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TEACHING THE POTENTIAL IMPACTS OF TECHNOLOGY GROWTH ON REQUIRED RATES OF RETURN

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ABSTRACT

As professors of economics and finance, we often teach that technology enhances profits, which is well and good, and probably true from a macroeconomic point of view. However, recent market experiences with respect to the technology sector show that the process of technological innovation is often messy, and subject to devastatingly high levels of risk at the firm level. It is the intent of this paper to provide financial educators with some tools to incorporate the assessment, and pricing of technology risk in the undergraduate and graduate curriculum.

I. BACKGROUND ON TECHNOLOGY GROWTH AND LITERATURE REVIEW

The richest literature on technology growth is in macroeconomics. While the evaluation of technology growth on the macro environment is important, the literature are not entirely connected to the issue of this paper, which is evaluation of risk at the firm level. It is sufficient to summarize that technology innovation is one of the important drivers of real growth rates in output, which can generally be decomposed into a few categories, namely:

Principle Drivers of Real Growth

1. Growth in the labor force
2. Growth in the capital stock per worker
3. Growth in technology
4. Growth in other efficiency inducing practices
5. Growth in other inputs.

Since real growth rates in GDP range between 2% and 3% per year, the labor force is growing a less than 1% per year, and net capital per worker (new investment
minus depreciation) is flat, it is clear that technology improvements, while significant, generate a net effect on real output of less than 2% per year. The reason for this is the notion of “creative destruction” described long ago by Joseph Schumpeter (1950; 1951).

While the literature regarding the macroeconomic growth process is rich and developing, there is little written that links the conclusions of these recent model developments to the financial markets, and to individual firms operating within an industry. An author who has attempted to make this link, from a Schumpeterian growth point of view is Philippe Aghion, who has written several articles with a number of other co-authors. Of particular interest is the paper by Aghion, Harris and Vickers (1997) wherein the authors model the implications of innovation-driven growth that can occur via the standard leapfrog assumption, which is, that competitor firms will continuously drive one another, switching places as the leader. Alternatively, there are also step-by-step, and neck-and-neck processes defined. Step-by-step processes occur when one (or presumably more) of the players choose a laggard/follower strategy. Neck-and-neck processes occur when technological knowledge is widely shared, firms watch each other carefully, and vigorously compete for market share. In this article, the authors conclude that competitors are more active in their efforts to innovate and gain advantage when the competitors are roughly equal (neck-and-neck) technologically. Approximate neck-and-neck competition can occur at times within the step-by-step and leapfrog processes at times but are more frequent in the step-by-step process as opposed to leapfrogging. Supposedly, this is due to the fact that adoption costs of existing technology that brings laggards close to the leader are declining over time. This paper creates a pedagogical model that allows for the possibility that lagging the technology leader can be purposeful, with consequences that are not severe at all, and at times may be beneficial.

An important line of thought one can derive from the above literature, that needs to be developed in finance, is that increasing the rate of competitive positioning via technology enhancements increases the variance of the distribution of net-income performance within the industry to the extent that the adoption costs remain roughly constant. This situation raises the perceived risk and required rate of return for that industry. Where adoption costs are falling faster than the rate of innovation is rising, technology risks could actually fall. Where adoption costs are falling at the same rate which innovation is rising, technology risks remain constant. The implication of this

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a See “National Economic Trends” Federal Reserve Bank of St. Louis.
conclusion is that firms can adopt/innovate new technologies at a rate that can be to their own detriment, as the cost of capital rises due to such activity faster than the returns on the investment. If returns on technology growth are rising as fast, or faster than the cost of capital, then profits can be preserved, but such is often not the case.

In 1992, Woody and Pourian pointed out that the risk associated with projects creating non-traditional projects requiring high levels of basic research will, by definition, require the use of untested technologies. Projects operating in this context will increase the rate of return required by lenders. Another important paper that nicely summarizes the process of growth through technology (and is also very approachable) is one by Richard Jenner (1998). In this paper, the author divides the technological growth into about four stages:

**Four Stages of Technological Growth**

1. Creation of a technological idea;
2. Combination of the new idea with other existing assets into a new possibility;
3. Search for and consolidation into a dominant design for that possibility (eg, vhs versus beta);
4. Seeking the lowest cost production methods.

At each step, the driving force that moves the process to the next step is the desire to maximize wealth. Also, at each step, there is uncertainty and considerable search cost incurred; and often times, money lost. The search process in steps two through four can look at times like throwing a pot roast into a tank of sharks, which creates a lot of activity, some of which is productive, and most of which is just froth. Financially, there is an increase in risk if the number of technological shocks increases per unit of time. Once again, the impact of technical innovation may actually increase the variance of net-income performance over time per dollar of investment, as well as increasing the variance of net income performance within an industry at any given point in time.

The process of growth described above is an ideal form of creative destruction. Often times, we teach about the “creative” benefits of technology driven growth, which are certainly many. However, there are also a fair amount of “destruction” effects that we often overlook, or do not understand.
Whether the outcome of a technology growth process is one of sustained net benefits, or net disruption, it has been the historical practice of investment bankers to view these processes as disruptive in order to hedge their risks. Thus, these bankers will subject all future expected returns to a higher discount rate to account for the perceived increase in risk. In an article written by Rea, just prior to the bursting of the tech stock bubble (2000), the author was arguing that old ways of evaluating a “new economy” investment were overly punitive and should be modified. Looking back, we clearly observe that there really is no “new economy” that is created by a technology innovation, and that in the end, technologies bring with them risks that are probably underestimated rather than overestimated.

One of the better treatments of technology risk comes from the insurance and technology literature. An excellent case that also provides a framework for analysis is by Hartmann and Lakatos (1998). In this article the authors show how the imposition of new technology projects has many disruptive spillover effects on other projects within the firm at least in the short run. One imagines that in the presence of higher rates of technology growth, that the ratio of new projects to old projects will rise, and that the rate of disruption will increase. Maia L. Hughes also succinctly stated technology risks her 1997 article. Her statements included the idea that technology risks are “potentially catastrophic... (and that) such exposures are often underestimated.” She noted that technology risks include at least the following:

**Categories of Technology Risk**

1. Business Risk (Loss of competitive capability, reputation, etc)
2. Infrastructure Risk (Hazards to existing systems, networks, etc.)
3. Project Risk (Risk due to unsuccessful project implementation)
4. Staffing Risk (Inability to attract, train and retain specific personnel)
5. Security Risk. (The extent to which technology projects expose proprietary information unintentionally)

These risks overlap, and, may in fact be overshadowed in the long run by realized gains, but these risks do tend to expose more traditional firms to additional risk, and thus would increase the required rate of return.

In a brief note, Salierno (2001) reveals some interesting data from a recent survey of 1,350 risk managers at companies with annual revenues in excess of $250 million. About half of those surveyed stated that they had only “fair-to-poor” understanding of how technology risks impact their companies. In an additional
survey in 2001, only 52 percent of American corporations have formally assessed and quantified technology exposures at their organizations. These findings clearly point out that we, as finance educators need to do a better job in this arena.

One of the primary drivers of technology growth has been the creation of the semi-conductor. An explosion of innovation has occurred in nearly every industry due to the invention of these devices. Early in the innovation process, Gordon Moore (1965) evaluated the rate at which the efficiency of these types of switches was advancing, and his conclusions continue to hold true today. Moore’s law goes something like this: The number of switches per square inch of silicon chip doubles every 18 months, which doubles processor speeds every two years. The impact of this law on business is far from simple, however. However, if we assume that Moore’s Law were true for all technologies, then technology growth rates would be around 36 percent annually, using the rule of 72. This implies that actual adoptable and adopted technology growth rates are far less than the growth in processor speeds. This is likely due to the fact that it takes time to integrate new technologies into existing production paradigms, and, that as new technologies are developed, old ways are simultaneously destroyed, thus creating a net effect that is far less than the maximum growth in productive capacity due to technology enhancements.

The review presented above lists several shades of technology risk. Integration of these concepts will mutually lead to higher risks for firms and industries. Observed deviations in industry performance will rise to the extent that individual firms do not adopt technologies in the same timing patterns. These considerations beg the question whether some of the increases of the real rate of return in the capital markets over the last 40 years are at least in part due to technology growth. The notion that technology innovation can create a shock that disrupts the status quo, and often sets off a frenzy of new activity, has profound implications on the required rates of return in the market. This is especially true if technology growth is pervasive, while recognition and adoption rates for those technologies both between and within industries are asymmetric. These asymmetries could lead to increasing the variance of net-income performance both between and within particular industry sectors and increasing variances of returns that will be priced by the market. Therefore, technology growth may be too weakly discounted, and may be responsible for the run-up in real rates of return in the capital markets. Following that statement, the pedagogical importance of this issue is that technology risks should be included more explicitly as one of the many risks we typically discuss in our finance courses. The potential disruptive effect of adding new technologies must be addressed and accounted for.
II. REVIEW OF PEDAGOGICAL MATERIALS/METHODS

Three authors, or groups of authors, dominate the corporate finance textbook market. These include Brealey, Myers; Ross, Westerfield and Jordan; and Brigham. If one reviews these texts (with various combinations of other co-authors) it is clear that there is no specific discussion on how to analyze the disruptive and risk-increasing effects of technology adoption. While each has sections on risk management, project analysis, CAPM, and include the idea of erosion, there is no example regarding how increasing technology adoption rates increases risk, in spite of recent market experiences.

Certainly, the tools for the evaluation of technology risk exist within finance, and we apply those tools in various ways already. Only slight modifications to existing methods are necessary to begin the process of enhancing knowledge regarding technology risk. One way is to use traditional break-even analysis, where the break-even level rises when increasing fixed cost and somewhat reducing variable cost. One of those fixed costs could be related to technology acquisition. This method demonstrates an increase in risk and therefore translates into a higher required rate of return.

More complex modeling, using advanced financial education methods such as Monte Carlo analysis, can be completed in estimating the co-varying shocks on existing projects within the firm, which may lead to increases in the overall variance of rates of return. The increases in co-varying risk can be due to negative spillovers that accompany the sometimes-chaotic impact of rapid change, and the sometimes-unforeseen cascading effects. Other applications along these lines include adding new projects with higher betas to the existing portfolio of assets, while increasing the betas of other existing assets due to the possible cost and revenue disruptions for those existing assets. Most often, projects involving new technology should always have higher than average betas within a firm, because by definition, the impacts of new technologies on an organization for the first time have uncertain effects, which should increase the variance that is modeled. Pure-play analysis will not often provide much insight as to the relative risk of a new technology project due to the fact that such projects rarely exist in isolation, allowing for independent pricing by the market.

III. SUGGESTED INSTRUCTIONAL IMPROVEMENTS

The most important conclusion finance educators should come to, given recent market experience and the technical difficulties within firms that go largely unseen by
the external public, is that technology growth implies risks that can be harmful to the firm. Because technology is increasingly important to firms as they attempt to remain competitive, a new category of costs along with a rubric for defining them should be created. I propose that these be called “disruption costs.” Disruption costs should be well thought out, estimated, and included in every cash flow model dealing with any technology acquisition. Disruption costs are not necessarily the same thing as erosion. Erosion implies that creating a new product line will reduce sales in existing lines. Disruption costs occur in existing firms because new technologies are adopted, which require the replacement of capital, retraining of people, re-design of organizations, etc. These costs are only rarely foreseen in their entirety. Surprises often occur, because we seem to not understand that technology growth, as “cool” as it is, imposes cost. One could suppose that rapid technology growth captures the imagination and hypnotizes its victims with dreams of “Star Wars” while it subtly picks the pocket. In the end, technology growth generally improves the bottom line (as we observe from the macroeconomic data), but hardly ever as much as is hoped for, or promised by the engineers and Information Technology staff.

Additional approaches should be developed that can illustrate the impact of technology growth on financial risk at the firm level. One that I often use is something I call “Context Shift/Risk Analysis.” This type of analysis is graphical and intuitively appealing. It involves the notion that every choice made to adopt some new process, product, or technology implies the creation of a new context, or future reality. As a result, some current options are lost due to irreversibility associated with that choice, while other options previously unattainable, are now possible.

A typical chalkboard discussion would be as follows:

1. Connect the idea that technology innovation creates increased risks for individual projects, and increases the overall risks of the firm, which is a portfolio of project assets. This can be done using typical project beta analysis, or one could develop a correlation matrix with other projects. I often use the Coefficient of Variation (CV) applied at project level. I like the CV rather than a project beta for introductory classes because I believe it is more intuitively appealing as it combines the risk-return tradeoff into a single measure for comparison purposes. I demonstrate that new project CV’s are often high, and that technology project risks often spillover into the CV’s for existing projects, causing the standard deviation of returns for the overall firm to rise.

2. I explain that the costs of pursuing a new project should include the
possibility of disruption costs due to the destruction of old methods/technologies, etc. These changes require transaction costs to retrain people, dispose of old equipment/processes, and possibly be forced to replace other interrelated systems/processes that end up being incompatible with the new technology. These possible incompatibilities, along with any increases in fixed costs, increase the overall costs of the firm.

3. Develop the concept of a firm as an adaptive or innovating agent moving through time. Explain that old projects are phased out as new ones are created, and that multiple options exist at each decision point, both with respect to timing, and alternative projects. Opportunity costs exist for each set of choices. Drive home the point that good strategic managers evaluate the consequences of the choices that drive this process in order to maximize shareholder wealth in the long run. Connect this idea to the notion of net present value of the firm.

4. In this discussion it is important to point out that the NPV of lost opportunities is related to a condition called irreversibility; that is, some opportunities are lost permanently by moving to a new technology/production context. If there is no irreversibility, then the NPV of lost opportunities becomes zero, although disruption costs may continue to exist.

5. The NPV that should logically drive the technology adoption decision becomes \( (NPV_{\text{new}} - NPV_{\text{lost opps}} - PV_{\text{disruption cos}}) \), where the NPV of overlapping opportunities are omitted because they do not affect the marginal decision to be made.

6. Graphically show the net present value effect of disruption, and lost opportunities over time due to technology changes via Venn diagrams as follows:
7. The final pedagogical tool I use is a thing I call the “Risk-Return/Context Shift” graph, which really is nothing more than a modified decision tree that maps out the Coefficient of Variation of the firm for various strategic decisions involving technology that may create a new context in which the firm will operate. It is assumed that the realized rate of return for each option is held constant, and thus the CV’s become a comparable measure of project quality. This graph is as follows:

Note in the “context shift” graph above, that the status quo option has a higher coefficient of variation on average, meaning it has more units of risk per unit of return. However, option C is less than any of the other options available. If the decisions shown above are mutually exclusive and irreversible, choosing the blue “Innovation Option” will lead to a higher level of overall risk per unit of
return, assuming the probability of occurrence of every branch option is the same. If the probability of branch option “C” is disproportionately small (less than .20), then the Innovation Option becomes superior to the Status Quo Option regardless of the duration of time between evaluation points 1 and 2.

The issue of risky disruption costs and new context creation with irreversible outcomes can be very difficult to estimate with any degree of exactness. However, the potential losses associated with these issues should compel financial professionals, and the students we train to become such, to include these considerations in a serious way before writing the check. Every new technology acquired should be exposed to this brief, but very important set of questions that can be used as a handout to students:

**IV. TWELVE QUESTIONS BEFORE YOU BUY TECHNOLOGY**

1. What existing systems and equipment may be incompatible with this new technology?

2. To what extent and cost can the new incompatible technology be effectively “patched” into the existing fabric of the operation?

3. If no effective patch can be made, what are the current systems that are Most Likely, Likely, and Somewhat Likely to be replaced as a result of this new technology, and at what cost?

4. What is the likely duration of any potentially disruptive episode, and how will it affect cost and revenue flows from other projects during those time periods?

5. What are the reliability impacts that this new technology will have on other existing systems, revenue, and cost?

6. What human resource turnover and training costs will be imposed due to the adoption of this technology?

7. What organizational changes and associated costs will be necessary due to the adoption of this technology?

8. Do sufficient cash reserves exist to carry the operation during the period of
disruption?

9. What is the financial consequence of doing nothing, on both cost and revenue?

10. What preferred options may emerge at a reasonably later date if we do nothing?

11. What legal liability issues and potential costs will this new technology create?

12. Is the adoption of this technology critical to the mission and strategic vision of the organization?

In addition to the questions presented above, financial educators could suggest that some ratios should be established to assist in tracking the potential for technology risk on the firm. A short list could include the following:

1. \( \frac{f_{tech}}{TC} \) = fixed costs associated with technology as a proportion of total costs;

2. \( \frac{a_{tech}}{A} \) = dollar value of technology assets divided by total asset value of the firm;

3. \( \frac{l_{tech}}{L} \) = compensation to dedicated technology support labor divided by total compensation.

Once these ratios are established, they can be used to track changes in exposure to technology risks, and possibly be used in an Arbitrage Pricing Theory (APT) model in the second stage equation where returns are forecasted via indices. Other methods would be to compute the historical residuals from a standard CAPM forecast of returns, and then fit these ratios as a model on those residuals.

V. CONCLUSIONS

While explicitly modeling technology risk at the firm level is difficult at best, there are a few important conclusions that can be drawn from the information presented above. First, and most importantly, technology impacts are not always positive at the firm or industry level. Second, it is important to understand that even if
introducing the new technology generates higher levels of net income, the risks of doing so are likely to rise, at least in the near-term. Third, the process of creating a new context in which the firm operates, with the possibility of irreversibility, should compel us to do something more than stare into the headlights of oncoming technology like a deer about to become roadkill.

The place to begin greater understanding of technology disruption risks is in our classrooms as we train the financial professionals of tomorrow. Based on recent events, there is an essential need for financial analysts to more fully integrate technology risks into their models. In no way, however, is this paper suggesting that adopting technology is a bad thing. Technology may in fact cause profit to rise, and well it should. This paper only addresses the risks associated with that adoption, and more clearly pointing out that, once again, nothing good comes without a price.

REFERENCES AND SUGGESTED READING


November 1997.


