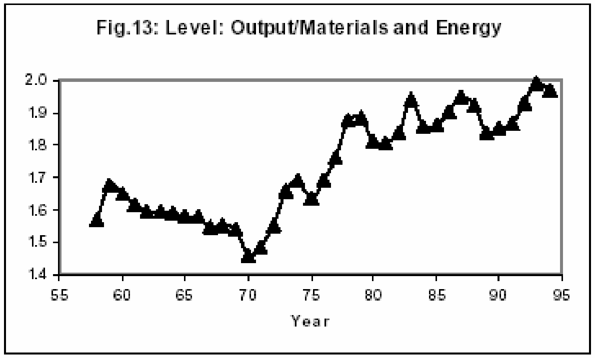
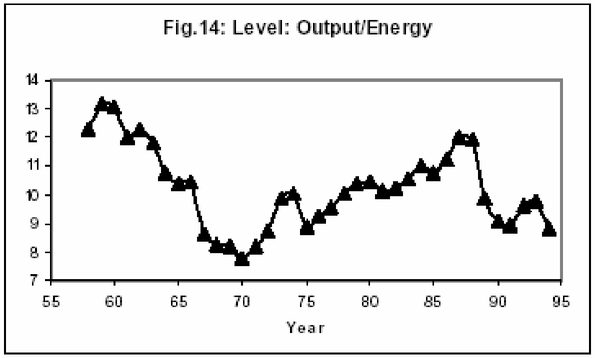
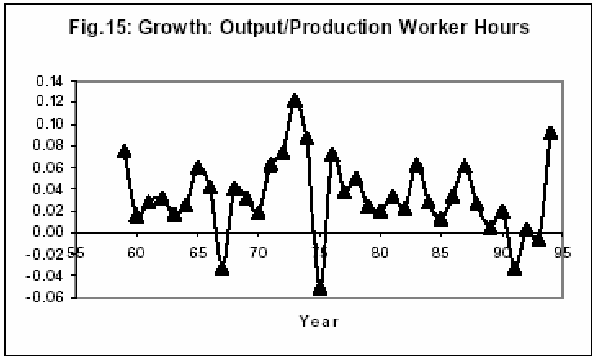


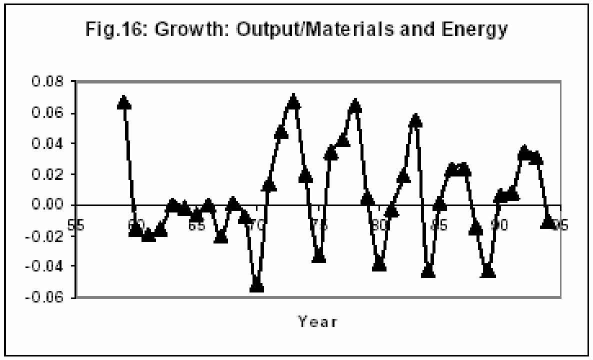
Notes: 'CTFP' is the index without cyclical capital-utilization correction and 'CTFP-Adj' with the correction. A paper mill represents a large discrete investment and the machines are long-lived. Given this, the utilization of the mill will vary considerably over business cycles. Hence it is meaningful to adjust the basic TFP measure for this cyclical utilization to get a clearer picture.

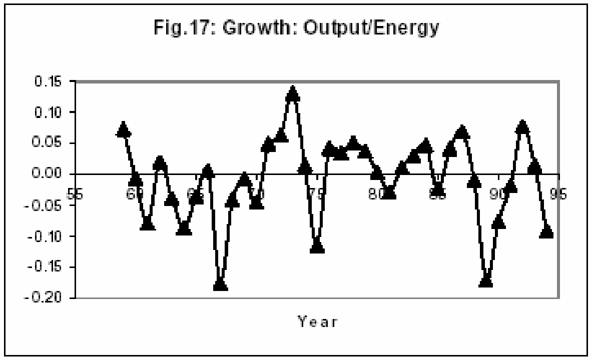




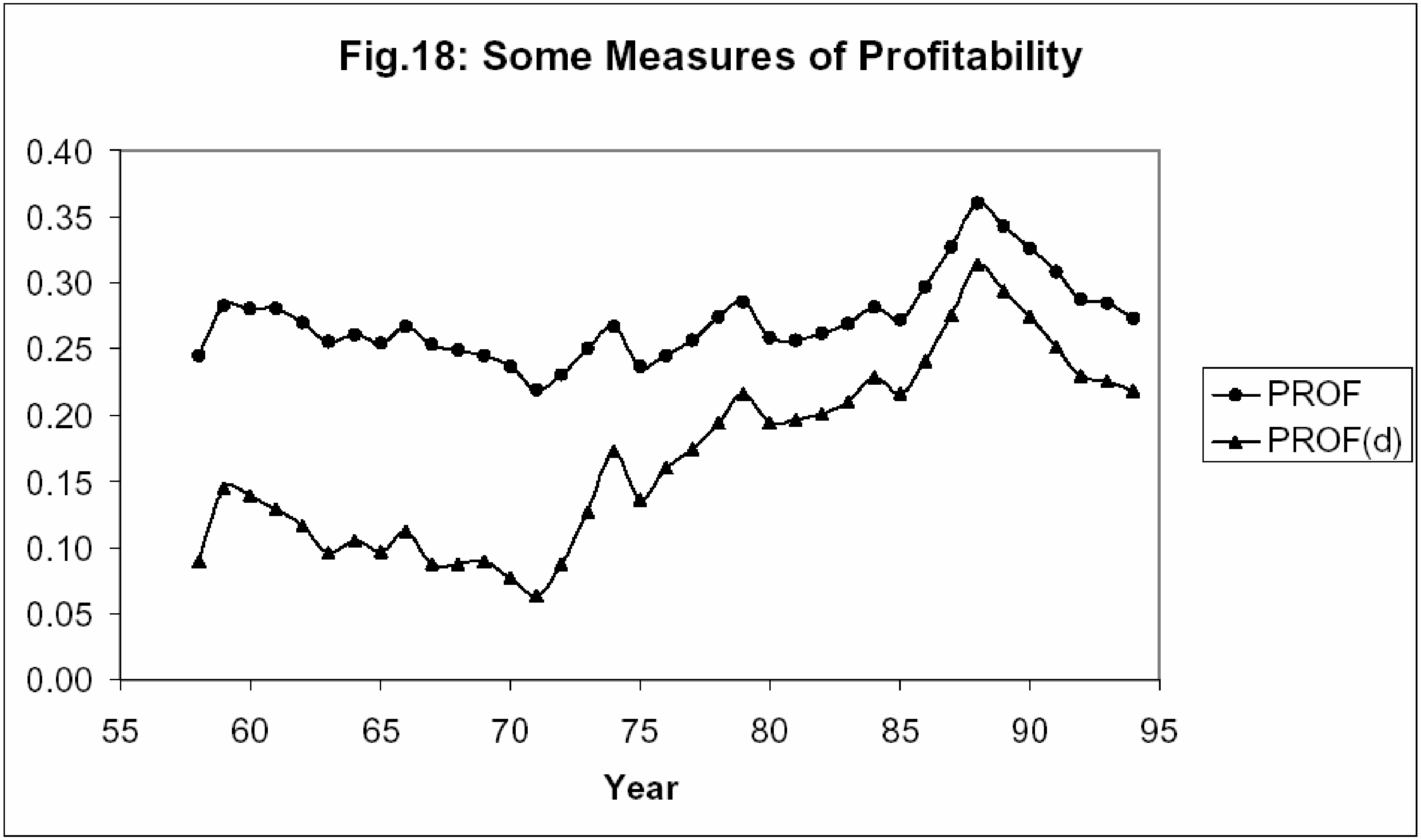








<u>Notes:</u>
Figures 12-14: The level of real output per (i) production worker hour, (ii) unit of materials and energy, and (iii) unit of energy.
Figures 15-17: The growth of the above productivity levels.



Notes: The two measures are as follows.
PROF=(Total Revenue - Total Materials and Energy Cost - Payroll)/(Total Revenue). This can be interpreted as short-run profits per unit of sales.
For PROF(d) we subtract depreciation expenses from the numerator. Using the SIC 4-digit Census data, the average industry-wide depreciation expenditures appear to be about 5.14% of the gross book value of the capital stock.