Topics in Law and Economics: Three Essays

by

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Abstract

In Chapter 1, the impact of proposed patent reform legislation is evaluated. Survival analysis is employed to ascertain what factors influence the length of time for patent grants. The role of these factors in potential reforms is also discussed. Surprisingly, corporations do not appear to have an advantage over individuals in terms of alacrity of patent grants, nor do US individuals or firms have advantages over foreign applicants. Industries such as software and pharmaceuticals do suffer from unusually long delays.

Chapter 2 examines the exercise of market power in the potash fertilizer industry using a dynamic cost analysis of an extractable resource industry inspired by (Hotelling, 1931), as well as the work of (Pindyck, 1985) on a dynamic Lerner index. Firm level data from leading North American firms, members of a legally sanctioned Canadian export cartel, suggests that market power is substantially affecting the price of potash fertilizer, and that the market power has increased in recent years.

In Chapter 3, the differences between traditional standards of scientific significance, empirical economic results, and legal evidence are discussed. The traditional standards of statistical significance were not designed with legal or evidentiary standards in mind, which leads to decisions regarding the presentation of economic evidence that don't necessarily jibe with the relevant legal standards.

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Introduction

This dissertation is divided into three chapters about the intersection of law and economics. Unifying each is an analysis of both the economic and legal impacts and effects of law and policy issues.

The first chapter, "Patent Reform Pending: Efficiency Issues in the United States Patent Process," takes a very technical, econometric heavy look at recently passed legislation. Parametric survival analysis methods are used and compared with less restrictive and non-linear specifications for probability and cumulative distribution functions to ascertain whether the rationale for the proposed patent reform legislation has merit. Building on the previous work of (Xie and Giles, 2011), Chapter 1 tests the hypotheses on which the policymakers and legislators relied in drafting the legislation.

The second chapter, "Market Power in Fertilizer: Has Potash Competition Gone to Pot?" derives a dynamic Lerner Index is derived, as well as an econometric framework for empirical analysis. This will determine the amount of market power exercised by a North American fertilizer cartel in the potash market. The cartel, Canpotex, consists of three major fertilizer producers in Canada and the U.S. This cartel behavior is legally sanctioned under the Webb-Pomerene Act, which allows exemptions from antitrust laws in order to allow firms to compete with foreign cartels. Such exemptions are supposed to be granted only in the case where they will not result in anti-competitive activity in domestic markets. This analysis, then, attempts to establish whether domestic competition has been harmed, and thus, whether or not the exemptions are justified.

The third essay, “Clear, Convincing, and Insignificant: Statistical Significance and Evidentiary Standards in Legal Proceedings,” the relationship is examined between statistical significance in economic research, in which significance at the 1%, 5%, or 10% level is required vs. legal standards, such as “preponderance of the evidence” or “clear and convincing,” that may be less stringent. This discrepancy arises largely from an information asymmetry of sorts between the legal systems and the economics profession. The standards of evidence, burdens of decision making, etc. in the legal system (such as reasonable doubt, preponderance of the evidence), do not always match up with the standards of reporting empirical results in scientific publications. This results in a difficulty in conveying information accurately between the two fields. The essay attempts to bridge the gap between the two worlds.

Chapter 1

Patent Reform Pending: Efficiency Issues in the US Patent System

Abstract: The impact of proposed patent reform legislation is evaluated. Survival analysis is employed to ascertain what factors influence the length of time for patent grants. The role of these factors in potential reforms is also discussed. Surprisingly, corporations do not appear to have an advantage over individuals in terms of alacrity of patent grants, nor do US individuals or firms have advantages over foreign applicants. Industries such as software and pharmaceuticals do suffer from unusually long delays.

Introduction

A patent is an intellectual property right granted by the Government of the United States of America to an inventor "to exclude others from making, using, offering for sale, or selling the invention throughout the United States or importing the invention into the United States" for a limited time in exchange for public disclosure of the invention when the patent is granted" United States Patent and Trademark Office (USPTO). Most patents in the United States and Canada last 20 years. Essentially, the patent is a temporary monopoly right to an invention in exchange for disclosure to the government of the invention.

This paper outlines the patent process, discusses the reasons why reform is proposed, reviews the relevant literature, and tests the hypotheses of the policymakers and reformers to ascertain whether the proposed reforms would accomplish the appropriate objectives.

The Process and Cost of Obtaining a Patent

The patent process begins with the inventor. The inventor may be a university scientist, an employee of a large corporation, or the proverbial "inventor in the garage." As the inventor completes the development of a new technology, he or she must begin the patent process (likely with the help of a patent attorney) before bringing the product to market with patent protection. In the United States, applications for patents are filed with the USPTO. If the invention is intended for international distribution, the inventor will need to file applications with the patenting authorities of other countries as well. There is no overarching global patent authority.

If the invention has already been patented, any subsequent application by another party will be rejected. The repeat applicant can market the product only by licensing the invention from the person who has already patented the product.

If, however, the invention has not been patented, the inventor may apply for a patent. He or she will include a series of claims (discussed further, *infra*), or descriptions of the invention. The application will also include citations to other patented inventions that influenced the patent application.

The application will be filed with the USPTO (and similar organizations in other countries). USPTO then will evaluate the application for a period of time, and render a decision. If the decision is made to deny the patent, the applicant can challenge the decision. If the decision is made to grant the patent, a period of time exists for others to challenge the grant of the patent. Litigation may subsequently ensue.

Uncertainty and risk dominate the patent process. Risk is defined as a situation in which the probabilities of possible future outcomes can be specified ex ante, while uncertainty refers to a situation in which such probabilities are unknown and cannot be calculated (Knight, 1933). The situation faced by the inventor is rife with uncertainty. The inventor is likely unaware of the activities of other potential competitors, may not be aware that his research will ever result in a patentable invention, may not be aware of the process, and then becomes further dependent on the unpredictable actions of the USPTO bureaucrats.

The process of obtaining a patent has become quite costly. In 2012, the median price paid for obtaining a patent was $221,000, while the mean was $374,000 (Burke, 2012). Of course, that addresses only the pecuniary costs of obtaining the patent. As noted below in the summary statistics (Table 1), the mean duration for a patent application exceeds 2 years, no doubt creating large opportunity costs while waiting on the patent grant.

Efforts at reforming the patent system in the US are underway. In September of 2011, President Obama signed into law the "America Invents Act". The Act reformed the patent system by switching the US from a First-to-Invent to a First-to-File system, changing the budgeting process by linking the USPTO process to fees and protecting it from Congressional raiding, and by streamlining the way litigation under the Act is pursued (Goldman, 2011).

The reasons for reform given by the USPTO's chief economist, Stuart Graham, and the Commerce Department's Chief Economist, Mark Doms, include the following:

> "Highly innovative firms rely heavily on timely patents to attract venture capital (VC)--76% of startup managers report that VC investors consider patents when making funding decisions. . . . Delay in the granting of rights has substantial costs. Recent reports conclude that the U.S. backlog (currently at 750,000 applications) could ultimately cost the U.S. economy billions of dollars annually in "foregone innovation." . . . The fee-setting authority patent reform gives to the USPTO will contribute significantly to the agency's planned 40% reduction in patent pendency. . . . The enhanced post-grant review provided by patent reform is intended to substantially reduce the need for inefficient court challenges. The cost of such proceedings is expected to be 50-100 times less expensive than litigation and could yield $8 to $15 in consumer benefit for every $1 invested." (Rai, Graham, and Doms, p.1).

The rationale for reforms, then, is that the system was unduly burdensome, inefficient, and untimely. This, many observers believe, stifles growth by unnecessarily keeping new technologies off the market for inappropriate amounts of time, and creating undue uncertainty about the time, or likelihood, of patent grant. In this paper, I seek to ascertain the impacts on patent application duration to evaluate whether the effects of the reform will address the concerns that the current US patenting system is too inefficient and cumbersome, and keeps valuable technologies off the market for excessive periods of time.

The most fundamental change in the reforms shifts the US from a "first to invent" system to a "first to file" system. The first to invent system awards the patent to the actual inventor. The theory behind first to invent is that it encourages innovation by rewarding the actual innovator, thus relieving him or her of the fear that his or her work will be wasted. The US was the last major adherent to the first-to-invent system[1] (Canada had also been a first-to-invent nation until 1989).The major criticisms of first to invent are that it delays patent filing and publication, and that if a dispute arises as to who is the actual first inventor of a patentable technology, that leads to a costly review process, and potentially to costly litigation. As of May 2011, there were 21,869 contests pending before the USPTO's Board of Patent Interferences and Appeals, the

[1] The US officially did not switch to a first-to-file system until March 16, 2013.

Board that hears those disputes (they may subsequently end up involved in federal litigation) (USPTO 2011). 8,011 cases were received in 2011 (the last year for which complete data were available), and 3,896 cases have been resolved (USPTO 2011).

A first to file system awards the patent to the first inventor to file the patent. The theoretical advantage to the first to file system is that it promotes earlier publication of patent information, which allows for more rapid technology diffusion. The earlier publication should lead to licensing of the technology, creating enhancements to the technology, and allowing potential competitors to direct resources more quickly to developing other technologies.

An online survey of patent bar members found a split among the lawyers who file the patents: 47% support the change to first to file; 42% oppose, and 11% are indifferent (Patently0, April 2011). An analysis of the efficiency of the current system and what factors contribute or detract thereto could help to resolve that split.

Literature Review

As much as 2.5% of the average annual 3.4% postwar GDP growth rate can be linked to innovation (Jorgenson et al, 2007). Much of the innovation is due to venture capital activity. (Kortum and Lerner, 2006) found that about 15% of industrial innovation is directly linked to venture capital activity. As mentioned above, 76% of venture capitalists indicate that patents are highly important to their decision making (Ray, Graham, and Doms, 2010).

Two distinct but complementary theories dominate the literature of patents: reward theory and contract theory. Reward theory, as first laid out in (Nordhaus, 1969), focuses on allowing the inventor to reap the benefits of the investment into the invention, and to incentivize increased research and development investment. Contract theory views the patent process as one in which the inventor discloses the proprietary technology to the public in exchange for a temporary monopoly right (Denicolo and Franzoni, 2003).

Efforts in the past were made to attempt to fit traditional economic optimization models to the patenting process. These often led to restrictions referred to by more recent researchers as highly restrictive (see e.g. Branstetter, 2001). More recent examples of analyzing of patents and response to policy changes have moved away from more traditional theoretical economic constructs to alleviate the restrictions (see Xie and Giles, 2011; Lo and Sutthiphisal, 2009).

Further, while some patent analyses focus on the decision to patent itself, and are more likely to use more traditional economic models, some others focus on the process (including timing related issues) after the decision has been made to patent. The latter are less likely to employ traditional optimization models. For example, (Denicolo, 2000) discusses the second stage of a two stage patent race. (Denicolo, 2000) defines that second stage as occurring after an initial innovation has occurred, and the patent has been secured. Thus, (Denicolo, 2000) employs no particular model with respect to the innovation decision itself, and instead focuses on the time to completion of the discovery process, assuming a Poisson process and linear hazard function.

One aspect of patenting addressed by the economic literature has been ascertaining the importance of patent "claims." A patent claim defines the scope of the protection offered by the patent (37 CFR 1.75). Put plainly, the claim establishes exactly what the invention is. If a new technology serves more than one purpose, multiple claims can be included in the same patent application (37 CFR 1.75 (b)). (Jaffe, 2000) found that the number of claims on a patent application directly correlates to its economic importance. Breadth of scope of the patent - and amount of claims as a proxy thereof – was found to be associated with economic value by (Denicolo, 1996).

Another aspect of patents that has received much attention is citation. A patent citation is a reference to a previous invention (often referred to as "prior art") upon which the patent in question is based. Citations contained in a patent application are backwards citations: citations of previously existing patents. Forward citation is a measure of the number of times a patent is cited as prior art by future inventions. Both types of citations have been found to be representative of the economic value of a patent (Trajtenberg, 1990).

The literature offers theoretical and empirical support for the economic value enhancements of both types of citations. Backward citations may reflect an economically more "important" invention because an invention that relies on more prior art may be more complicated, or perform multiple functions. Forward citations represent the importance of an invention going forward: the more often it is cited, the more economically productive uses the invention is likely to have had. Other literature has focused on the amount of citations as evidence of economic value because citations represent knowledge sharing/spillovers, which in and of themselves create economic value (Moretti, 2004), (Trajtenberg, Jaffe, and Henderson, 1993).

Further, (Kortum and Lerner, 2006) found that patenting activity was a generally good measure for innovation as a whole. Others would contend otherwise. Earlier efforts at US patent reform occurred in the early 1980s. Patenting activity in the US increased dramatically in the early 1980s, and that trend has continued. The US government created the Federal Circuit, an appellate court specifically designated to hear patent cases. The idea was to streamline the court system, and allow for more efficiency in litigation. However, the new system has led to an increase in victories for patent-holders: holders now win 90% of their appeals, as opposed to 62% prior to the reform (Gallini, 2002). Thus, there is concern that the near certainty of victory under the new system would simply create a propensity for patent, regardless of the strength of the underlying reason to patent.

Another change was the enactment of the Bayh-Dole Act, which allowed universities, non-profits, and certain small businesses to retain the rights to patent technologies developed by public subsidy. In the early 1980s, the Act was amended to permit sharing such rights with larger corporations. There is evidence that this change had an impact on the patenting activity.

One-third of patenting activity and half of licensing activity amongst universities belongs to just 10 universities (Leaf, 2005). What's more, those 10 universities (such as MIT, Stanford, Wisconsin, and Columbia) all had technology transfer offices in place before the passage of Bayh-Dole (Leaf, 2005). Concern about large entities getting larger also often revolves around the concept of patent "thickets": patent holders applying for large numbers of patents very similar to one another in order to intentionally slow down the process, and thus make things more difficult for competitors.

(Cockburn and MacGarvie, 2009) stated the following:

> In such circumstances, critics argue, any "stimulating" effect of stronger patents on incentives to innovate will be offset, or even swamped, by the "stifling" effect of higher transactions costs, increased threat of litigation, and constraints imposed on the cumulative development of technologies by multiple blocking patents. New enterprises that have limited resources and lack experience and managerial expertise in "working the patent system" are likely to be among those most severely affected by these stifling effects. (p.750)

Implicit in such a claim is that larger, more experienced corporations have more access to expensive patent attorneys who know how to “work the patent system,” and can afford to pay them large sums of money to file numerous patents and create a thicket. If those critics are right, we would likely expect to see the time between application and granting of the patent increase significantly after the adoption of the early 1980s reforms.

Very little literature has evaluated the effect of patent reform in developed countries such as the US and Canada. However, (Branstetter, 2004) evaluated Japan’s 1988 reforms which broadened the definition of patent and found no effect. Branstetter used patenting as innovative activity and supplemented with surveys and interviews of inventors. He found no significant effect on patenting activity. However, the Japanese reforms, while involving a major developed and highly technologically advanced economy, were of a fundamentally character. The old system awarded very narrow patents that were not as broad in scope as those awarded by Western nations. The Japanese reforms were aimed at harmonizing the type of patents with those in Western nations. (Lo and Sutthiphisal, 2009) did a difference-in-differences examination of the Canadian reforms – switching from first to invent to first to file -and found no impact on patenting, and a negative impact on R&D.

The primary approach used in this paper is survival analysis. The amount of uncertainty faced by inventors, combined with the reform goals of the policymakers, lends itself to survival analysis. Efficiency gains in the process of obtaining patents are a primary goal, and the multiple functional forms permitted in survival analysis could perhaps shed light on the uncertainty faced in the process.

Survival analysis has been applied to patents in individual jurisdictions. (Xie and Giles, 2011) examined US patents (on a smaller and less recent dataset than the one in this paper), and found that the claims and citations in an application increase the application duration, and that corporations have shorter application durations than do non-corporate entities. The same findings were confirmed for European patents. (van Zeebroek, 2007). However, (Harhoff and Wagner, 2005) found the opposite with respect to Europe: more valuable patents took less time to be granted. In this paper, I look to examine the effects of the aforementioned covariates on the application duration to ascertain their effects on patent application duration. (Marco, 2006) applied survival analysis to a random sample of 20,000 utility patents, and found that unobserved heterogeneity impacts citation rates.

Survival analysis measures the transition across time from one state into a failure state (Cameron and Trivedi, 2009). The term "survival" comes from its frequent application to biostatistics where the "failure" event is the death of the person in question, and what is measured is, quite literally, the length of time the person survives.

(Bofondi and Lotti, 2006) framed the question of survival, also called duration, analysis in technology diffusion in the following way:

> From an econometric point of view, our problem can be easily viewed in a duration model framework. Suppose we start observing a set of N banks at time T =0. The continuous random variable T (known also as lifetime) represents the duration of stay in the state "non-adopter". Accordingly, the probability that a bank which has been in the state "non-adopter" state for a time t leaves that state right after t (i.e., at time $t + \Delta t$) is $P(t \leq T \leq t + \Delta t | t \leq T)$. Averaging over the interval Δt and considering a very short interval, one gets: $\lambda(t) = \lim P(t \leq T \leq t + \Delta t | t \leq T) \Delta t = (f(t)/1 - F(t))$. $t \to 0$. (Bofondi and Lotti, 2006, p. 348)

Other economic applications of survival models include analyzing the length of strikes (Kennan, 1985) (Jaggia, 1991).

Survival analyses may be non-parametric, semi-parametric, or parametric. The key functions for the analysis are the cumulative probability distribution function, the probability density function, the survival function, and the hazard function.

Applying the findings from the literature to our survival analysis, we arrive at the following hypotheses:

1) Application duration for patents increase over time

2) Application duration for patents is higher for individuals or governments, and shorter for corporations more used to "working the system."

3) Application duration is higher in industries such as software or pharmaceuticals that are known for patent "thickets."

4) Application duration increases in claims and citations

Data

The data source for this paper is the patent and citation database created and maintained by the National Bureau of Economic Research (NBER). The process and the data are described in great detail in (Hall, et al, 2001). The data cover all patents awarded in the US between 1976 and 2006 (a little more than 3,000,000). The important variables for the paper at hand are as follows:

The first specification is very basic. The beginning time is the application year, and the ending time is the grant year. The parameters are assignee code (whether that assignee of the patent is a US or foreign corporation, government entity, individual, etc.), number of claims, and technological category.

Summary Statistics are shown below in Table 1. *Allcites* is a continuous variable representing the number of citations (backwards) listed in each patent application from 1976-2006. *Appyear*, and *gyear* represent the application year and grant year respectively. The variable *nclaims* is a continuous variable representing the number of claims in the patent application. *Asscode* is the assignment code. The types of entities included are listed in Tables 2-4.

The variable *cat* is a categorical variable representing the categories assigned by the USPTO. Category 6, others, is treated as the reference category in the regressions. These variables were selected from the database for analysis because these are the variables shown to have economic value, as discussed in the Literature Review, and/or because they were considered to be of importance to policymakers.

Empirical Model

As noted earlier, survival is the empirical modeling approach applied in this paper. Survival analysis will be used to analyze the length of time between patent application and patent approval. The analysis sheds light on the efficiency concerns raised by the reformers. What factors are affecting lag time of grant length? Is it, as the reform-minded policymakers suggest, increasing numbers of claims and citations that are associated with increasing lag times? What industries are associated with longer or shorter lag times?

This paper attempts to expand on the work of (Xie and Giles, 2011) and thus begins with the Accelerated Failure Time (AFT) specifications. Specifically, (Xie and Giles, 2011) found the lognormal AFT specification to be preferred. A sub-class of parametric models run in this analysis is the accelerated failure time (AFT). AFT models follow the parameterization

(1) $$ln(t_j) = x_j \beta_x + \varepsilon_j$$

where t_j is the survival time, $= x_j$ is a vector of descriptive variables about the patent applications, and ε_j is the error term. Initially, the model tests the impact of the basic descriptive variables in the dataset: category, number of citations and number of claims. Thus, the basic model is as follows:

$$(2)\ \ln(t_j) = \beta_0 + \beta_{1-5}CAT_j + \beta_6 ALLCITES_j + \beta_{7-12}ASSCODE_j + \beta_{13}NCLAIMS_j + e_j$$

All variable names have the same meanings described above. The Lognormal AFT distribution – found to be preferred by (Xie and Giles, 2011) – is included, as well as the Weibull AFT distribution (the selection of those two distributions, as well as comparison between them, is included below). Results are shown in Table 2 below. The results relatively little difference between individuals and corporations, with the US government the laggard. These results do show support for the thicketing hypothesis because Computer and Communications and Medical and Pharmaceutical patents have a longer duration than other categories.

Expanding on the work of (Xie and Giles, 2011) work, we also explore non-linearities across the sample. Because the sample spans 3 decades, which include multiple reform efforts, in addition to economic and technological change, it is worth exploring whether the rate of change in impact on application duration shifts over the course of the sample.

Consistent with the (Xie and Giles, 2011) framework, interaction terms were added to the model. Because of the size of the dataset, and the length of the sample, second-order effects from such interactions can be revealing. For example, as noted in Table 3, the effects of citations and claims are both significant, and of similar magnitude. However, as noted earlier, both are potential measures of the amount of information/complexity contained within the patent. An interaction term potentially reveals the combined effect (or lack thereof) of the measures.

Further, given that survival is itself an inherently temporal measure, and evaluating the impact of changes in application year throughout the sample is of particular interest, understanding the interaction between application year and the claims and citations variables could be valuable in showing the effect of those variables at different points in the sample. The expanded model is shown as follows, with results reported in Table 3.

$$(3)\ ln(t_j) = \beta_0 + \beta_{1-5}CAT_j + \beta_6 ALLCITES_j + \beta_7\, CITESCLAIMS_j + \beta_8 CLAIMS2_j + \beta_9 CITES2_j + \beta_{10} APPYEAR_j + \beta_{11} APPYEAR2_j + \beta_{12} APPYEAR3_j + \beta_{13} APPYEARCITES_j + \beta_{14} APPYEARCLAIMS_j + \beta_{15-20} ASSCODE_j + \beta_{21} NCLAIMS_j + e_j$$

The final model continues the extension on the basic model by including dummies for earlier reforms. The first reforms were the 1982 US reforms (creating separate courts amongst other changes). Additionally, the 1989 Canadian reforms left the US as the final “first to invent” jurisdiction in the world. Thus, dummies for the 1982 and 1989 reforms are incorporated into the model. Further, because this paper seeks particularly to examine the effects on United States firms, a dummy is included for US based applicants. The model is expressed as follows:

$$(4)\ \ln(t_j) = \beta_0 + \beta_1 CAT_j + \beta_2 ALLCITES_j + \beta_3\, CITESCLAIMS_j + \beta_4 CLAIMS2_j + \beta_5 CITES2_j + \beta_6 APPYEAR_j + \beta_7 APPYEAR2_j + \beta_8 APPYEAR3_j + \beta_9 APPYEARCITES_j + \beta_{10} APPYEARCLAIMS_j + \beta_{11} AFTER82_j + \beta_{12} AFTER89_j + \beta_{13} US_j + \beta_{14} ASSCODE_j + \beta_{15} NCLAIMS_j + e_j$$

The Results are reported in Table 4.

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Results and analysis

Expanding on the work of (Xie and Giles, 2011) we find extensive additional non-linearities and interactions that substantially impact the results. This is true both within the AFT-lognormal framework, used by (Xie and Giles, 2011) and the AFT-Weibull distributional form, which is found to be preferable on the extended dataset (including patents granted through 2006, instead of 1999 as in the case of the database used by (Xie and Giles, 2011)). These results, from non-linear terms, additional interaction terms, and additional covariates, shed additional light on the nature of the survival functions, and illustrate potential limitations.

Weibull vs. Lognormal

(Xie and Giles, 2011) concluded that the functional form that best fit the data was the AFT-lognormal. However, their dataset included patents granted from 1963-1999, while this paper covers those granted from 1976-2006. This paper finds that the AFT-Weibull distribution fits the data better. The results of both specifications, including the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for both, are reported in Tables 2-4.

Because ordinary measures of goodness of fit, robustness, etc. are unavailable in the context of parametric survival models, we largely must rely on the AIC and BIC. A lower AIC and BIC indicates a better fit. As shown in Tables 2-4, the AIC and BIC improve for each model as each new set of covariates is added. Further, across the models, the Weibull specification is preferred, in contrast to (Xie and Giles, 2011) who found Lognormal preferred.

Application year effects

The first extension to the (Xie and Giles, 2011) model is to evaluate the effect of the application year. Tables 3 and 4 show that the linear, quadratic, and cubic terms of the application year term are significant. The linear term of the application year is negative and significant, with the squared term being positive and significant, and the cubic term being negative and significant.

This indicates that the effects of these parameters shift over the course of the sample. The results show a shift in sign from negative (linear term) to positive (quadratic term) to negative again (cubic term). Thus, a traditional interpretation of uniform linear effects is inappropriate.

The application year coefficients, with all other results reported herein, are probabilistic in nature. Thus, the Weibull coefficient for appyear reported in Table 3, -0.412, would indicate that an increase in the application year (being a year later) would lead to a reduction in the probability of the patent remaining in application limbo by that amount. Traditional marginal effects interpretations are unavailable for these coefficients (more discussed *infra*).

Category and Assignment Code Effects

Tables 2-4 report the results by industry category, and assignment code. By far the largest effect is for category 3, medical and pharmaceutical applicants. The coefficients for the medical category are large, positive, and significant. Being in the drug/medical category increases the likelihood of a patent remaining un-granted by anywhere from 23% and 50%. Other categories show a greater variance across models. This shows some support for the hypothesis that highly “thicketed” industries (such as pharmaceuticals) have longer lag-times than other industries. While not conclusive, it is evidence to support the assertion that the patent process is open for “gaming” in those industries enabling incumbent firms to artificially prolong the patent process as a form of protection against would be competitors.

Cites, Claims, and US effects

Linear and quadratic cites and claims terms were estimated. The effect of citations was, as predicted earlier, generally positive, both in the linear and quadratic terms. However, the claims term has a positive linear effect on the survival function, and a negative quadratic effect. Also included was a binary variable indicating whether the applicant was from the United States or not. The effect of the US variable was positive, indicating that domestic applicants have generally longer patent lag-times.

Interaction Term Effects

This model also considers the interaction effect of the application year on cites and claims, and the interaction of cites and claims together. The cites and claims interaction term is negative and significant, indicating that the combination of more cites and claims has an impact on decreasing the lag-time of a patent grant. The magnitude, however, is relatively small, indicating that the decrease in probability is relatively small. However, the interaction of both cites and claims with the application year is negative, indicating that as we move through time in the sample, both types of information measures are associated with reducing the lag-time of a patent grant.

Heteroskedasticity

I also tested the data to see if heteroskedasticity was present, and if it was affecting the significance of the results. I tested for heteroskedasticity by regressing the square of the residuals of the regression on the independent variables. Most variables show strong significance, indicating that heteroskedasticity is indeed present. That variance is inconsistent across the sample is perhaps supported by the previously discussed empirical evidence, as well as the hypotheses of the policymakers. The multiple policy changes, as well as the different strategies employed by patent applicants – and the massive amount of heterogeneity inherent in those applying for patents – certainly could contribute to such heteroskedasticity. Indeed, the mere existence of heteroskedasticity itself is a potentially important observation from a policy perspective.

In correcting for the heteroskedasticity, I used a transformation to robust standard errors. The results of that regression are reported in Tables 2-4. While the AIC indicates that the corrected model is a slightly better fit, little is changed with the results themselves; thus, the heteroskedasticity did not appear to be leading to erroneous determinations of significance.

Conclusion

Non-linearities discovered in this study show that the survival functions are more complicated than previously suggested by (Xie and Giles, 2011) and others. In particular, the application year matters, and the effect changes throughout the course of the sample. Further, the largest and most significant effects are in the computer and medical categories. This provides support for the policymakers' hypothesis that heavily thicketed industries have longer lag times for patent grants.

Other hypotheses are also supported. For example, claims and citations both increase the survival function, though the quadratic and interaction terms show that that effect isn't necessarily consistent throughout the sample.

However, domestic corporations and the US government do not, according to this study, enjoy shorter durations than other categories of applicants. In fact, the survival times are longer both in relation to the reference category (unassigned), and in relation to other categories (domestic and foreign individuals, foreign corporations, and foreign governments).

The main item to improve analysis in the future would be for NBER or USPTO to provide application and grant date information with more specificity (month, week, or day would be preferable to the current dataset, which includes only application and grant year). Other potential future topics would be exploration of the models in this study applied within various subcategories. Repetition of this particular model on patents granted by other authorities (such as Japan, Canada, and various European countries) would also shed light on the potential for successful efficiency based reforms.

Table 1 - Summary Statistics

Variable	N	Mean	Std. Dev.	Min	Max
allcites	3,279,509	7.34	13.22	0	1804
appyear	3,279,509	1992.13	8.47	1901	2006
asscode	2,952,232	2.32	.86	1	7
cat	3,278,174	3.62	1.76	1	6
gyear	3,279,509	1994.28	8.66	1976	2006
nclaims	3,279,499	14.39	12.53	1	887

Table 2 - Results of Initial Accelerated Failure Time Models

Variable	AFT Weibull	AFT Lognormal
US corp	-.133 (.001)***	-.095(.001)***
Non-US corp	-.128 (.001)***	-.112(.001)***
US indiv	-.089(.005)***	-.110(.005)***
Non-US indiv	-.123(.005)***	-.088(.007)***
US Gov	.297(.002)***	.032(.002)***
Non-US gov	-.032(.006)***	-.016(.006)***
allcites	-.001(.001)***	-.002(.001)***
Chemical	.037(.001)***	.033(.001)***
Comput/Comm	.313(.002)***	.204(.002)***
Medical	.501(.001)***	.480(.001)***
Electric	-.029(.001)***	-.038(.001)***
Mechan	.113(.001)***	.093(.001)***
Nclaims	.004(.001)***	.006(.001)***
constant	.774(.001)***	.536(.001)***
AIC	4576962	4005291
BIC	4577156	4005486
N	3237735	3237735

*significant at 10%
** significant at 5%
***significant at 1%

Table 3 - Results of Intermediate Accelerated Failure Time Models

Variable	AFT Weibull	AFT Lognormal
US corp	.027(.001)***	.024(.001)***
Non-US corp	.047(.001)***	.043(.001)***
US indiv	-.052(.003)***	-.112(.004)***
Non-US indiv	-.082(.005)***	-.101(.006)***
US Gov	.163(.002)***	.110(.002)***
Non-US gov	-.011(.004)***	-.079(.005)***
allcites	.004(.001)***	.010(.001)***
citesclaims	-.001(.001)***	.001(.001)***
claims2	-.001(.001)	-.001(.001)***
cites2	.001(.001)***	.001(.001)***
appyear	-.412(.040)***	-.289(.007)***
appyear2	.509(.001)***	.043(.001)***
appyear3	-.002(.001)***	-.001(.001)***
appyearclaims	-.001(.001)***	.001(.001)***
appyearcites	-.001(.001)***	-.001(001)***
Chemical	.058(.001)***	.088(.001)***
Comput/Comm	-.039(.001)***	.030(.001)***
Medical	.224(.001)***	.458(.001)***
Electric	.023(.001)***	.029(.001)***
Mechan	-.059(.001)***	-.040(.001)***
nclaims	.013(.001)***	-.021(.001)***
constant	1109.3(1.089)***	85.384(.325)***
AIC	2433283	3343950
BIC	2433581	3344249
N	3237735	3237735

Table 4 - Results of Full Accelerated Failure Time Models

Variable	AFT Weibull	AFT Lognormal
US corp	-.014(.006)**	-.022(.007)**
Non-US corp	.056(.001)***	.076(.001)***
US indiv	-.051(.003)***	-.092(.004)***
Non-US indiv	-.077(.005)***	-.084(.006)***
US Gov	.113(.007)***	-.008(.008)
Non-US gov	-.016(.004)***	-.057(.005)***
allcites	.002(.001)***	.015(.001)***
citesclaims	-.001(.001)***	-.001(.001)***
claims2	.001(.001)*	.001(.001)***
cites2	.001(.001)***	.001(.001)***
appyear	-.470(.061)***	-.162(.007)***
appyear2	.580(.001) ***	.022(.001)***
appyear3	-.002(.001)***	-.001(.001)***
appyearcites	-.001(.001)***	-.001(.001)***
appyearclaims	-.001(.001)***	.001(.001)***
after82	-.361(.002)***	.180(.001)***
after89	-.042(.001)***	-.408(.001)***
US	.039(.006)***	.054(.007)***
Chemical	.059(.001)***	.089(.001)***
Comput/Comm	-.034(.001)***	.008(.001)***
Medical	.236(.001)***	.372(.001)***
Electric	.027(.001)***	.048(.001)***
Mechan	-.063(.001)***	-.064(.001)***
Nclaims	.013(.001)***	-.025(.001)***
constant	1270.006(1.671)***	38.882(.187)***
AIC	2381401	3043978
BIC	2381739	3044316
N	3237735	3237735

*significant at 10%
** significant at 5%
***significant at 1%

Chapter 2

Is Potash Competition Going to Pot?

Abstract: This chapter examines the exercise of market power in the potash fertilizer industry. It uses a dynamic cost analysis of an extractable resource industry inspired by (Hotelling, 1931), as well as the work of (Pindyck, 1985) on a dynamic Lerner index. Firm level data from leading North American firms, members of a legally sanctioned Canadian export cartel, suggests that market power is substantially affecting the price of potash fertilizer, and that the market power has increased in recent years.

I. Introduction

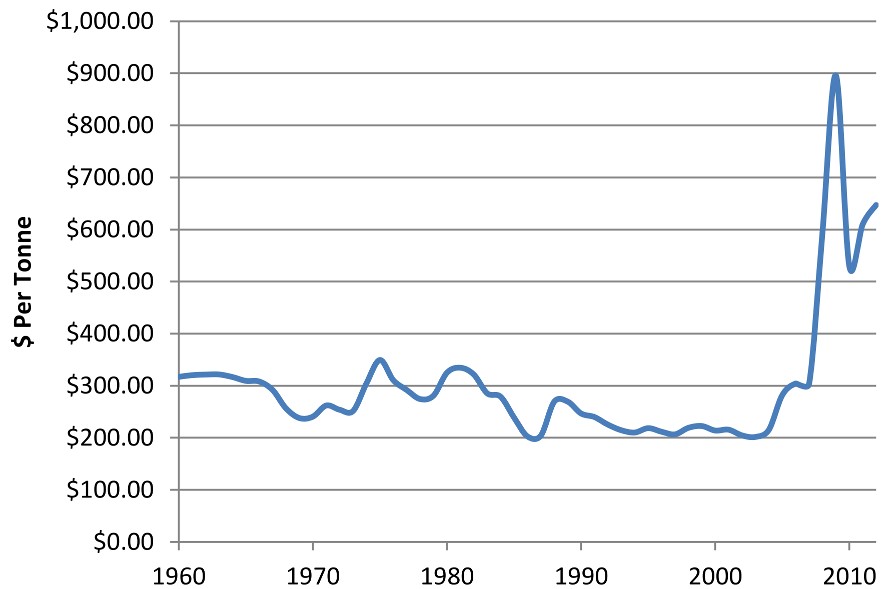
Potash is the common name of potassium chloride (KCl), a mineral primarily mined in Canada, Russia, and Belarus. Potash is one of the three primary plant nutrients (the other two components are nitrogen and phosphorous). More than 90% of the mined potash is used for fertilizer. In the US, 45% of potash is used in fertilizer for corn. Soybeans, rice, and grain crops are the primary recipients of potash fertilizer in the world.

The United States and China are the largest consumers of potash. In 2008, the United States consumed approximately 6.2 million tons of potash, 5.3 million of which was imported from outside the United States. North America accounts for 17.1% of the world's potash consumption. In 2007, 344,000 tons of potash produced in Russia were exported into the United States.

Canada is the world's largest producer and exporter of potash, accounting for nearly a third of total production and 40% of world trade. Nearly half of Canada's exports go to the United States, and that accounts for roughly 70% of the yearly consumption of potash in the United States

Recently, potash fertilizer prices have increased dramatically (shown in Figure 1), from $197 per ton in 2003 to $875 per ton in 2009 (both in 2011 USD). Potash industry analysts forecast that the price could rise as high as $1500 by 2020 (Toovey 2009). According to publicly filed documents by Potash Corporation of Sasketchewan, the world's #1 potash fertilizer producer, the primary determinants of the price increases for potash fertilizer are increasing demand for fertilizer (due to increasing population, and thus increasing food production), and increasing energy costs (Potash Corporation Annual Report, 2011).

Figure 1 - Real Price of Potash in Current Dollars



Others postulate that another factor driving the price increases is the exercise of market power by large potash fertilizer companies due to market concentration. As of 2008, the global market share of the potash market controlled by the 6 largest firms was 71%. Such concentration is largely a result of two primary cartels: Canada's Canpotex and the Belarus Potash Corporation, a Russian and Belarusian cartel. The members of Canpotex are Potash Corporation of Saskatchewan (POT), Mosaic (MOS), controlled by Cargill, and Agrium (AGU). While each has equal voting rights, the fixed market share of each firm is as follows: 54% POT, 37% MOS, and 9% AGR. Canpotex has operated since 1972. POT and MOS are also members of PhosChem, a similar cartel in the phosphate fertilizer industry. Phoschem is officially sanctioned under United States law as a legal cartel under the Webb-Pomerene Act, and Canpotex operates under a similar exemption under Canadian law. Further, Canpotex members own interests in foreign firms, such as POT's ownership of large stakes in a Chinese fertilizer giant, as well as major Israeli firms.

Canpotex has its roots as much in politics as in business. In 1969 and 1970, New Mexico Governor David Cargo, and Saskatchewan Premier Ross Thatcher, both governing areas with large potash production facilities, sought to stave off a trade or price war between Saskatchewan and New Mexico producers. The result was a plan to "control production" in order to "boost the price." (Waldie, 2010). Canada's top English language newspaper, the Toronto *Globe and Mail*, describes the origins of Canpotex as follows:

During three days of meetings, Mr. Cargo proposed a "pro-rationing" system for Saskatchewan to regulate potash production from each mine, based on a similar program New Mexico used to regulate its oil and gas industry. He also suggested that producers join together through a provincial agency to sell potash abroad. While collusion is prohibited inside the U.S. under anti-trust law, there is an old exemption for export associations that permitted U.S. companies to collude internationally in order to build export markets. Canada had similar exemptions to its competition laws.

> Soon after, Mr. Thatcher announced strict limits on how much the province's potash mines could produce and created Canpotex as an "association of Saskatchewan potash producers" to market potash outside North America. All producers had to join Canpotex

> or risk losing their production quota. To stay onside U.S. law, Canpotex would sell to overseas markets only.
>
> Within weeks, talk of a trade war ended and the price of potash shot up to $18.75 a ton, just above Mr. Cargo's threshold. "It saved the industry in New Mexico," Mr. Cargo said of Canpotex. "And I think likewise it saved it up in Saskatchewan."
>
> So the precedent was set. By restricting how much potash they supplied, and by co-operating instead of competing in foreign markets other than the U.S., Canada's potash business stabilized. (Waldie, 2010).

Canpotex contends that its sole focus is overseas, and that it does not "restrict or regulate" potash supplies. However, Canpotex in public documents admits that its members enter into product supply agreements based on "producer commitments."

The Wall Street Journal has compared the dominance of these companies in fertilizer to Saudi Arabia's position in the oil industry:

> Potash Corp. owns 22 percent of the world's potash production capacity, while Saudi Arabia accounts for roughly 13 percent of global oil production. ... The Middle East has more than 60 percent of the world's proven oil reserves, while Canada sits on about 57 percent of the world's potash reserve base. (Etter, 2008)

That prices are rising is not in dispute. The *Journal* reports the following:

> In April [2008], farmers paid 65 percent more for fertilizer than they did a year earlier, according to the U.S. Department of Agriculture. That compares with price increases of 43 percent for fuel, 30 percent for seeds and 3.8 percent for chemicals such as weedkillers and insecticides over the same period ...(Etter, 2008)

An additional source of the market concentration was consolidation that occurred between 1999 and 2004. During that period, the larger producers acquired smaller producers in the US, Chile, and other places. The reduction in potential competitors corresponds with the start of the recent price spike shown in Figure 1 above.

While many factors, discussed herein, affect the cost of potash production, the potash industry officials clearly see themselves as being in a position to *make* prices rather than *take* them, as they would in a competitive environment. POT executives have acknowledged as much in conference calls with institutional investors and analysts:

> We don't see any downturn in our business. The whole concept of potash prices peaking, we've just announced a big increase here in the domestic market September 1 and of course Canpotex has just increased prices up to the $1,000, about a $250 per ton increase there also, which we'll see really take effect in the fourth quarter . . .
>
> A $100 per ton increase is worth only $0.03 to a corn farmer in the Midwest of the U.S. So you start doing the leverage on that, while it's huge for us, that $100 increase, it's not a big deal to the corn farmer and they clearly see the benefit. We showed you a little bit of the economics in our formal earnings release where we referred to $1,000 potash in there. But if you're adding $500, you're only adding $0.15 to the cost of production of a bushel of corn. So you can see, we've got a lot of pricing room going forward and we don't see a peak in our business. (2008 Q2 Earnings call, accessed via seekingalpha.com)

Further, the integrated nature of the Canpotex members has permitted them to insulate themselves against the potential of rising input prices:

> To offset these rising costs, producers have raised prices for fertilizer, animal feed and industrial products**.** For our company, which has an integrated supply of high quality rock for phosphate production and lower cost natural gas contracts to fuel our nitrogen production in Trinidad, this presents an opportunity to capture greater margins on our products.

(Potash Corporation of Saskatchewan, 2008)

This paper will examine the competitiveness of the potash fertilizer industry. Part II will review the literature. Part III will derive the theoretical model. Part IV will show the empirical model and results. Part V will provide conclusions drawn from the model.

II. Literature Review

The use of cost information to determine market power owes its origins to the development of the Lerner Index, which is equal to (P-MC)/P, where P=price and MC=marginal cost (Lerner, 1934). The values of the Lerner Index can take a value from 0 to 1, with 0 representing perfect competition (no market power exerted by the firm), and 1 representing perfect monopoly behavior.

Other measures of market power take a different approach than Lerner's, and look to other factors to measure market power. The most basic measure is a simple concentration ratio. The most popular concentration ratio measures are the CR-4, CR-5, and CR-8, which are simply the summed market shares of the top 4, 5, and 8 firms, respectively, in the industry.

Another market concentration measure, employed by the United States Department of Justice (DOJ) and the Federal Trade Commission (FTC) is the Herfindahl-Hirschman Index (HHI), a measure of market concentration. The HHI is the sum of the squared market shares of the individual firms within the relevant market (as defined by the FTC itself). A pure monopolist would have an HHI of 10,000. A purely competitive market would have an HHI approaching zero.

The FTC considers a market with an HHI less than 1500 to be un-concentrated (FTC Horizontal Merger Guidelines 2010). Markets with HHI scores between 1500 and 2500 are considered "moderately concentrated," and markets with an HHI above 2500 are deemed "highly concentrated" (Federal Trade Commission, 2010)Mergers that raise the HHI by under 100 points are deemed to not increase the exercise of market power; 100 to 200 point increases are viewed as potential increases of market power; increases of more than 200 points are presumed to increase the exercise of market power (Federal Trade Commission, 2010).

Such concentration ratios were critical in the structure-conduct-performance school of competition analysis, popularized by (Bain, 1951). Subsequently, the New Empirical Industrial Organization (NEIO) methodology became preferred. The NEIO approach attempts to build on earlier work in the industrial organization field by generalizing traditional perfect competition, monopoly, and Cournot and Bertrand duopoly models.

The NEIO approach allows for an intermediate exercise of market power between perfect competition and monopoly. Such an approach has been referred to as an example of "generalized Cournot and Bertrand oligopoly models" (Suzuki, 2006)

The NEIO literature often attempts to estimate the conjectural variation of firms in a market (Martin, 1993). One view of conjectural variation is a very literal interpretation: the amount of a firm's change in activity that can be ascertained from its conjecture about its competitors. A second, more common approach is as a generalized measure of market competitiveness (Karp, 1989). This attempts to measure how much of the market price of a given product is due to the exercise of market power. This has been shown to be the same solution as a quantity setting repeated game (Cabral, 1995).

Lerner and others have argued that the cost based approach to determining market power is superior to other measures of market power, because it is not subject to complicated discussions about market definition, and focuses on the firm's decision to price above marginal cost due to firm-specific factors such as demand elasticity (Elzinga, 2011).

Further, Lerner argued that his Index appropriately measured "monopoly *in force*," as opposed to mere "*potential* monopoly." (Lerner, 1934 p.170, emphasis in original). Subsequent commentators have supported that conclusion, offering substitution in consumption, substitution in production, the presence of a competitive fringe of firms, and potential entry of new competitors as factors that may mitigate the exercise of market power by firms with large market share (Landes, 1981).

While the Lerner Index is an important and often cited measure of market power, it is not without its limitations. Landes and Posner contend that the Lerner Index is an "upper estimate, not a precise estimate" of the deviation from the competitive price (Landes and Posner, p.941). Others contend that some deviations from marginal cost pricing arise from reasons that are not anti-competitive, such as the need to cover fixed costs, or from efficient uses of scale (Lindenberg, 1981).

Another limitation addressed is that the Lerner Index measures only static exercises of market power. Lerner posited that the Index over a series of periods would simply be the average of the Index over each individual period. That definition, however, does not help determine market power in industries where pricing decisions are made intertemporally, such as those with extractable resources.

The intertemporal nature of price and cost determination in industries with extractable resources is represented by a "user cost" or Hotelling rent, term. The Hotelling rent represents the decrease in future profit based on extraction of the resource today (Hotelling, 1931). (Pindyck, 1985) includes a term for the Hotelling rent in the static price expression, so that P=MC becomes $P=MC + \lambda$ in the case of the extractable resource firm, with λ representing the user cost/Hotelling rent.

Hotelling concluded that in determining the user cost, "[i]t is likely that . . . no large errors will be made using the market rate of interest." (Hotelling, p. 145). Subsequent commentators have concluded that many factors affect the costs related to extraction. One aspect is that continued depletion of the resource can lead to increased extraction costs through time (Ellis and Halvorsen 2002). However, there is also a potential "learning curve" effect across time as firms "learn by doing" and discover better extraction methods (Pindyck, 1985 p. 207). The learning curve effect could lead to a generally decreasing cost function across time.

III. Theoretical Model

Modeling the dynamic cost function of a firm in an extractable resource industry begins with a quadratic cost function:

$$(1)\ TC_t = \alpha_1 + \alpha_2 Q_t + \alpha_3 {Q_t}^2 + \alpha_4 Q_t X_t + \alpha_5 Z_t$$

Where Q is the quantity sold; X represents exogenous unit input costs, and Z is the cumulative production (the sum of the quantities into from the beginning of the time horizon to the previous time period).

The cumulative production, Z, term allows us to ascertain the user cost term. In keeping with the (Ells, 2002) approach, the user cost here also reflects the marginal cost of any increase in the future cost of production resulting from extraction in a given period.

From the user cost, we can ascertain the marginal user cost, which will lead to a testable hypothesis concerning market power. In the static case of a perfectly competitive market, the following condition would hold:

$$(2) P_t - MC_t = 0$$

However, in the case of dynamic optimization of an extractable resource, the following is the condition for perfect competition:

$$(3) P_t - MC_t - MUC_t = 0$$

Where MUC is the marginal user cost.

From the total cost function, we can find the Present Value of the Total Cost function over the entirety of the planning horizon:

$$(4)\ PVTC_t = TC_t + BTC_{t+1} + B^2TC_{t+2} + ...B^TTC_T$$

PVTC is the net present value of the total cost of the firm over the entire planning horizon, TC is the individual cost function at any given time t, and B is the discount factor.

Obtaining marginal cost from (4) is shown as follows:

$$(5)\ \frac{\delta PVTC_t}{\delta q_t} = \frac{\delta TC_t}{\delta q_t} + \beta \frac{\delta TC_{t+1}}{\delta Z_{t+1}} \frac{\delta Z_{t+1}}{\delta q_{t+1}} + ...\beta^T \frac{\delta TC_T}{\delta Z_T} \frac{\delta Z_T}{\delta q_T}$$

T represents the final period in the planning horizon. $\frac{\delta TC_t}{\delta q_t}$ is the marginal cost for the current period. Additionally, because Z is the cumulative quantity in the current period, the change in Z from on period to the next is the same value as the quantity. Thus, $\frac{\delta Z_{t+1}}{\delta q_{t+1}}$ equals 1. Finally, the $\frac{\delta TC_{t+1}}{\delta Z_{t+1}}$ equals the α_5 coefficient from equation (1). Equation (5) then reduces to the following:

$$(6)\ \frac{\delta PVTC_t}{\delta q_t} = MC_t + \beta\alpha_5 + \beta^2\alpha_5 + ...\beta^T\alpha_5$$

We then factor (6) to arrive at the following:

$$(7)\ \frac{\delta PVTC_t}{\delta q_t} = MC_t + \beta\alpha_5(1 + \beta + \beta^2 + ...B^{T-1})$$

Equation (7) can then be rewritten as follows:

$$(8)\ \frac{\delta PVTC_t}{\delta q_t} = MC_t + \beta\alpha_5\left(\frac{1-\beta^T}{1-\beta}\right)$$

In (8), the term $\beta\alpha_5(\frac{1-\beta^T}{1-\beta})$ represents the marginal user cost term in (3). The real interest rate is assumed to be 5% over the planning horizon, which is assumed to be 100 years (or 400 quarters) based on the reported reserves of the Canpotex firms.

IV. Empirical Model

For the dynamic cost model, the basic model for each of the three Canpotex firms is as follows:

$$(9) TC_{it} = \alpha_0 + \alpha_1 Qi_t + \alpha_2 Q_{it}{}^2 + \alpha_3 X_{it} Q_t + \alpha_4 Zi_t + \varepsilon_{it}$$

The variables are as described in (1). The regressions in this paper use average cost as the dependent variable rather than total cost. Thus, each term in (9) is divided by Q, yielding the following estimating equation:

$$(10) AC_{it} = {}^{\alpha_0}/_{Q_{it}} + \alpha_1 + \alpha_2 Q_{it} + \alpha_3 X_{it} + \alpha_4 {}^{Z_{it}}/_{Q_{it}} + \varepsilon_{it}$$

Summary Statistics are reported in Tables 5 and 6.

V. Results

Results for each firm are shown below in Table 7. Of note in the results is that the firms all face declining average cost over the observed range of quantities. As noted earlier, declining average cost industries present problems for economic analysis, and potentially leads to a “natural monopoly.” Whether this is one such instance will be discussed later. Also of note is that for the significant variables, the sign and magnitude of the coefficients are similar for POT and AGR. This indicates that the firms are facing substantially similar cost structures. For both firms, we see that the cumulative production term is positive and highly significant, showing that increased cumulative extraction is associated with increased overall costs for the firm. This is consistent with theoretical expectations that the user cost would be positive. Further, it indicates that a static Lerner Index would, as expected, understate the relevant costs, and thus overstate market power.

Originally, the MOS results produced a nonsensical estimate for the cumulative production term. The sign was negative, and the result was insignificant. Because data for MOS was reported only back to 2004, only 26 quarters of data are available, as opposed to 57 for POT and AGU. Because of the irregular results, the model was estimated again without the average cumulative cost term, and the results are presented above. Once again, the limited sample size creates problems of lack of significance.

For MOS, then, MUC is determined to be zero, because the extraction cost was insignificant. A number of possibilities may explain that. First, the small sample size could be affecting the results. Additionally, as noted earlier, MOS was founded in 2004 as a result of a merger of other companies. Further, MOS was acquisitive during this period, adding new operations domestically and internationally. This increased volatility, and presents a number of economic, accounting, and logistical issues. All results are reported. The full model, accounting for the time trend to reflect the time related changes, is used to provide the estimate of the change in AC with respect to quantity in the calculation of MC. Though none of the estimates of that coefficient were significant, their magnitudes are relatively similar. The lack of significance may make the P-AC measure more economically meaningful.

Heteroskedasticity was a potential problem for these results. Breusch-Pagan and Cook-Weisberg tests did show that heteroskedasticity was present in the data. Regressions were then run on the data with heteroskedasticity corrected errors, and showed substantially similar results.

In addition to the marginal and average cost data, the marginal user cost of the extractive resource is needed to ascertain whether market power is being exerted. In perfect competition, price minus marginal cost minus marginal user cost would be equal to zero, in accordance with equation (3). Price-MC-MUC results for all 3 firms are shown below in Figure 2, while P-AC-MUC results are shown in Figure 3.

Figure 2 - Deviation from First Order Conidtion

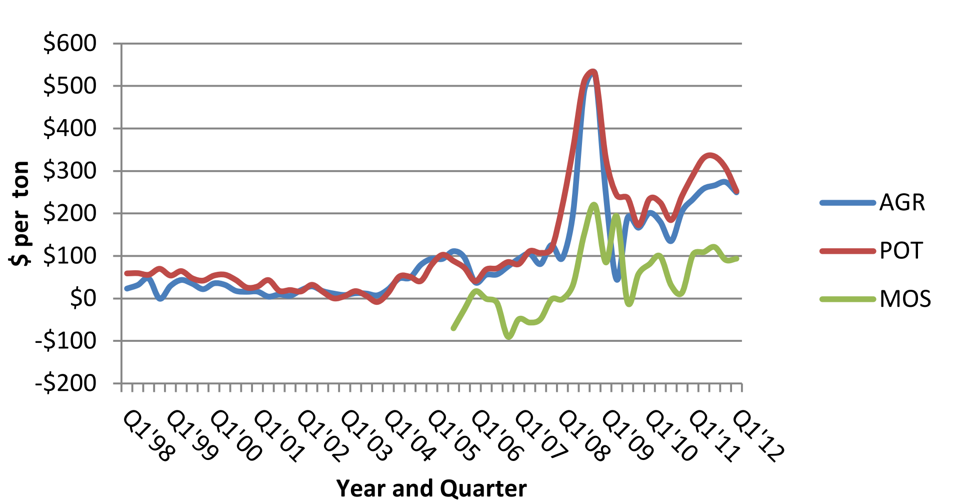
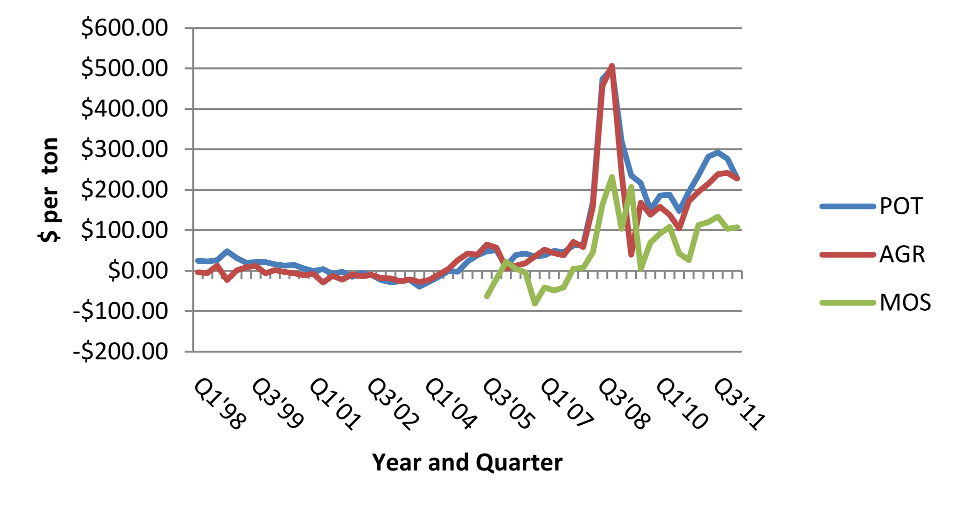


Figure 3 - Deviation from AC pricing



From the above, we see that market power diminished until approximately 2004, and then substantially increased. This is apparent on the chart when P-MC-MUC becomes much larger than zero.

The AC analysis is important because the industry appears to be a declining cost industry. In the presence of declining long run AC at every point, the long run MC curve will be perpetually below the AC curve. Thus, MC pricing would lead to losses, and we'd expect the prices to be different from marginal cost. Pricing based on AC is often used by regulators in the case of declining long run AC leading to a natural monopoly situation.

Also of interest is that P-AC-MUC was often negative for POT and AGU between 2000-2004, as well as P-AC and P-MC in some early MOS quarters. A potential explanation could be predatory pricing behavior: the firms may have been intentionally lowering prices to artificially low levels in an effort to squeeze higher cost competitors out of the market or force them to sell. Indeed that period – and the sample period generally – has seen much acquisitive activity for POT and AGU. Over the course of this sample, POT acquired or increased equity stakes in other producers 15 times.[2] Between 1999 and 2004, POT acquired or expanded equity stakes in companies in Israel, Chile, Jordan, and China. AGU made 17 such acquisitions over the sample period.[3] MOS, as noted earlier, was formed in 2004 as the result of a merger between IMC Global and a division of Cargill. While this paper does not attempt to prove predatory pricing behavior – and indeed does not prove it – these results would be consistent with such behavior.

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[2] http://www.potashcorp.com/about/history/
[3] http://www.agrium.com/includes/Corporate_History_Summary_2011_AWB.pdf

Further supporting such a hypothesis is the subsequent large spike in price relative to MC and AC immediately after that period.

In order to test these hypotheses, t tests were run to ascertain if the means of the P-MC-MUC and P-AC-MUC results are equal to 0. Such tests were run on the entire sample for each firm, as well as the suspected periods of predatory pricing. The results are shown below in Table 8.

Here, we see that the mean for all firms is greater than zero; that is to say that price is deviating from the assumed competitive level even when accounting for marginal user cost and the possibility that average cost pricing, not marginal cost pricing, would be preferred. Further, Table 8 shows that price was indeed below AC-MUC during the periods in question for POT and AGU. Those periods of below average cost pricing were followed by periods of a sharp increase in price. This is consistent with the hypothesis that prices were artificially low in order to squeeze competitors out and raise prices above the competitive level later. We do see a similar pattern with MOS over a different time period, though different explanations may be in order.

The broader implications are clear across the Canpotex firms: pricing is deviating from apparent competitive levels, even accounting for the declining cost nature of the industry and the dynamic effects of the user cost. Further, this deviation appears to be increasing over time beginning from around 2005 to the present.

V. Conclusion

The exercise of market power in the potash fertilizer market appears substantial, and market power has been on the rise in the past 5-7 years. Canpotex member companies are charging a retail price substantially higher than the sum of marginal cost and marginal user cost. Further, the difference between the two is increasing dramatically.

That such market power induced price hikes began around 2004 corresponds with the end of an acquisition spree by the larger producers (i.e. the Canpotex and BPC firms) suggests that the acquisitiveness substantially harmed competition. Further, that prices, and price versus cost margins, dropped during the time periods immediately preceding the spike (the margins dropping to near zero), suspicion of predatory pricing behavior by the leading firms during that period may have been occurring.

Appendix A

Data

The data for the firm level cost analysis come from the 10-Q[4] filings – required disclosures under federal securities law including, inter alia, financial statements – of Potash Corporation of Saskatchewan (POT), Mosaic (MOS), and Agrium (AGU). For POT and AGU, public filings date from the first quarter of 1998 to the first quarter of 2012, for a period of 57 quarters. MOS did not go public until the mid 2000s. Thus, only 26 quarters of data, from the first quarter of 2007 to the first quarter of 2012, are available.

Price and cost data are in real terms subject to the implicit price deflator and producer price index (PPI) for mining industries.

[4] A 10-Q form is a required quarterly disclosure form for publicly traded companies in the United States. The filings include, among other items, financial statements.

Table 5 Summary Statistics – POT/AGU

	N	Mean	Std.Dev	Minimum	Maximum
Quantity	57	1804.035	521.562	394	2318
Quantity reciprocal	57	.000636	.000360	.000356	0.00253
PPI/IPD	57	1.563	0.115	1.408	1.837
AvgCumProduct	57	32.159	35.528	0	206.541

Table 6 Summary Statistics – MOS

	N	Mean	Std.Dev	Minimum	Maximum
Quantity	26	1660.37	491.013	647	2510
Quantity reciprocal	26	.000682	.000296	.000398	.00155
PPI/IPD	26	1.190	.103	.994	1.332
AvgCumProduct	26	15.332	11.817	0	40.884

Table 7 Estimated Cost Functions

	POT	MOS	AGU
constant	157.653***	-1420.791**	34.05603
	(33.111)	(657.823)	(80.763)
Quantity	-.0195***	.0711	-.081**
	(.004)	(.093)	(.032)
Quantity reciprocal	-79279.28***	248818**	-5425.619
	(12496.33)	(137328.2)	(6062.979)
PPI/IPD	-12.336	1200.794**	64.99
	(18.185)	(432.759)	(43.541)
AvgCumProduct	1.4656***	-6.564	1.088***
	(.110)	(3.183)	(.248)
R-squared	.945	.659	.892
Adj R-squared	.941	.554	.884
N	57	26	57

Standard errors appear in parentheses
*significant at 10%
** significant at 5%
***significant at 1%

Table 8 – Deviations from FOC Consistent with predatory pricing

Company and period	P-MC-MUC	P-AC-MUC
POT full sample	122.85(16.86)***	82.09(16.44)***
POT 2000-2004	26.57(4.29)***	-8.88(3.49)**
POT 2005-2012	207.55(24.10)***	160.06(24.61***
AGU full sample	99.55(14.94)***	64.72(15.09)**
AGU 2000-2004	22.57(4.13)***	-12.03(2.89)**
AGU 2005-2012	172.10(21.99)***	135.67(22.87)***
MOS full sample	41.98(15.37)***	52.25(15.77)**
MOS 2004-2007	-30.69(10.28)**	-23.67(10.07)**
MOS 2008-2012	91.94(15.30)***	104.44(15.32)***

Standard errors in parentheses
*significant at 10%
** significant at 5%
***significant at 1%

Chapter 3

Clear, Convincing, and Insignificant: Economics as Legal Evidence in the Age of *Daubert*

Abstract: The difference between traditional standards of scientific significance, empirical economic results, and legal evidence is discussed. The traditional standards of statistical significance were not designed with legal evidentiary standards, which can lead to decisions regarding the presentation of economic evidence that do not necessarily jibe with the relevant legal standards.

Introduction

This paper attempts to address the intersection of economics, legal fact finding, evidentiary standards, and statistics – to bridge the gap between the "numbers crunching" world of modern empirical economics, and the largely non-quantitative world of legal theory and practice

Section I describes the relevant legal standards, both for fact finding (e.g. reasonable doubt, preponderance of evidence), and for the weight and admissibility of evidence. Section II describes the standards behind statistical measurement and reporting of statistical results. Section III describes the types and instances of the introduction of economic evidence. Section IV discusses the relationship between statistics and economic analysis. Section V analyzes the confluence of the legal, statistical, and economic issues, and Section VI concludes with policy recommendations.

I. Legal Standards

A variety of legal standards exist for fact-finding, admissibility, regulatory review, and other decisions. The Supreme Court has noted as follows:

> "The function of a standard of proof, as that concept is embodied in the Due Process Clause and in the realm of fact-finding, is to 'instruct the fact-finder concerning the degree of confidence our society thinks he should have in the correctness of factual conclusions for a particular type of adjudication. . . . The more stringent the burden of proof a party must bear, the more that party bears the risk of an erroneous decision."[5]

Thus, standards vary based on the confidence level deemed appropriate based on the consequences of an erroneous decision. This section describes briefly the most important standards of proof for decision making by fact finders.

A. Reasonable Doubt

Perhaps the most widely known standard for legal fact-finding/decision-making is "beyond a reasonable doubt." Proof beyond a reasonable doubt is constitutionally required in the United States for a criminal conviction.[6] The Supreme Court has held that such a standard must be met in order to ‘‘impress on the trier of fact the necessity of reaching a *subjective* state of certitude of the facts in issue.’’[7] The use of the word "subjective" indicates the reality that a precise definition of "reasonable doubt" has not emerged. The Supreme Court has acknowledged as much, stating that ""[a]ttempts to explain the term 'reasonable doubt' do not usually result in making it any clearer to the minds of the jury."[8]

It is clear that "reasonable doubt" does not mean the absence of any doubt whatsoever:

> Proof beyond reasonable doubt does not mean proof beyond a shadow of doubt. The law would fail to protect the community if it admitted fanciful possibilities to deflect the course of justice. If the evidence is so strong...as to leave only a remote possibility in [the accused's] favor, which can be dismissed with the sentence "of course it's possible but not in the least probable," the case is proved beyond reasonable doubt, but nothing short of that will suffice."[9]

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[5] *Cruzan et al v. Director, Missouri Department of Health,* 497 U.S. 261 (1990).
[6] *In re Winship*, 397 U.S. 358, 90 S. Ct. 1068, 25 L. Ed. 2d 368 (1970).
[7] *Ibid.* at 397 U.S. 364 (*emphasis added).*
[8] *Miles v. United States* 103 U.S. 304 (1880)
[9] *Phipson on Evidence* 17th ed (2009)

The Supreme Court has even applied the language of probability and statistics in discussing the reasonable doubt standard:

> "[t]here is always in litigation a margin of error, representing error in factfinding, which both parties must take into account. Where one party has at stake an interest of transcending value—as a criminal defendant his liberty—this margin of error is reduced as to him by the process of placing on the other party the burden of persuading the fact-finder at the conclusion of the trial of his guilt beyond a reasonable doubt.[10]

Difficulty in defining "reasonable doubt," or in quantifying the appropriate amount of doubt "permitted" under the standard has led some courts, including the 7th Circuit (the Court most traditionally associated with Law and Economics analysis) to refuse to precisely define it. The 7th Circuit compares attempting to define "reasonable doubt" to "playing with fire."[11] It is worth noting that the 7th Circuit has defined what "reasonable doubt" is *not*, rejecting "substantial doubt," and "honest doubt."[12]

Some jurisdictions have, in fact, attempted to define reasonable doubt. Georgia notes that the "reasonable doubt" standard does not require "mathematical certainty"[13], but merely that a juror's mind is "wavering, unsettled, or unsatisfied."[14] Massachusetts, like many other jurisdictions, equates "reasonable doubt" to "moral certainty."[15] Florida defines a "reasonable doubt" as one which is more than merely "speculative," and one that causes the juror's mind to "waver or vacillate" vis-à-vis the defendant's guilt.[16]

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[10] *Speiser v. Randall*, 357 U.S., 513, 525—526, 78 S.Ct.1332, 1342 (1958) (*emphasis added*).
[11] *United States v. Shaffner*, 524 F.2d 1021, 1023 (7th Cir. 1975),cert. denied, 424 U.S. 920 (1976).
[12] *Pattern Jury Instructions of the 7th Circuit*
[13] Georgia Pattern Jury Instructions
[14] *Ibid.*
[15] Mass. Pattern Jury instructions
[16] Florida Pattern Jury Instructions

Clearly, no quantifiable definition of "reasonable doubt" exists. Instead, perhaps most instructive are the negative definitions, defining proof beyond a reasonable doubt as something greater than mere speculation, but less than 100% absolute proof of guilt.

B. Preponderance of the Evidence

The most common evidentiary standard in civil proceedings requires proof by a preponderance of the evidence. To prevail under the preponderance standard, a plaintiff must establish his or her claim by "the greater weight of the evidence."[17] As with the reasonable doubt standard, a precise definition of preponderance of the evidence in quantitative terms has not emerged. However, the general layman's interpretation – slightly more than 50% likelihood – has support in the law.

An influential English case[18] summarized the standard as follows:

> That degree [preponderance of the evidence] is well settled. It must carry a reasonable degree of probability, not so high as is required in a criminal case. If the evidence is such that the tribunal[19] can say: 'we think it more probable than not', the burden is discharged, but if the probabilities are equal it is not.[20]

In that vein, American authorities have used substantially similar language, such as, "[t]o establish by a preponderance of the evidence means to prove that something is more likely so

[17] Hill, Gerald and Kathleen. *The People's Law Dictionary.*

[18] While English law is not binding in the United States, our common law system is inherited from the British legal system. In the American legal system, English legal decisions are often cited as instructive or persuasive, but not binding, authority.

[19] It's worth noting that in the British civil justice system, juries are not usually the trier of fact. By contrast, in the United States, the 7th Amendment to the United States Constitution guarantees the right to a jury trial if the parties so demand.

[20] *Miller v. Minister of Pensions. 2* All ER 372 (1947).

than not so."[21] Other variations on the same motif include California's Pattern Jury Instructions, which state the following:

> A party must persuade you, by the evidence presented in court, that what he or she is required to prove is more likely to be true than not true. . . . After weighing all of the evidence, if you cannot decide that something is more likely to be true than not true, you must conclude that the party did not prove it.[22]

While "preponderance" can be generally said to equate to "more likely than not," quantifying how much more likely has been more problematic. Sources attempting to define "preponderance" for laypeople may say things such as, "[t]he plaintiff must convince the judge or jury by a preponderance of the evidence that the plaintiff's version is true -- that is, over 50% of the . . . evidence is in the plaintiff's favor."[23] Such a direct quantitative comparison would make translation of legal standards to probabilistic and statistical decision making quite easy.

However, legal authorities have been more reluctant to be so quantitatively specific. For example, Illinois has stated that "the slightest preponderance" is sufficient for a plaintiff to prevail, but advises against any specific instructions to jurors on any description of how much more the evidence must favor the plaintiff.[24] Another interpretation is that, "[a] bare preponderance is sufficient, though the scales [of justice] drop but a feather's weight."[25] While statisticians and econometricians may not have a precise equivalent for "a feather's weight," a safe definition of "preponderance of the evidence" for the purposes of this paper is a likelihood of somewhat greater than 50%.

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[21] Devitt and Blackman, *Federal Jury Practice and Instructions* (1977).
[22] California Civil Jury Sections §200.
[23] "No-Lo's Online Legal Dictionary." http://www.nolo.com/dictionary/preponderance-of-the-evidence-term.htmlaccessed June 30, 2013.
[24] Teter v. Spooner, 305 Ill. 198, 211, 137 N.E. 129, 135 (1922)
[25] *Livanovitch v. Livanovitch*, 99 Vt. 327 131 A. 799 (1926).

C. Clear and Convincing

Another, somewhat less frequently used, standard of proof is "clear and convincing."[26] Clear and convincing lies somewhere between reasonable and doubt and preponderance of evidence on the continuum of legal standards. It can be described as follows:

> . . . [a] medium level of burden of proof which is a more rigorous standard to meet than the preponderance of the evidence standard, but a less rigorous standard to meet than proving evidence beyond a reasonable doubt. In order to meet the standard and prove something by clear and convincing evidence, a party must prove that it is substantially more likely than not that it is true.[27]

Once again, terms such as "medium level" and "more/less rigorous than reasonable doubt/preponderance" are of limited utility in assigning quantitative interpretations. This problem is compounded by the fact that the two standards in between which clear and convincing falls – reasonable doubt and preponderance of the evidence – are themselves difficult to pin down precisely. Thus, for the purposes of this paper, we'll have to simply evaluate clear and convincing as somewhat higher than the "just over 50%" probability required to satisfy the preponderance requirement, and somewhat less than the very, very high probability required to meet the reasonable doubt standard.

D. Standards for Scientific Evidence: *Frye, Daubert,* and beyond

Economists, like other scientists and social scientists, sometimes are called upon to present evidence via expert testimony. Such testimony may include scholarly work specific to the facts and circumstances of the litigation, work that precedes the litigation, or both. Admissibility of expert testimony was traditionally governed by various common law standards[28] and rules of

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[26] Clear and convincing evidence is often required to establish civil fraud, and in various family law situations, ranging from child custody to "right to die." It is also frequently required to prevail in various intellectual property related actions, as well as in proving the availability of punitive damages.

[27] Legal Information Institute, Cornell University.

[28] See, e.g., *Frye v. United States*, 293 F. 1013, (D.C. Cir.).

evidence.[29] For much of the 20th century, the *Frye* standard for expert and scientific evidence was predominant in the United States. The *Frye* standard required that scientific evidence be "generally accepted."[30] In 1993, the United States Supreme Court announced major changes for standards of expert testimony in its ruling in *Daubert v. Merrell Dow Pharmaceuticals*.[31]

Daubert was an action on behalf of two minor children from California, alleging that they had suffered birth defects as a result of their mothers use of the pharmaceutical Bendectin[32] while pregnant. The plaintiff presented the testimony of some eight experts, testifying that Bendectin was indeed a potential cause of the malady in question.[33] However, the defendants' expert countered (correctly) that the existing literature did not suggest a link between Bendectin and the deformity.[34] The Supreme Court found the *Frye* standard incompatible with the "liberal thrust" of the Federal Rules of Evidence[35], and announced a new standard (for Federal jurisdictions).

The *Daubert* standard is as follows:

1) The trial judge serves as "gatekeeper," to ensure that expert testimony is based on scientific knowledge;
2) The putative evidence must be based on reliable methods and relevant to the task at hand;
3) The evidence must be based on the scientific method.[36]

Whether or not the methods are reliable and based on the scientific method is to be determined based on the following criteria:

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[29] See, e.g., Fed R. Civ. P. 702.
[30] See *Frye*, *supra,* at n. 24.
[31] 509 U.S. 579 (1993).
[32] *Ibid.*
[33] *Id*. at 583.
[34] *Id.* at 582.
[35] *Id.* at 589.
[36] *Id.* at 584-593

1) Whether the evidence is falsifiable empirically;

2) Whether the evidence has been subject to peer review and has been published;

3) The "known or potential error rate" of the technique involved in the empirical testing;

4) The degree to which the evidence proffered is "generally accepted" in the scientific community.[37]

The Court in *Daubert* was clear that this standard is "flexible," and at the discretion of the judge (gatekeeper).[38] The *Daubert* standard has been extended to all "technical" evidence (beyond evidence that would traditionally be understood to be "scientific,")[39] and all testimony by experts.[40]

II. Statistical Standards and Tests

Basic concepts and issues in utilizing statistical results are discussed in this section.

A. Classical Type I & Type II Error

The issues discussed in this section largely arise from the statistical concept known as "hypothesis testing." Hypothesis testing is a dichotomous way to test claims or ideas about a group or population using data about that population. The maintained hypothesis being tested is known as the "null hypothesis."[41] The other possibility is known as the "alternative hypothesis."[42]

For example, if we suspect that the mean value of a population is 15, the null hypothesis would be denoted as $H_0 = 15$. The alternative hypothesis, denoted as H_A, would be that the mean

[37] *Id.* at 593-594.
[38] *Id.* at 594.
[39] *General Electric Co. v. Joiner*, 522 U.S. 136 (1997).
[40] *Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999).
[41] Greene, William H. *Econometric Analysis* (2008)
[42] *Ibid.*

does not equal 15. In classical statistics, the sample data are then analyzed based on a pre-determined "significance level" to ascertain whether to accept or reject the null hypothesis.

In the legal context, a "null hypothesis" is roughly analogous to a "rebuttable presumption." The most famous such presumption is, of course "innocent until proven guilty." Thus, in the criminal context, the null hypothesis for each element of the claim would be "not guilty;" conviction would be the equivalent of rejecting the null. It's important to acknowledge that the analogy generally holds up even farther: failure to reject the null is not conclusive proof that the alternative hypothesis is true; to the contrary, it merely means that there isn't enough evidence to reject it. This is similar to a finding that the party with the burden of proof failed to meet its burden in litigation.

The following figure shows us the possible outcomes of the hypothesis test:

Figure 4 – Legal and Statistical Decisions Compared

Decision	H_0 is true		H_0 is false	
	Statistical Term	**Legal Equivalent**	**Statistical Term**	**Legal Equivalent**
Reject Null	Type I error	Convict an innocent party	No error	Convict guilty party
Do not reject Null	No error	Acquit an innocent party	Type II error	Acquit a guilty party

Color code:

Red= factually and legally erroneous

Green=factually and legally correct

Yellow= factually incorrect, but legally acceptable

In the above chart, we see the two types of error: Type I error (erroneously rejecting a true null), and Type II error (erroneously accepting a false null). The level of significance, described *supra,* can be described as the probability of making a Type II error. That level is sometimes referred to as a p-value.[43]

B. Regression Analysis, Causation, and Correlation

The most common form of analysis in empirical economics – and one commonly used by expert witnesses in litigation - is called regression analysis. Regression analysis is a statistical measure of the relationships between variables.[44] Take, for example, an antitrust investigation. In such an investigation, we would be seeking to ascertain if a firm or firms were exercising market power in pricing. We would create an equation in which the output price was "dependent variable," and a variable representing a market power term was an "independent variable." A full regression analysis would include the type of hypothesis testing described, *supra*, testing whether there is a significant relationship between the dependent and the independent variables related to market power.

Classical statisticians conclude that correlation is "significant" if the test statistic shows that the probability of Type I error is less than the pre-established criterion. "Correlation" is a numerical measurement of the relationship between two variables. The null hypothesis is that the correlation between the dependent and independent variables is zero – that is, in our above example, that there is no relationship between potential market power and the output price of the product. If we reject that null hypothesis, we find that the relationship is "significant," and thus there is correlation between the two.

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[43] *Ibid.*
[44] Sykes, Alan "An Introduction to Regression Analysis." Coase Lecture, 2002.

We can also measure the correlation of a model that includes more than one independent variable. This measure is called the "R^2" measure. The R^2 measure is between 0 and 1, and shows how much of the variation of the dependent variable is explained by the model including all independent variables. If, for example, the R^2 is .50, then the model explains half of the variation in the dependent variable.

In the legal context, however, correlation alone is insufficient. In criminal and civil litigation, causation is almost always an element that must be established in order to assign liability. Even in pre-litigation or non-litigation contexts, causation looms large. Continuing with the market power example, the Federal Trade Commission (FTC) or Department of Justice (DoJ) may perform a regression analysis like the one described in this section as part of a preliminary investigation to determine if further inquiry is needed. In any context, however, ascertaining whether the potential market power causes the price increase, or is merely associated with such an increase is important to determining the appropriate legal response.

The existence of correlation does not necessarily guarantee such a causal relationship. One potential non-causal source of correlation is spurious correlation. "Spurious correlation" is a correlation between two variables that arises as a result of a primary correlation between other variables.[45] The Supreme Court[46] has addressed this issue in the context of a case in which strip clubs were purported to cause prostitution and other sexual offenses:

> To say that pernicious secondary effects are associated with nude dancing establishments is not necessarily to say that such effects result from the persuasive effect of the expression inherent in nude dancing. It is to say, rather, only that the

[45] *Barnes v. Glen Theatre, Inc. (Souter, J)* 501 U.S. 560 (1991).
[46] *Ibid.*

> effects are correlated with the existence of establishments offering such dancing, without deciding what the precise causes of the correlation actually are. It is possible, for example, that the higher incidence of prostitution and sexual assault in the vicinity of adult entertainment locations results from the concentration of crowds of men predisposed to such activities, or from the simply viewing of nude bodies, regardless of whether those bodies are engaged in expression or not. In neither case would the chain of causation run through the persuasive effect of the expressive component of nude dancing.

A similar rationale could potentially explain away a correlation in our antitrust example: the rise in prices could be caused by increased by increased input prices in the industry, which in turn force inefficient producers out of the market. Thus, a firm may have an increasing market share, for example, and be raising output prices, but for no other purpose than keeping up with rising input prices. Further discussion on establishing causation (including actual and proximate causation), controlling for other factors, etc. is *infra* in Section III.C.

C. Statistical Significance as a Continuum

As noted, *supra*, most scientific journals implicitly require significance at the 5% level. If relationships are not significant at that level, they will be reported as insignificant, as if there were zero relationship between the dependent and independent variables. For reasons of admissibility and weight in litigation, especially in a post-*Daubert* world, the standards for publication are highly important. More on that will follow, *infra*, in Section III.A. However, while academic journals may approach significance as a type of cliff effect – where variables go from being highly significant at the 5% level to totally insignificant at the 6% level – the underlying statistical theory tells a different story.

As noted earlier, statistical significance is the probability of making a Type I error (incorrect rejection of a true null) at given critical values. Because the value is a probability, it may take any value between 0 and 1. Thus, a 5% significance level means that there is a 5% likelihood of rejecting a true null; 10% a 10% likelihood, 20% a 20% likelihood, etc. The decision of what significance level is appropriate depends on many factors. As Snedecor and Cochran[47] have noted,

> There is no single answer [to what significance level should be used]. . . . The practice most commonly followed in statistics is to choose a critical value . . . such that the probability of rejecting [the null hypothesis] when it is true is 0.05, or 5%. . . . A level of 0.01, or 1%, is sometimes employed when incorrect rejection of the null hypothesis is regarded as a serious mistake. Other levels - 10% or 20% - may be used when considered appropriate.

Warning against "rigid or hard and fast approach[es] to the setting of significance levels,"[48] venerable statistician Sidney Siegel stated the following:

> . . . [O]bjectivity demands that α [the level of significance] be set in advance of the collection of the data. *The level at which the researcher chooses to set α should be determined by his estimate of the importance or possible practical significance of his findings.* In a study of the possible therapeutic effects of brain surgery, for example, the researcher may well choose to set a rather stringent level of significance, for the dangers of rejecting the null hypothesis improperly (and therefore justifiably advocating or recommending a drastic clinical technique are great indeed. In reporting his findings, the researcher should indicate the actual probability level associated with his findings, *so that the reader may use his own judgment in deciding whether or not the null hypothesis should be rejected.* A researcher may decide to work at the .05 level, but a reader may refuse to accept any finding not significant at the .01, .005, or .001 levels, while another reader may be interested in any finding which reaches, say, the .08 or .10 levels. The researcher should give his readers the information they require by reporting, if possible, the probability level actually associated with the finding. *[Emphasis added]*

Thus, according to Siegel, 1) there is no "bright line" rule regarding significance levels; 2) reasonable observers can disagree as to what the appropriate significance level is; 3) the

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[47] Snedecor, George W. and William G. Cochran. *Statistical Methods 7th Edition* pp. 64-65.
[48] Siegel, Sidney. *Nonparametric Statistics for the Behavioral Sciences*, pp.8-9. (1956)

appropriateness depends largely on the circumstances, and 4) it is the researcher's job to present as much information as possible to the reader so that the reader can make up his or her own mind. All of these observations are critical in the legal context. The lack of a "bright line" will be addressed, *infra* in discussions of the *Daubert* standard. That the appropriate significance level varies with particular situations already lends itself to legal situations: different burdens of proof or standards for admissibility may call for different levels of significance. In the same way that criminal sanctions – those that can deprive a person of life or liberty – require a heightened standard of proof, in statistics "the choice of [s]ignificance level' will depend on the seriousness of a wrong decision."[49]

Perhaps most importantly, per Siegel, whether or not a particular variable is significant based on the pre-selected standards of the researcher, whatever level of significance should be reported to the reader. In the legal context, the "reader" may be a judge, jury, arbitrator/mediator, or some other decision maker.

D. Experimental vs. Non-experimental Statistical Analysis

One area in which economic evidence (and other statistical evidence from other social sciences) differs from statistical evidence from "hard sciences" is that the overwhelming majority of empirical economic data are observational – in other words, non-experimental - data. This is in contrast to hard sciences – such as chemistry or biology – that rely mainly on data from controlled, laboratory experiments. Such laboratory environments allow the researcher to directly control relevant aspects of the experiment, ensuring that the relationships between the variables – including causal, and not just correlative, relationships – are clear.

[49] Steel, Robert G.D and James H. Torrie. *Principles and Procedures of Statistics* pp. 46-47. (1960).

Economists must attempt to replicate experimental conditions from observational data in order to ascertain economic relationships, such as in the previous example of market power and market price. Economists often refer to such data as resulting from "natural experiments" and attempt to design their research questions accordingly[50]:

> A design of experiments (a prescription of what the physicists call a "crucial experiment") is an essential appendix to any quantitative theory. And we usually have some such experiment in mind when we construct theories although – unfortunately – most economists do not describe their design of experiments explicitly. If they did, they would see that the experiments they have in mind may be grouped into two different classes, namely, (1) experiments that *we should like to make* to see if certain real economic phenomena – when artificially isolated from "other influences" – would verify certain hypotheses, and (2) the stream of experiments that Nature is steadily turning out from her own enormous laboratory, and which we merely watch as passive observers. In both cases the aim of the theory is the same to become master of the happenings of real life. [*Emphasis in original*]

Thus, the ideal economics study attempts to replicate experimental conditions. So, in our market power example, we would attempt to construct the research question in such a way that we could mimic a laboratory experiment in which the effect of market power – and only the effect of market power – was evident on the market price of the good. However, econometricians have acknowledged the difficulty with such a process[51]:

> Economic theory, through a formal deductive system, provides the basis for experimental abstraction and the experimental design, but society in most cases carries out the experiment, possibly using its own design. Therefore the economic researcher observes the outcome of society's experiment or performance but has little or no impact on the experimental design and the observations generated. This means that the economist is often asked to estimate the impact of a change in the mechanism that produces the data when there is limited or no possibility of producing the data beforehand in a laboratory experiment. Thus, by the passive nature of the data, economic researchers are, to a large extent restricted in their knowledge search to the process of non-experimental model building. . . . .

[50] Haavelmo , Trygve. 1944. "The Probability Approach in Econometrics."
[51] Judge, George G., W.E. Griffiths, R. Carter Hll, Helmut Lutkepohl and Tsoung-Chao Lee. *The Theory and Practice of Econometrics, Second Edition* pp. 2-4.

> Unfortunately, postulation typically provides many admissible economic and thus statistical models that do not contradict our perceived knowledge of human behavior or the economic and institutional processes through which these data are generated. Therefore, in most econometric work, there is uncertainty as to the economic and statistical model that is used for estimation and inference purposes and the sampling model that actually was the basis for the data generation. . . . . . .
>
> The non-experimental restriction also means that in addition to being efficient in using the data that are available, one must, in many cases, use non-sample information in order to adequately support the parameter space. Thus, much of econometrics is concerned with how to sort out and make use of this non-sample information in conjunction with the sample observations. . . . .
>
> Therefore, in econometric work, as one goes from the conceptual model to the observed data and from prior information to the estimated relations, many interrelated questions face the researcher.

The above illustrates the challenges, uncertainties, and problems that the non-experimental approach presents. This begins with the basic truth: we can't, in fact, place the fertilizer industry in a laboratory, and run a controlled experiment on the effect of market power on output price. We must take the information from the "experiment" conducted by "nature" (observed data about prices, quantities, and market concentration in the fertilizer industry) and attempt to ascertain the nature of the relationship. As Judge, Griffiths, et al note, there are often many theoretical and statistical ways empirical economists can model such a relationship. In litigation, differing models are often the focus of expert witnesses representing plaintiff and defense.

The "nonsample information" referenced above may reflect other economic variables that affect the dependent variable under observation. In the market power example, that may include related economic variables (such as the supply, demand, or prices of related goods). It may also refer to inclusion in regressions of "mathematical information," such as nonlinearities (e.g. squaring or cubing the value of an observation), dynamic or lag terms (e.g. taking into account the values of observations from previous time periods to reflect changes over time), and other such terms. Further discussion of the strengths and weaknesses of this approach, and tests for validating (or invalidating) the statistical models, follows *infra* in Section III.C.

III. Analysis

Having outlined first the legal issues, and subsequently the statistical/econometric ones, this section now turns its attention to the intersections of the two.

A. The Publication Process

As noted, *supra*, the *Daubert* standard relies heavily on the scientific/academic publication process. As the publication process in economics (and other hard and social sciences) differs substantially from that in law, the publication process itself merits discussion. Typically, an academic paper submitted to an economics journal includes some sort of problem statement, a theoretical model (usually, but not always, involving a series of mathematical equations), an econometric analysis performed on a data set[52], followed by analysis and the drawing of conclusions from the research.

Continuing with the fertilizer antitrust example, a paper on that issue would introduce the problem: that fertilizer prices are rising, and the market is becoming more concentrated. The paper would introduce a theoretical model that includes a mathematical term, or variable, to measure the impact of market concentration/market power on the price charged to farmers for fertilizer. A section would follow that performed econometric and statistical analysis to ascertain to what extent, if any, market power had on the price of fertilizer. Appropriate analysis and conclusions of the results would follow.

[52] Some economics journals publish purely theoretical pieces (that do not contain empirical analyses of data). Because such publications are less likely to be relevant in a litigation context, this paper focuses on empirical analyses.

In order to publish, the manuscript would then be submitted to a journal. Generally, scholarly economics papers may be submitted to only one journal at a time. An editor will then submit the proposed manuscript to one or more reviewers or “referees.” The referees are generally other academic economists, usually economists who publish on similar topics within the discipline of economics. The paper on fertilizer cartels/antitrust issues would likely be assigned to a reviewer who had published in the areas of antitrust, monopoly and competition, or some related issue under the economics umbrella of “industrial organization.”

The referees then send reports to the editor, recommending one of three options: 1) accept the paper with no revisions; 2) reject the paper out of hand; 3) require revisions and wait to re-evaluate a subsequent draft. Option 3) is the most common, but does not guarantee publication. Ultimately, the decision lies with the editor whether to accept, reject, or require revision and resubmission.

B. Publication Bias

An issue that arises in academic publication is “publication bias;” that is, a tendency of academic journals to reflect certain preferences. One source of publication bias is the tendency to prefer significant results. Papers that have many variables that show statistical significance are more likely to be approved for publication than those that do not. This form of publication bias potentially creates a misleading impression in the literature: because studies with significant results are more likely to be published, a false confidence could arise as to the significance of the variables in question. Such a false confidence could unfairly favor the plaintiff/prosecution or defense, depending on the circumstances.

Further, a preference for significant results obscures the fact that insignificant variables also transmit information: that certain variables do not have a relationship. Returning to the fertilizer cartel example, a publication bias in favor of significant results may lead to the publication of a disproportionate amount of studies showing that the price is heavily impacted by market concentration. There may in fact be as many or more studies showing the opposite, but that did not survive the refereed publication process. Those studies showing that there is no significance are also providing valuable information – that market concentration is not, in fact, causing price increases.

Another form of publication bias is the tendency of scholarly economics journals to favor publication of studies whose results support maintained economic theory. This also would potentially lead to a tendency to over-represent studies showing that market concentration increases the price of fertilizer: economic theory predicts that, *ceteris paribus,* less competitive market structures yield higher prices.

A related publication bias is the tendency to prefer *existing* economic theory to *novel* economic theory. University of California-Berkeley economist George Akerlof became a Nobel laureate in Economics largely due to his work on asymmetrical information. His seminal work on the topic was a now legendary paper called "The Market for Lemons." That paper described the bargaining difficulties for used automobiles and its impact on prices and economic activity.

Akerlof's paper was initially rejected by multiple journals. The rejections became so numerous that Akerlof nearly abandoned the quest to get the paper published. The reason for the lack of publication success is that Akerlof's theories were so new that they were too unorthodox for the referees and editors. This bias persists across the Economics profession (and indeed in other disciplines as well), and affects the definition of "accepted science."

That would not have been the case in the late 1960s and early 1970s when Akerlof first proposed his theories. What another Nobel laureate economist, Milton Friedman called "long and variable lags" in another context are present in this context too. Even if and when the bias against novel developments is overcome, the diffusion of the information takes time before it rises to the level of "accepted science" within the economics profession.

Taken together, these publication biases present the opportunity for a "feedback loop" of self-reinforcing pre-conceptions. Such a feedback loop would, however, be considered "accepted science" under the *Daubert* standard. Because of the preference for the consensus views of the editorial establishment, the publication biases effectively become "baked in the cake." Thus, though potentially erroneous and exclusionary, the publication biases make studies that purport to show significant result that validate existing economic theory – and *only* existing economic theory – more likely to be accepted as evidence, and studies not fitting that description less likely.

C. Discrepancies Between Economic Analysis, Statistical Analysis, and Legal Standards

Now that the various statistical and legal standards have been defined, we can turn our attention to the intersection among those standards as well as those of economic decision making.

1. "Causation" in Economics, Statistics, and the Law

In our heretofore ubiquitous example of an antitrust inquiry into the fertilizer industry, we've understood the point at issue to be whether increased market concentration "caused" higher output prices of fertilizer. The question of what "causation" means, and how (and whether) it can be determined yields potentially three different answers in each of economics statistics, and law.

For example, suppose econometric testing shows that the market power term in the theoretical economic model is positive and highly significant. As noted, *supra*, in Section II.B., classical statistics would only conclude that there was a correlation between the two, not an issue of causation. Indeed, most statisticians have historically taken the position that in non-experimental situations, there can be "no causation without manipulation." [54] That is, the classical statistical view is that a causal relationship cannot be established directly from non-experimental data without some sort of external manipulation. While that view has softened somewhat of late[55], there still remains quite a divide between statisticians and economists/econometricians on the ability to discern causality.

One source of causal inference from economists is economic theory itself. For example, it may be perfectly acceptable for publication in economics journal to show that 1) the market concentration term in the fertilizer model is positive and significant, and 2) therefore conclude that the exercise of market power is indeed increasing the output price of fertilizer. This could apply in many other examples of economic research: if econometric results provide the predicted sign (positive or negative) and significance, causality can be inferred.

[54] Holland, Paul W. "Statistics and Causal Inference." *Journal of the American Statistical Association.* Vol. 81, No. 396 (1986). 945-960.
[55] See, e.g. Freedman, D.A. "Statistical Models for Causation." (2005) accessed at http://www.stat.berkeley.edu/~census/651.pdf

Not all empirical economic research relies solely on theory to establish causation. Indeed, as noted by labor economist/econometrician Joshua Angrist, something ". . . that distinguishes us from statisticians - and indeed from most other social scientists - is an arsenal of statistical tools that grew out of early econometric research on the problem of how to estimate the parameters in a system of linear simultaneous equations."[56]

In layman's terms, those "linear simultaneous equations" that required the development of an "arsenal of statistical tools" were the bedrock equations of economics: simple supply and demand curves. For this reason, econometrics has developed a number of ways of testing for causation. One popular such test is "Granger causality." Granger causality tests variables in time series, and ascertains whether the earlier values of one variable can predict the subsequent values of another variable.[57]

The basic Granger causality test begins by regressing the values of a stationary time series "y" on its own lagged values (the values of y in previous time periods). A subsequent regression is then run with y as the dependent variable and lagged values of y and x both as independent variables. If the coefficients of the lagged x-values are significant, and the overall explanatory power of the model increases with the inclusion of the x-values, then it can be said that x "Granger causes" y.[58]

In the fertilizer cartel example, we could perform such a test with the output price of fertilizer as y, and the market concentration term as x. If we found significance in the x

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[56] Angrist, Joshua and Jorn-Steffen Pischke. *Mostly Harmless Econometrics.* (2009).
[57] Readers interested in a full mathematical derivation of the Granger causality test ,see Granger, C.W.J "Investigating Causal Relations by Econometric Models and Cross-Spectral Models. *Econometrica,* Vol. 37, No. 3 (Aug. 1969). pp. 424-438.
[58] In addition to economic applications, Granger causality has become important in neuroscience. See, e.g. Roebroeck, A. et al. "Mapping directed influence over the brain using Granger causality and fMRI. " *Neuroimage* 25. 230-242.

values, and joint significance in terms of explanatory power, we could conclude that increased market concentration Granger causes the increase in price. However, such causality doesn't truly prove "causation" in the traditionally understood sense, and certainly not in the legal sense (more on that definition, *infra*). Rather, Granger causality merely tests the predictive power of the x variable on the y variable, or the "precedence" of x over y. If a third process were actually "causing" both x and y, the simple Granger test would not detect that.

Other efforts at proving causality by econometrics have been advanced by those favoring "natural experiments," or "quasi-experiments," as discussed, *supra*. However, the limitations thereof have been discussed.[59] Other methods of discerning causation, most prominently advanced by Nobel laureate James Heckman[60], have gained traction in econometrics, though none is without its critics. All produce challenges in reconciling themselves with the legal definitions of causation.

2. Legal Definitions of Causation

The causation-correlation debate heavily influences the use of econometrics and statistics in legal settings. The Federal Judicial Commission's *Reference Manual on Scientific Evidence* states the following: "In many cases, the court needs more than a description of a population. It seeks an answer to a question of causation."[61] However, though the previous section indicates that economists have difficulty defining "causation," it gets no clearer on the legal side: *Black's Law Dictionary* includes 29 different entries for types of "cause" recognized under the law.[62]

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[59] See also Angrist and Prischke, *supra*
[60] Heckman, James. "The Scientific Model of Causality." *Sociological Methodology*, 35(1): 1-97 (2005)
[61] Kaye, David H. and David A. Freedman. *Reference Manual on Scientific Evidence.* 3rd edition. p. 346. (2011).
[62] *Black's Law Dictionary 9th Ed.* (2009)

The key types of causes understood in litigation, and thus the ones focused on here, are "actual cause" and "proximate cause.

a. Actual cause

"Actual cause" under the law is often referred to as "but for" causation. The derivation of such a term is fairly straightforward: an action is a "but for" cause of a subsequent event if and only if the subsequent event would not have happened "but for" the antecedent event. *Black's* defines "but for" cause as "The cause without which the event could not have occurred."[63] The legal understanding owes a great debt to philosophy, including philosopher/political economist John Stuart Mill's understanding of causation as, "the antecedent, or the concurrence of antecedents, on which [a given phenomenon] is invariably and *unconditionally* consequent."[64] [emphasis in original]

Here, we can already see a difficulty in terms of applying statistical and econometric results toward establishing causation. First, as noted, *supra*, many empirical economic works assume causation if econometric results comport with theory. However, this may not be sufficient to clearly establish actual cause. For one reason, the theory may be wrong. In the fertilizer cartel example, the expected sign and significance on the market power term may be enough to satisfy publication standards, but can it really tell us that the increase in price was "invariably and unconditionally consequent" on the market power? Even if it's proven that the increased market concentration Granger caused the increase in price, that proves only that the concentration preceded the price and is predictive of it. It does not exclude the possibility of another cause.

[63] Ibid.
[64] Mill, John Stuart. *A System of Logic* p. 245. (1874)

b. Proximate Cause

Proving "but for" causation is a necessary, but not sufficient, concept to proving liability in most civil law contexts. If our fertilizer cartel case came before a jury, the jury would have to answer something to the effect of "Did market concentration proximately cause the price of fertilizer to be higher than it otherwise would have been?"[65] The elusive concept of "proximate cause," also known as "legal cause," is vital, but difficult to define. *Black's* defines proximate cause as "A cause that is legally sufficient to result in liability; an act or omission that is considered in law to result in a consequence, so that liability can be imposed on the actor."[66]

The pre-eminent element of proximate cause is foreseeability.[67] This means that the cause of the harm must be reasonably foreseeable by the alleged tortfeasor. In the fertilizer cartel example, in order to prevail, plaintiffs would have to show that the increase in fertilizer price was a reasonably foreseeable consequence of increased market concentration. In that example, foreseeability may seem obvious: it is nearly axiomatic in economic theory that increased market power leads to increases in price. Yet, that once again leaves us in the position of depending on direct inferences from economic theory – not invalid, but not proven as causative by our quantitative evidence.

Further, the foreseeability test of proximate cause relies upon an "objective" standard of whether a "reasonable" person would have foreseen the consequence. Because most theoretical economic models assume rationality to begin with, the use of an economic model to establish proximate cause could potentially give rise to an accusation of question-begging. For these

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[65] *Pickett v. Tyson Fresh Foods, Inc.*
[66] *Black's Law Dictionary* 9th Ed.
[67] *Restatement (Second) of Torts*

reasons, it's quite likely that the best evidence of economic proximate cause is often likely to be non-quantitative.

3. Non-quantitative evidence of economic causation

Thus far, we've primarily focused on quantitative economic work, both theoretical and empirical. As noted, *supra*, the "state of the art" in Economics, both theoretical and empirical, is heavily quantitative. However, the limitations of such evidence, particularly with regards to causation, have been lain out in the foregoing sections. But non-quantitative evidence can often supplement quantitative economic evidence in establishing economic causation. Returning to our fertilizer cartel example, if we have an empirical model showing that the market power term is positive and significant, that certainly shows an association between market concentration and higher prices. However, that in and of itself doesn't establish causation.

Other sources of evidence may well assist us in establishing that, however. If an executive of a company involved in the potash fertilizer cartel were to say the following, it could supplement that knowledge:

> We don't see any downturn in our business. The whole concept of potash prices peaking, **we've just announced a big increase here in the domestic market September 1 and of course Canpotex has just increased prices up to the $1,000, about a $250 per ton increase there also, which we'll see really take effect in the fourth quarter .** . .
>
> A $100 per ton increase is worth only $0.03 to a corn farmer in the Midwest of the U.S. So you start doing the leverage on that, while it's huge for us, that $100 increase, it's not a big deal to the corn farmer and they clearly see the benefit. **We showed you a little bit of the economics in our formal earnings release where we referred to $1,000 potash in there. But if you're adding $500, you're only adding $0.15 to the cost of production of a bushel of corn. So you can see, we've got a lot of pricing room going forward and we don't see a peak in our business**. . . .
>
> To offset these rising costs, producers have raised prices for fertilizer, animal feed and industrial products**. For our company, which has an integrated supply of high quality rock for phosphate production and lower cost natural gas contracts to fuel our**

nitrogen production in Trinidad, this presents an opportunity to capture greater margins on our products.[68]

The foregoing is from an actual transcript from a quarterly earnings report of Potash Corporation of Sasketchewan (POT), a member of Canpotex, a legally sanctioned cartel of North American exporters of potash fertilizer.[69] The bolded portions of the transcript indicate that 1) the company believes it has market power, 2) the company is setting the price as opposed to "taking" a market price (as would be the case if it the market were competitive, per economic theory), 3) the company believes its price is relatively inelastic due to the relatively small proportion of the total production costs represented by fertilizer cost, and 4) the company is highly vertically integrated,[70]thus allowing it greater control over price (in the present and in the future).

Combined with the quantitative econometric results, this evidence helps establish causation. Actual, or "but for" causation is clearly established because the executives admit to increasing the price at their own discretion, rather than taking a market price. Further, they acknowledge that "the economics" of the market for fertilizer – including the relative responsiveness of price changes on demand for their product, and the degree to which their industry is integrated – is the underlying reason for the price increase. Clearly, the price rises because of the market power exerted by POT and its fellow cartel members. Further, the

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[68] Potash Corporation of Saskatechewan Quarterly Earnings call transcript, Second Quarter 2008, as reported on www.seekingalpha.com, retrieved on July 21, 2013.

[69] The cartel is permissible under Canadian antitrust law, allegedly for export purposes only. For more on the cartels and their effects, see Francisco (2013) and Taylor (2013)

[70] Vertical integration refers to the control of the factors of production, or inputs, by the producer of the output. In the fertilizer context, it largely refers to ownership of the mine or other source of the raw mineral input. In the seminal antitrust case decided by the United States Supreme Court, *Standard Oil Co. of New Jersey v. United States*, 221 U.S. 1 (1911), the Court found that Standard Oil had vertically integrated by acquiring the rights to the oil under the ground, owning and operating the drilling operation, acquiring the refineries, and controlling the retail distribution.

"proximate cause" element is established because it was reasonably foreseeable that the prices would increase, given that POT itself initiated the price increase.[71]

Not all investigations will yield such striking non-quantitative evidence – the above is taken from investor calls as a part of public disclosures required for publicly traded corporations, such as POT – but the wide access granted to attorneys and investigative authorities in discovery could generate similar non-quantitative evidence to support quantitative evidence.

IV. Conclusion

The thrust of this paper thus far can perhaps be best summed up by Steven L. Willborn, who said "Statistics and law may use the same words quite differently, creating a significant possibility of miscommunication. A partial list of such words … include reliable, valid, significant, power, and causation."[72] The first issue legal practitioners and economists must reconcile is the language. A failure to address such incongruities of verbiage could lead to a "ships passing in the night" scenario, where alternative definitions of "causation" (or any other item from the list) are presented as the same. Further, in cases of disagreement the lawyer and the economist may find themselves "disputing" terms on which they have no common definition, thus leading to a misunderstanding of Abbott and Costello proportions.

The first and most obvious solution to this issue is to create a clear definition of the term in issue, and make certain that all parties involved agree to adhere to the same definition. For example, any potential economist that is acting as a witness, expert, investigator, commenter on a proposed regulation, etc. needs to be informed of the appropriate legal definition, and adjust

[71] Were it not for the legal exemptions, discussed *supra* at note [], from the Canadian and American government, the existence of the cartel meeting itself, followed by price increases, could be evidence of criminal and civil violations of Section 1 of the Sherman Antitrust Act, 15 U.S.C §1.
[72] Willborn, Steven. 2005. "A Lawyer's View of the Statistical Expert." *Law, Probability, and Risk.* 4(25-31).

accordingly. Another potential "solution" is simply for attorneys, judges, and other legal professionals to become better acquainted with the differences between the traditional legal and economic differences. In our adversarial legal system, the responsibility typically falls with the attorney as advocate to bring out weaknesses in testimony against his client. Thus, an attorney for a fertilizer company that is allegedly involved in a cartel should bear much of the responsibility of establishing whether or not an opposing expert economist is relying on theoretical or speculative assumptions to prove causation or not.

A second solution to the "problem" of differences in terminology, approach, or standards, is simply to allow more information to be presented to the jury, judge, or whoever sits as the trier of fact. Further, the information should be presented in such a way as to be as precise, and free of potential misunderstandings, as possible. For example, as noted *supra* in Section II.C., the results from econometric analysis relate information on a continuum of probabilities. They should be reported as such to fact-finding legal authorities: rather than reporting a variable as "significant," or "insignificant," reporting the t-score/p-value, and interpreting it in terms of probabilities would shed more light. For example, if our regression in the fertilizer case shows a p-value of .15 for the market concentration variable, the most informative report would be that there is an 85% probability that the market concentration is affecting the output price of fertilizer. Such a report would avoid any confusion around the ambiguity of words like "significant" or "insignificant."

Further, reporting of the data in terms of probability helps to address the issue of different evidentiary standards. An 85% probability likely doesn't suffice to meet the "reasonable doubt" standard (see Section I.A., *supra*), but likely is sufficient to satisfy other burdens, such as "preponderance of the evidence," and "clear and convincing" (see Section I.B and I.C, *supra*). Reporting in such a way isn't likely to be inconsistent with *Daubert*: the method of arriving at such a conclusion – and indeed the conclusion itself – is the same as the published material. The result is the same; all that has changed is the threshold standard for decision making.

Conclusion

The three essays in this dissertation have examined the intersection of law and economics. Each has provided insight into the ways in which the legal and economic systems interact, and the way economic analysis can be used to measure, evaluate, and enhance the legal and policymaking arena.

With regards to patents, we see that some of the policymakers' hypotheses find support: industries, that are alleged to be thicketed, do have substantially longer lag times in having their applications granted than other industries. Lag times are generally increasing across the sample period. However, the non-linearities across the sample suggest that more issues are in play than simply a generalized increase in application duration time.

Additional study that would enhance this understanding would begin with obtaining the micro-data, the application level information. Such data would permit analysis based on more precise application information (it would have the specific grant date, not merely the year). Further, given that excessive litigation is a rationale often cited for need for reform (such as the 1982 reforms discussed in Chapter 1), data regarding litigation and its impact on the length and cost of the patent process would be helpful to providing a full and complete picture of the situation.

Further, the emerging literature on survival models generally - and their application to economic problems in particular - allow for the potential for further development of the models used in this paper. For example, the difficulty of interpreting results from parametric survival models as marginal results in the traditional linear regression sense was noted earlier. However, developing such a way to translate the probabilistic results into more traditional marginal effects would lead to a more thorough understanding. Some researchers from the field of biostatistics have suggested using a Buckley-James estimating equation for the parametric accelerated failure time specifications used in this paper, so perhaps that has viability in an economic context as well (Jin, Lin, and Ying, 2006).

Chapter 2 shows evidence that suggests that domestic competition in potash fertilizer is being harmed, contrary to the terms of the antitrust exemption granted under Webb-Pomerene. This suggests that, at the very least, the appropriate federal authorities should consider revoking the exemptions. The framework for deriving the dynamic Lerner Index could be applied to the other major fertilizer components, nitrogen and phosphorous.

Additionally, the spike in prices that began in 2004 was also accompanied by an apparent discrepancy between the domestic price and the international price. Given that potash is largely a standardized, homogenous product, the Law of One Price (LOOP) should hold. Yet, the Canpotex producers' public securities filings show that, in real terms, the price for potash fertilizer in North America is higher than abroad. Analysis of whether the LOOP holds, and assessing the determinants of why it does not (if it indeed does not) could prove a useful avenue for further research.

Finally, in Chapter 3, I established that econometric evidence as applied in legal contexts often is presented in such a way that may be misunderstood by one or both sides. This could lead to information being incorrectly interpreted by legal decision makers, and/or information being concealed from such decision makers because it does not meet standards for "significance" called for in scientific publication, but not in legal settings.

References – Chapter 1

Aalen, O.O. 1978. “Nonparametric inference for a family of counting processes.” *Annals of Statistics*, 6: 701-726.

Burke, Kelly. “Report Finds Average US Patent Cost $374,000 in 2012.” http://www.ip-watch.org/2013/02/12/first-patent-value-quotient-report-shows-average-price-paid-for-issued-us-patents/. Accessed July 21, 2013.

Bofondi, Marcello, and Lotti, Francesca**.** 2006. **“**Innovation in the Retail Banking Industry: the Diffusion of Credit Scoring.” *Review of Industrial Organization*, 28(4): 343-358.

Branstetter ,Lee and Sakakibara, Mariko. 2001. “Do Stronger Patents Induce More Innovation? Evidence From the 1988 Japanese Patent Law Reforms.” *Rand Journal of Economics,* 32(1): .77-100.

Cameron, A. Colin, and Trivedi, Pravin K. 2009. *Microeconometrics: Methods and Applications.”* New York: Cambridge University Press.

Cleves, Mario, Gutierrez, Roberto, Gould, William, and Marchenko, Yulia. 2010. *An Introduction to Survival Analysis using Stata.* Third Edition. College Station, TX: Stata Press.

Cox, D.R. 1972. “Regression models and life tables (with discussion).” *Journal of the Royal Statistical Society,* 34(2):187-220.

DeNicolo, Vincenzo. 1996. “Patent Races and Optimal Breadth and Length.” *Journal of Industrial Economics,* 19(3): 249-265.

DeNicolo, Vincenzo. 2000. “Two Stage Patent Races and Public Policy.” *Rand Journal of Economics,* 31(3): 488-501.

DeNicolo, Vincenzo and Franzoni Luigi Alberto. 2003.“The Contract Theory of Patents.” 16(2): *International Review of Law and Economics*, 23(4): 365-380.

Gallini, Nancy. 2002. “The Economics of Patents: Lessons from Recent US Patent Reforms.” *Journal of Economic Perspectives*, 16(2): 131-154.

Harhoff, Dietmar and Stefan Wagner. 2005. “Modeling the Duration of Patent Examination at the European Patent Office.” CEPR Discussion Papers: 5283

Hall, Bronwyn, Adam Jaffe, and Manuel Trajtenberg 2001. "The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools." NBER Working Paper 8498.

Jaffe, Adam B. 2000. "The U.S. Patent System in Transition: Policy Innovation and the Innovation Process." *Research Policy.* 29(4): 531–57.

Jin, Zhezhen, D.Y. Lin, and Zhiliang Ying. 2006. "On Least-Squares Regression with Censored Data." *Biometrika,* 93(1): 147-161.

Jorgenson, Dale, Mun Ho, Jon Samuels., and Kevin Stiroh. 2007. "Industry Origins of the American Productivity Resurgence." *Economic Systems Research,* 19(3):229-252.

Kaplan, E. L., and Paul Meier. 1958. "Nonparametric estimation from incomplete observations." *Journal of the American Statistical Association,* 53(282):457–481.

Kortum, Samuel, and Josh Lerner. 1998. "Does Venture Capital Spur Innovation?" NBER Working Paper 6846.

Leaf, Clifton. "The Law of Unintended Consequences." *Fortune,* 2005. http://money.cnn.com/magazines/fortune/fortune_archive/2005/09/19/8272884/. Accessed July 21, 2013.

Lo, Shih-tse, and Dhahoos Sutthiphisal,. "Does it Matter Who Has the Right to Patent: First-to-Invent or First-to-File? Lessons From Canada." NBER Working Paper 14926.

Nelson, Wayne. 1972. "Theory and Application of Hazard Plotting for Censored Failure Data." *Technometrics* 14(4): 945-966.

Nordhaus, W. 1969. Invention, Growth, and Welfare: A Theoretical Treatment of Technological Change. Cambridge: MIT Press.

Rai, Arti, Mark Doms, and Stuart Graham. 2010. "Patent Reform: Unleashing Innovation, Promoting Economic Growth, and Creating Jobs." USPTO White Paper.

Trajtenberg, Manuel. 1990. "A Penny for Your Quotes: Patent Citations and the Value of Innovations." *Rand Journal of Economics,* 21(1): 172-187.

USPTO. 2011. "FY 2011 Process Production Report."

Van Zeebroeck, Nicolas. 2007. "Patents only Live Twice: A Patent Survival Analysis of Europe." Centre Emile Bernheim, Working Papers 07-028.RS

www.patentlyO.com "Patent Reform Survey on the Pulse of the Patent Bar." April 23, 2011. http://www.patentlyo.com/patent/2011/04/patent-reform-survey-results-on-the-pulse-of-the-patent-bar.html. Accessed July 21, 2013,

Xie, Ying, David E. Giles. 2011."A Survival Analysis of the Approval of US Patent Applications." *Applied Economics, 43(11): 1375-1384.*

References – Chapter 2

Bain, Joe S. (1951). "Relation of Profit Rate to Industry Concentration: American Manufacturing, 1936-1940." *Quarterly Journal of Economics,* 65 (4):602.

Cabral, Luis M.B.(1995). "Conjectural Variations as a Reduced Form." *Economic Letters,* 49: 397-402.

Ells, Gregory M. and Robert Halvorsen (2002). "Estimating Market Power in a Nonrenewable Resource Industry." *The Journal of Political Economy,* 110(4): 883-899.

Elzinga, Kenneth G. and David Mills. (2011). "The Lerner Index of Monopoly Power: Origins and Uses." *American Economic Review,* 101(3): 558-564.

Etter, Lauren. 2008. "Lofty Prices for Fertilizer Put Farmers in a Squeeze." *Wall Street Journal*. May 27. Accessed July 21, 2013. http://online.wsj.com/article/SB121184502828121269.html

Federal Trade Commission. (2010). *Horizontal Merger Guidelines.* Washington, DC: Federal Trade Comission .

Hotelling, Harold. (1931). "The Economics of Exhaustible Resources." *The Journal of Political Economy,* 39(2): 137-75.

Kaiser, Henry and Nobuhiro Suzuki,(2006). *New Empirical Industrial Organization and the Food System.* New York: Peter Lang.

Karp, Larry S. and Jeffrey Perloff. (1989). "Dynamic Oligopoly and the Rice Export Market."*Review of Economics and Statistics* 71: 462-470.

Landes, William M. and Ricard Posner. (1981). "Market Power in Antitrust Cases." *Harvard Law Review*, 94(5): 937-996.

Lerner, Abba. (1934). "The Concept of Monopoly and the Measure of Monopoly Power." *The Review of Economic Studies*, 1(3): 157-75.

Lindenberg, Eric B. and Stepen A. Ross. (1981). "Tobin's q ratio and Industrial Organization." *The Journal of Business*, 54(1): (1-32).

Martin, Stephen. (1993). *Advanced Industrial Economics.* Oxford, England, Cambridge, MA: Blackwell.

Pindyck, Robert (1985). "The Measure of Monopoly Power in Dynamic Markets." *Journal of Law and Economics*, 24(1): 193-222.

Potash Corporation of Saskatchewan. (2008). *Quarter 2 Earnings Call.* http://seekingalpha.com/article/91014-intrepid-potash-inc-q2-2008-earnings-call-transcript. Accessed July 21, 2013.

Waldie, P. (2010, October 29). "Canpotex and Potash: the monopoly beind the mineral." *Toronto Globe and Mail*.