Law and Innovation: 
Evidence from State Trade Secrets Laws

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Abstract

Here, I study the effect of trade secrets laws on R&D and patenting. Stronger secrecy protection could increase or reduce R&D. By reducing spillovers, stronger protection might reduce or raise the return to R&D, depending on whether spillover and own R&D are complements or substitutes. By strengthening appropriability, stronger protection would raise the return to R&D.

Empirically, I find a nuanced relation between changes in trade secrets law and R&D among U.S. manufacturers between 1976 and 2006. The relation increased with company size, as measured by sales revenue, and was present among high-tech companies, but not among low-tech companies. The increase in trade secrets protection in California between 1978-84 and 1990-98 was, for the average company in the respective industry, associated with 4.9% less R&D in industrial inorganic chemicals (SIC 2810), a low technology industry, and 14.8% more R&D in pharmaceuticals (SIC 2834), a high technology industry.

Further, I find that stronger trade secrets law was associated with reduced patenting, suggesting that trade secrets and patents served as substitutes.

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1 Introduction

Wall Street Journal: “Is it true that the original WD-40 formula is locked in a bank vault?”
Mr. Ridge (CEO, WD-40 Company): “Absolutely. We have only ever taken it out of the vault, well, twice. Once when we changed banks. ... It’s a trade secret.”


“Although Genentech relies extensively on its patents to protect inventions arising from research activities ... we also rely heavily on trade secret protection provided by State and Federal law ... many of the trade secrets held by Genentech concern process technologies we have created during development of our new products.” (Genentech 2004).

Innovation depends on tangible investments such as plant and equipment and intangible investments such as research and development (R&D) and marketing. In turn, commercial investment depends on formal and informal property rights. To date, policy makers and scholars of innovation have tended to focus attention on technical innovation and on patents (Jaffe and Lerner 2004; Hall 2007).

However, almost all European and American technology managers report secrecy to be more important than patents as a way to appropriate the returns from innovation (Arundel and Kabla 1998; Cohen et al. 2000; Arundel 2001). Coca Cola (probably the world’s most famous trade secret), the hugely popular lubricant, WD-40, and Genentech’s process technologies exemplify the importance of secrecy to innovation.

Patents provide broad exclusivity but only for a fixed period of time, are limited to technical innovations that meet particular standards, and require disclosure of the innovation as well as application fees and other expenses. By contrast, trade secrets can be unlimited in time, are not limited by particular technical standards, do not require disclosure, and cost relatively less. However, secrecy does not protect against accidental disclosure, independent discovery, or reverse engineering.

Moreover, the scope of trade secrecy is much broader than that of patents. Trade secrecy protects work in progress as well as completed innovations. This protection is important even for innovations that will be patented, as it reduces the time for competitors to invent around the innovation. In addition, trade secrecy extends beyond technical
innovations to commercial innovations including business plans, marketing concepts, and customer lists.

Of course, as illustrated by the WD-40 Company’s precautions, secrecy works even in the absence of trade secrets law. However, as Genentech (2004) stressed, trade secrets law substantially bolsters the protection of innovations through secrecy.

Like intellectual property in general, the purpose of trade secrets law is to encourage innovation and ultimately foster economic growth. Generally, trade secrets law can affect innovation at two stages. In the investment stage, the law affects the extent of spillovers from the R&D of others, and so, influences the innovator’s expenditure on R&D. In the exploitation stage, the law affects the degree of appropriability, and so, influences the innovator’s decision how to commercialize and protect the innovation.

Secrecy laws may have conflicting effects on investment in innovation. On the one hand, stronger secrecy laws would strengthen appropriability and so, provide better assurance of exclusivity. This would increase the innovator’s return from investment. On the other hand, stronger secrecy laws would reduce the extent to which innovators would receive spillovers from others. The impact of reduced spillovers would depend on whether spillovers are complements or substitutes for own investment in innovation.

Despite the practical importance of trade secrecy to innovation, there has been relatively little empirical research into the economic impact of trade secrets. The only work to date is indirect (focusing on patent rather than secrecy laws) and based on innovations presented at 19th century World’s Fairs. In twelve countries, inventors specialized by industry according to whether their home country allowed patents (Moser 2005). However, in Britain and the USA, most innovations were not patented and the extent of patenting did not vary with national patent laws (Moser 2010).

Here, I compile a rich data set from multiple sources to address two research questions. The principal question is how trade secrets law affects investment in R&D. A secondary question is how trade secrets law affects patenting.

This paper makes two contributions. First, motivated by Garmaise’s (2011) index of state law on covenants not to compete, I draw on various legal authorities and compile an index of U.S. state-level trade secrets law. In the United States, patents, trademarks, and copyrights are governed by federal law. By contrast, civil trade secrets law is within state jurisdiction. In most states, civil trade secrets law comprises a mixture of statute (Trade Secrets Act) and case law. Massachusetts, New York, and Texas have not enacted any civil statute, and rely completely on case law. Further, some states have enacted
criminal statutes on misappropriation or theft of trade secrets. My index characterizes civil statutes and case law and criminal statutes to represent the strength of trade secret protection in each state over time.

Second, I combine the index of state trade secrets law with company-level data on innovation (R&D expenditure and patenting) from Compustat, the NBER Patent Database, and other sources to assemble a rich data-set of innovative activity by U.S. manufacturers between 1976 and 2006. I use the variation across and within states in the index of trade secrets law to identify the impact of trade secrets protection on company-level R&D and patenting.

The impact of trade secrets law on R&D was quite nuanced, and varied with company size and industry. The association between stronger trade secrets protection and R&D was increasing in company size, as measured by sales revenue. Further, stronger trade secrets protection was associated with more R&D among high-tech companies, but there was no significant effect among low-tech companies. And, stronger trade secrets protection was associated with more R&D among companies using complex technologies that require the combination of multiple patentable elements (Cohen et al. 2000), but there was no significant effect among companies using discrete technologies.

I interpret the empirical findings as showing that, among small companies in low-tech industries, own and spillover R&D were complements. So, stronger trade secrets protection, by reducing spillovers, lowered the expected return from R&D, and hence, led to less R&D. Among large companies in high-tech industries, the interpretation is less clear. It could be that the increase in appropriability, which would increase R&D, was sufficiently strong to outweigh the complementarity between own and spillover R&D. Or, it could be that, among large companies, own and spillover R&D were substitutes, so, stronger trade secrets protection, by reducing spillovers, raised the expected return from R&D, and hence, led to more R&D.

In addition, I found that stronger trade secrets protection was associated with reduced patenting overall. The effect increased to the extent to which technology managers reported patenting to be effective in appropriating the returns from innovation (Cohen et al. 2000). My findings were buttressed by multiple robustness checks for alternative characterizations of trade secrets law, geographic samples, and omission of possibly relevant variables.

Given the importance of innovation for economic growth, my empirical findings are significant for public policy and management practice. Policy-makers and managers should look beyond patents, copyright, and trademarks. Trade secrecy matters. By
harnessing the property rights arising from this relatively under-explored area of the law, nations and businesses can increase innovation, and achieve faster economic growth and higher long-run welfare.

2 Biotechnology

To motivate the study of the effect of trade secrets law on innovation, it is helpful to consider the biotechnology industry. Biotech manufacturers use living cells to produce so-called “large molecules” in biologically active environments. Biotech is a high-technology industry which is R&D-intensive and which uses patents intensively. Yet, Genentech (2004), one of the world’s leading biotech manufacturers, stressed, “we also rely heavily on trade secret protection provided by State and Federal law to protect our confidential information and know-how”.

Commercial success in biotech depends critically on the efficiency of the manufacturing process. The procedures that biotech manufacturers apply to purify the product are critical to achieving the desired biological characteristics (Walsh: 134-40). Indeed, an industry analyst remarked that, “much of what makes the product unique is the trade-secret protected manufacturing process that isn’t part of the patent that covers the molecule itself” (Xconomy 2011).

Biotech manufacturers guard these processes and procedures very carefully: “Specific information about the steps, equipment, organisms, and production and purification variables used to produce our products is closely protected and kept secret” (Genentech 2004). Proprietary technologies and know-how are protected through procedures for handling information and restrictions on access to facilities. These precautions are bolstered by trade secrets law: “each step in the manufacturing process, as well as the process in toto, is considered a trade secret under State law” (Genentech 2004).

Biotech manufacturers use secrecy to protect processes and procedures for various reasons. Some information, generally called “know-how”, does not meet the standards (novel, not obvious, utility) required for a patent, and so, can only be protected through secrecy.

Even for technologies that are patentable, manufacturers may still decide against patent protection (Genentech 2004).\(^1\) One possible reason is to guard against competi-

\(^1\)This illustrates strategic non-filing of patents, which contrasts with the strategic filing of patents (Hall and Ziedonis (2001).
tors inventing around patented technologies (Jorda 2008: 24). If the innovator were to patent both the product and manufacturing process, they must be disclosed and competitors could use the patent disclosures to invent around the product and process. However, by keeping the process secret, the innovator could hamper such inventing around and fend off competition.

Besides relying on trade secrets law to protect process technologies and know-how, biotech manufacturers have been advised to use trade secrets law to protect the R&D itself (Payne 1988). This is obviously appropriate for R&D of technologies and know-how that the innovator intends to keep secret. It is also relevant for R&D to develop products that innovator intends to patent. One reason is to reduce the time for competitors to invent around. Another reason is to provide a fall-back in case the patent is not granted (Payne 1988).

To understand how trade secrets law actually protects biotech innovation, I reviewed all suits involving trade secrets in state courts reported by the Courthouse News Service from 2001 to 2011. Among the 275 cases, the following examples were typical of the biotech-related cases. Ortho Biotech sued Hoffman LaRoche, Kevin Statz, and Alison Handel, claiming that its employees had taken trade secrets to a competitor (Los Angeles Superior Court, November 16, 2006). IVG Energy sued Atlas Commodity Markets and others, claiming that they had misappropriated its customer lists (Harris County District Court, September 23, 2008). Bristol-Myers Squibb sued Scott Liu and others, claiming that Mr Liu had used its trade secrets to start-up his own biopharmaceutical business (Alameda County Superior Court, April 21, 2009).

The biotech study provides several insights into the effect of trade secrets law on innovation. The law limits the flow of information and protects trade secrets by restricting employees from passing information to competitors. The law possibly affects innovation at two separate stages. One is at the R&D stage, when the innovator invests to develop new processes and products. The other is at the exploitation stage, when the innovator chooses how to appropriate the return from a successful innovation. At the exploitation stage, patents and secrecy can serve as complements: “Patents and trade secrets are not incompatible but dovetail: the former can protect patentable inventions, and the latter, the volumes of important, if not essential, collateral know-how” Jorda (2008: 1).

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4 Bristol-Myers Squibb Co. v. Scott Liu and Does.
3 Background Research

The prior empirical literature on trade secrecy mostly comprises analyses of litigation and surveys of technology managers. Among all suits filed in state and federal court by 530 manufacturers headquartered in Middlesex County, Massachusetts, between January 1990 and June 1994, the proportion of trade secrets actions was higher among businesses with lower revenues and fewer employees (Lerner 2001). This result suggests that secrecy was relatively more important to smaller businesses, which is consistent with previous research showing economies of scale in patenting (Lerner 1995).

Trade secrets cases also varied by subject matter. Among reported California and Massachusetts state and federal cases up to 2006, many involved industries in which innovations were not patentable (Lerner 2006). (Reported cases are a subset of cases that are tried, which in turn are a subset of cases that are filed.) In samples of reported state and federal trade secrets cases, 70% of state cases and 48% of federal cases involved internal information such as customer lists, while 36% of state cases and 58% of federal cases involved technical information (Almeling et al. 2010 and 2011). One reason that relatively more federal cases involved technical secrets could be that cases involving both patents and trade secrets must be tried in federal courts.

As to the misappropriators of trade secrets, the findings of Almeling et al. (2010 and 2011) were consistent with the biotech case study. More than 75% of trade secrets cases in state courts and over half of cases in federal courts involved an existing or former employee.

Various surveys have asked technology managers about how they appropriate the returns to innovation. European R&D managers were more likely to patent product innovations than process innovations, and the propensity to patent increased with sales and the importance of patents, but did not vary with R&D intensity (Arundel and Kabla 1998). European R&D managers generally rated secrecy as more valuable than patents, but the advantage of secrecy over patents decreased with R&D expenditure for product innovations, but not for process innovations (Arundel 2001). U.S. R&D managers cited secrecy and lead time most frequently as providing effective protection for product innovations, and cited secrecy and complementary manufacturing most frequently.

While civil trade secrets law is a state matter, federal courts do try trade secrets cases, applying the relevant state law, in two circumstances. One is situations of diversity, where plaintiffs and defendants reside in different states and the amount at stake exceeds $75,000 (Perritt 2005: 10-3). The other is cases that combine a federal action – patent, trademark, or copyright – with trade secrets action.

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as providing effective protection for process innovations (Cohen et al. 2000). However, German businesses rated patents as being more important than secrecy (Hussinger 2006).

The only empirical studies that considered the impact of laws on innovation were based on innovations presented at 19th century World’s Fairs. Moser (2005) found that patent laws affected the direction of innovation in 12 countries. Inventors specialized by industry according to whether their home country allowed patents. Separately, Moser (2010) found that most British and U.S. innovations were not patented and that the extent of patenting did not vary with national patent laws. However, neither of these studies addressed the impact of patent laws on R&D and the extent of innovation. And, of course, the effect of trade secrets laws on innovation remains an open issue.

Most analytical research on trade secrecy has focused on the exploitation of completed innovations and on the choice between secrecy and patents as ways to protect against competitors. Anton and Yao (2004) addressed the competitor’s decision whether to imitate and possibly infringe the innovator’s patent. They showed that the first mover would patent minor innovations and use secrecy for major innovations.  This proposition was supported by evidence from France (Pajak 2009). Denicolo and Franzoni (2004) considered the competitor’s investment in possibly duplicative R&D, while Kultti et al. (2007) studied the choice between patents and secrecy when multiple innovators may discover the same innovation. By contrast with earlier research, Ottoz and Kugno (2008) allowed patents and secrecy to be complements, and analyzed the innovator’s decision on the fraction of innovations to patent.

As the biotech study suggests, trade secrets law also plays an important in the R&D stage. Depending on patent law, patents might not protect work in progress, in which case, the only available protection is secrecy. Even for innovations that are intended to be patented, trade secrets protection of R&D is still important. It reduces the time for competitors to invent around, and also provides a fall-back in case the patent is not granted (Payne 1988).

Moreover, trade secrets law affects the extent of R&D spillovers. In a context of cumulative innovation, Fosfuri and Ronde (2004) showed that an innovator could benefit from spillovers which substitute for its own R&D in building on earlier innovations. The effect of trade secrets law on investment in R&D depends on the relation between

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6See, however, Mosel (2011).

7Patent laws differ according to whether priority is established by being first to invent (which would protect work in progress) or by being first to file (which would not protect work in progress).
own and spillover R&D. If own and spillover R&D are substitutes, then a reduction in spillovers would increase the return to own R&D, and so, increase R&D spending. By contrast, if own and spillover R&D are complements, then a reduction in spillovers would reduce the return to own R&D, and so, reduce R&D spending. A recent study of pharmaceutical manufacturers between 1997-2005 provides some evidence on the relation between own and spillover R&D. Higher inward licensing was associated with higher own R&D, which relation was interpreted as showing complementarity between external and internal R&D (Ceccagnoli et al. 2011).

Implicit throughout the analytical research is that technical innovation and intellectual property matter relatively more in high-technology industries. These industries are characterized by more intensive R&D (higher ratio of R&D to sales). Various studies have reported other systematic differences in R&D strategy and the impact of R&D between high-tech and other industries. The differences include faster growth of R&D (Brown et al. 2009), and stronger impact of R&D on labour productivity, whether measured by sales per employee (Harhoff 1998) or value-added per employee (Ortega-Argiles et al. 2010).

4 Trade Secrets Law

Trade secrets may possibly be governed by civil and criminal law. The scope of civil trade secrets law includes substantive law – what may be a trade secret, what the owner of secret must do to gain legal protection, and what others may not do with the secret, as well as procedures for legal action and remedies for misappropriation. The scope of criminal trade secrets law is similar, except that criminal law provides for penalties rather than remedies.

Historically, in the United States, civil trade secrets law comprised the accumulated stock of precedents, i.e., case law (as distinct from statute). The case law originated in England and was then applied in Massachusetts. In the seminal case of Peabody v. Norfolk, the court held that the owner of a trade secret is “entitled to protection against those who in, or with knowledge of, violation of contract and breach of confidence, undertake to disclose it or to reap the benefit of it” (98 Massachusetts 452 (1868)).

Subsequently, the American Law Institute, a standing organization of legal academics and practitioners, consolidated the substantive aspects of civil trade secrets law in the Restatement (First) of Torts (1939). The Restatement, Section 757, defined a trade
secret to “consist of any formula, pattern, device or compilation of information which is used in one’s business, and which gives him an opportunity to obtain an advantage over competitors who do not know or use it”. The Restatement stipulated the conditions under which a person who used or disclosed a trade secret would be liable for misappropriation.

While influential, the Restatements of the Law are not binding legal authority. In 1968, the National Conference of Commissioners on Uniform State Laws, another legal organization, began work on a uniform trade secrets law. Then, in 1979, the Commissioners published the Uniform Trade Secrets Act (UTSA) for enactment by the states. The Commissioners justified the UTSA as:

- Providing a comprehensive statute for the many states without substantial case law; and
- Even for states with substantial case law, clarifying injunctive and damages remedies, and the statute of limitations.

Compared with the Restatement (First) of Torts, the UTSA strengthened the protection of trade secrets in two ways. First, it expanded the definition of a trade secret. The UTSA does not require that the information be business related or in continuous use (Pooley 1997- : 2.03[2][c]). The Commissioners emphasized that the definition of a trade secret encompasses negative information such as “the results of lengthy and expensive research which proves that a certain process will not work”. The UTSA also covers work in progress (see, for instance, BlueEarth Biofuels, LLC (2011)). Second, under the UTSA, mere acquisition of a trade secret is a misappropriation. The secret need not be used or disclosed to be misappropriated (Pooley 1997- : 2.03[3]).

Besides substantive law, the UTSA also covered procedure and remedies. It specified a three-year limitation, so, the owner of a trade secret must commence legal action within three years of the misappropriation. The UTSA specified that an injunction could be long enough to eliminate any advantage from misappropriation. The UTSA specified punitive damages up to twice the actual damages for willful and malicious misappropriation.

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9 Subsequently, in 1985, the Commissioners made three technical amendments to the UTSA, which “did not alter the underlying philosophy of the Act” (Lydon 1987: 439).
To date, 47 states and the District of Columbia have enacted a Trade Secrets Act, most of which conform or are similar to the UTSA. However, the statutes do not encompass all aspects of civil trade secrets law, so, practically, the law combines statute with case law and continues to evolve. Massachusetts, New York, and Texas have not enacted any civil statute, and rely completely on case law.\textsuperscript{12} Separately, some states have enacted criminal statutes to govern misappropriation and theft of trade secrets.

Given the differences between the states in their civil and criminal trade secrets law, it is challenging to compare trade secrets law across and within states. Motivated by Garmaise’s (2011) index of state law on covenants not to compete, I compiled an index of state law of trade secrets to represent the strength of trade secret protection in each state over time.

The index encompasses four broad aspects of the law of trade secrets: within civil law, the substantive law, procedure, and remedies, and for criminal law, the presence of a criminal statute. Based on the American Bar Association’s periodic survey of state trade secrets law (Pedowitz et al. 1997; Malsberger et al. 2006) and other legal sources (Pooley 1997- ; Almeling 2009), I identified particular items to represent differences between the states and within states over time in each aspect of the law:

- **Substantive civil law:**
  - Whether a trade secret must be in continuous business use;
  - Whether the owner must take reasonable efforts to protect the secret;
  - Whether mere acquisition of the secret is misappropriation; and
  - Types of information covered by trade secrets;

- **Civil procedure:** The limitation on the time for the owner to take legal action for misappropriation;

- **Remedies:**
  - Whether an injunction is limited to eliminating the advantage from misappropriation;
  - Whether an injunction may be granted to prevent inevitable disclosure; and

\textsuperscript{12} Strictly, Massachusetts has enacted a statute (General Laws, Chapter 93, Section 42, and Chapter 266, Section 30(4)), but it is so rudimentary that I treat it as a state without a statute. Indeed, the state Appeals Court held, “we do not in any way intimate that these statutes change the ambit of trade secret protection in a civil action” (Chomerics, Inc. v. Ehrreich, 12 Mass App. Ct. 1, 8 n. 14).
The multiple of actual damages available in punitive damages;

- Criminal statute: Whether the state has enacted a statute to govern the misappropriation or theft of trade secrets.

The index was constructed as the sum of the scores for each of the nine items that had been decided up to that year divided by the number of items that had been decided up to that year, so the index was scaled between 0 and 1. In turn, the score for each item was specified so that a higher value represented stronger protection of trade secrets.

For instance, in substantive law, if the law did not require a trade secret to be in continuous business use, as under the UTSA, the score was 1, while the score was 0 if the law did impose such a requirement, as under the Restatement. With regard to procedure, the score for the time limitation was the limit divided by six, which was the longest such limit (New Jersey). As for remedies, if the law allowed injunction to prevent inevitable disclosure, as in Illinois, Pennsylvania, and Texas, then the score was 1, while it was 0 if the law did not allow such injunctions, as in California, Michigan and Virginia. Please refer to the Appendix for details of the index.

For each item, I used the American Bar Association’s survey (Pedowitz et al. 1997; Malsberger et al. 2006; ) and other legal sources (Milgrim on Trade Secrets; Connelly 1986-87; Goulet 2004; Kahnke et al. 2008), to identify the relevant milestones and the direction of change of law. The milestones included both statutes taking effect and decisions in cases that set legal precedent.

Figure 1 illustrates the evolution of the index of state trade secrets law between 1976-2006 for the six states accounting for the largest number of observations in the R&D sample. Four states – California, Illinois, Massachusetts, and Pennsylvania – exhibited a clear upward trend in the strength of trade secrets law. In the other two states – New York, which relies completely on case law, and Ohio, which enacted the Uniform Trade Secrets Act in 1994, the law evolved in a "U"-shape over time.

The primary contribution of this paper is to analyze the effect of state trade secrets law, as represented by the index, on company-level R&D and patenting. Accordingly, a key question is why state law on trade secrets changed. The concern for my research into the effect of trade secrets law on innovation is that the law evolved in response to companies’ decisions on innovation. Such reverse causation would present a serious challenge to the interpretation of any regression of R&D and patenting on the index of state trade secrets law.
To check for reverse causation, I analyzed the subject matter of the milestones in the index of trade secrets law. Among states accounting for 80% of the R&D sample, there were 125 milestones in civil trade secrets law. Of these, 54 were enactments of trade secrets statutes taking effect. In an earlier version of this paper, I checked and confirmed that enactment of trade secrets statutes was unrelated to state R&D or other state policies related to R&D including the R&D tax credit and tertiary education. Of the 125 milestones, 48 were cases involving inventions but 25 of those were decided in 1971 or earlier, and so were unlikely to have been influenced by R&D taking place in 1976 and after. This left 23 of 125 milestones being possibly related to R&D within the sample period.

It is important to stress that precedents from the cases involving business trade secrets, such as customer lists, apply to technical trade secrets as well. For instance, the seminal case on inevitable disclosure (as distinct from actual misappropriation) concerned marketing. When William E. Redmond, General Manager of Pepsi-Cola in California, quit to join Quaker Oats as Vice President-Field Operations for Gatorade, PepsiCo sought and obtained an injunction against Mr Redmond working for Quaker Oats in the pricing, marketing, and distribution of beverages. Subsequently, the PepsiCo case has been widely cited as precedent in suits to block engineers and scientists from working for competitors.

As a more formal check, I regressed the index of state trade secrets law on the state gross product, population, and R&D. As Table 1 reports, the index was not significantly related to state R&D, either in levels or in rates of growth.

5 Empirical Strategy and Data

My main objective was to study the impact of trade secrets laws on R&D expenditure and patenting. I applied an empirical strategy similar to those in recent studies of the impact on innovation of various U.S. state-level laws, including enforcement of non-competition covenants (Marx et al. 2010; Garmaise 2011; Samila and Sorensen 2011) and wrongful discharge laws (Bird and Knopf 2009; Acharya et al. 2010).

Besides directly identifying the effect of trade secrets law on R&D and patenting, I also identified the effect through two contingent factors. Generally, referring to Figure 2, trade secrets law possibly affects innovation at two stages. In the (later) exploitation

\[13\]PepsiCo, Inc. v. Redmond, 54 F. 3d 1262 (U.S. Court of Appeals, 7th Circuit, 1995).
stage, the law affects the degree of appropriability, and so, influences the innovator’s
decision how to commercialize and protect the innovation, and also affects the return to
R&D.

Stronger trade secrets protection would strengthen appropriability and so, provide
better assurance of exclusivity. This would increase the innovator’s return from investment
in R&D. The impact of the stronger appropriability would increase directly with
the size of the business, and specifically, the sales revenue. The larger is the sales re-
v enue, the larger would be the impact of a given increase in appropriability. Accordingly,
the impact of trade secrets law can be identified by its effect contingent on business size:
Changes in trade secrets law should have a bigger effect on larger businesses.

Patenting is subject to economies of scale, so, larger businesses would make more use
of patents (Lerner 1995; Arundel and Kabla 1998). Depending on whether patents are
complements or substitutes with trade secrets, stronger trade secrets protection might
increase or reduce patenting.

In the (earlier) investment stage, trade secrets law affects the extent of spillovers from
the R&D of others. Stronger trade secrets protection would reduce the extent to which
innovators would receive spillovers. The impact of reduced spillovers on investment in
R&D would depend on whether spillovers are complements or substitutes for own R&D.

Regardless of whether spillover and own R&D are complements or substitutes, the
impact of stronger trade secrets protection would be larger in high-tech businesses.
Various studies have reported systematic differences in R&D strategy and its impact
between high-tech and other industries (Brown et al. 2009; Harhoff 1998; Ortega-Argiles
et al. 2010). It is reasonable to expect that technical innovation would matter relatively
more in high-tech businesses. Accordingly, the impact of trade secrets law can also be
identified by its effect contingent on the nature of the business: Changes in trade secrets
law should have a bigger effect on high-tech businesses.

Specifically, I estimated the following model, for company $i$, in state $s$, in year $t$:

$$\ln R_{ist} = \beta \cdot X_{ist} + \gamma \cdot L_{st} + \gamma_e \cdot L_{st} \ln E_{ist} + \gamma_h \cdot L_{st} \cdot H_i + \beta_i + \beta_t + \epsilon_{ist}. \quad (1)$$

In (1), $R_{ist}$ represented R&D expenditure, $L_{st}$ represented the index of trade secrets law,
$E_{ist}$ represented the company sales revenue, $H_i$ indicated a high-technology company,
$X_{ist}$ were time-varying company characteristics, $\beta_i, \beta_t$ were company and year fixed
effects, and $\epsilon_{ist}$ was an error term. Further, $\beta, \gamma, \gamma_e, \gamma_h$ were the coefficients of
the time-varying controls, and the index of trade secrets law and the interactions of the
index with sales revenue, and with the high-tech indicator respectively.
The time- and company-varying controls, $X_{ist}$, comprised sales revenue, market-book ratio, and EBITDA. Sales revenue represented the scale of the company and controlled for any economies of scale in R&D, the ratio of the market-to-book value of the company controlled for other investment opportunities (Acharya et al. 2010), while EBITDA represented cash flow and controlled for the availability of investment funds. The company fixed effects accounted for non time-varying heterogeneity across companies, while the year fixed effects accounted for changes over time that equally affected companies in all states, such as interest rates and the federal R&D tax credit. Following Bertrand et al. (2004), the estimated standard errors were robust and clustered two ways, by state and company.

In all regressions, I specified absolute measures such as R&D expenditure and sales in logarithms, and relative measures such as the trade secrets index, market-book ratio, and industry R&D intensity, and indicators in their absolute form. For brevity, the discussion below simply refers to the variable itself and omits mention of the logarithm.

Technical innovation is relatively more important in manufacturing than service industries. Accordingly, much previous research into the protection of technical innovation has focused on manufacturing (Arundel and Kabla 1998; Cohen et al. 2000; Arundel 2001). Likewise, I also focused on manufacturing and compiled, from Compustat, company-level financial information including R&D expenditure, sales revenue, EBITDA (earnings before interest, tax, depreciation, and amortization), market value, book value, and industry (SIC 4-digit). I deflated sales revenue and EBITDA by the U.S. GDP deflator, and R&D expenditure by the U.S. deflator for gross private domestic investment.

An immediate issue was the location of R&D over time. A company may conduct R&D at multiple locations, which might change over time. Compustat reports only the current location of the company headquarters. This would measure the actual location(s) of R&D with error.

I identified the state-wise location of R&D through the patents assigned to the company. Using the NBER Patent Database (Hall, Jaffe, and Trajtenberg 2001; Bessen 2009) and the U.S. Patent Inventor Database (Lai et al. 2011), I compiled for each company and year, the total number of patents and the fraction of patents from each state by inventor address. I dropped any company and year in which the company filed one or zero patent, and any state that accounted for less than 5% of patents in the year. I then used the top five patent fractions by state to allocate the company R&D, as reported by Compustat, to the corresponding state.
The NBER Patent Database covers patents from 1976 to 2006, so I set the period of study accordingly. As the empirical analysis focused on R&D and patenting, I dropped observations for which both R&D and the number of patent applications were missing. Further, I dropped extreme outliers those with negative values for sales, R&D, or other measure used in the study, or in which the ratio of R&D to sales revenue exceeding the 99th percentile, or in which the ratio of patent applications to sales revenue exceeding the 99th percentile. The sample comprised 1611 companies in 4080 state-wise locations, with the median company having patents assigned from inventors in four states. Table 2 presents summary statistics of the data, and the Data Appendix provides details of the variables including sources and construction.

6 Results – R&D

Using least squares, I first estimated a background specification, regressing company-level R&D expenditure (in logarithm) on the controls – sales revenue, market-book ratio, EBITDA, and company and year fixed effects. As reported in Table 3, column (1), the coefficient of sales revenue was positive and significant, the coefficient of market-book ratio was positive but not significant, and the coefficient of EBITDA was negative and significant.14

The next specification included the index of trade secrets law. As reported in Table 3, column (2), the coefficients of the controls were similar to those in the background estimate. The coefficient of the index of trade secrets law, −0.052 (±0.051), was negative but not precisely estimated.

Intuitively, the method of appropriation might also vary with the nature of the business, and, in particular, the R&D intensity. Accordingly, the third specification included the index of trade secrets law as well as the interaction of the index with company sales revenue (measured as the difference from its sample mean), and the interaction of the index with an indicator of a high-technology industry. The indicator followed a classification by the U.S. Department of Commerce (1983) as refined by Brown et al. (2009).15

As reported in Table 3, column (3), the coefficient of the interaction of the index of trade secrets law with company sales revenue, 0.160(±0.030), was positive and signifi-

14All R&D regressions were estimated with the STATA routine, XTIVREG2 (Schaffer 2010).
15I included aerospace (SIC 372 and 3760), which Brown et al. (2009) excluded as they focused on financing of R&D. I excluded software computer and data processing services (SIC 737) as it is not a manufacturing industry.
cant. Since sales revenue was measured as the difference from its sample mean, for small companies, with sales revenue below the mean, an increase in the index of trade secrets law was negatively associated with R&D. By contrast, for large companies, with sales revenue above the mean, an increase in the index of trade secrets law was positively associated with R&D.

Further, the coefficient of the interaction of the index of trade secrets law with the high-technology indicator, $0.495(\pm 0.135)$, was positive and significant. Combined with the coefficient of the main effect of the index of trade secrets law, this coefficient was significantly different ($\chi^2(1) = 12.30, p = 0.0005$) from zero. Hence, among high-tech companies, an increase in the index of trade secrets law was positively associated with R&D, while among low-tech companies, there was no significant association.

To better appreciate these estimates, Table 4 presents counterfactual estimates of the effect of an increase in the index of trade secrets law on company R&D. Suppose that the index rises by 0.30, which was the increase in California between 1978-84 and 1990-98. In industrial inorganic chemicals (SIC 2810), a low technology industry, the average company revenues were $3.13 billion, which was less than the overall average. The increase in the index would have been associated with a 4.9% reduction in R&D. Stronger trade secrets law would have reduced spillovers of R&D. For the reduction in spillovers to have been associated with less R&D, the return to own R&D must have been lower, implying that own and spillover R&D must be complements.

By contrast, in pharmaceuticals (SIC 2834), a high technology industry, the average company revenues were $8.67 billion, which exceeded the overall average. The increase in the index would have been associated with a 14.8% increase in R&D. The interpretation of the higher R&D is not so clear. Stronger trade secrets law would have reduced spillovers of R&D. It could be that the increase in appropriability, which would increase R&D, was sufficiently strong to outweigh the complementarity between own and spillover R&D. Or, it could be that, among large companies, own and spillover R&D were substitutes, so, stronger trade secrets protection, by reducing spillovers, raised the expected return from R&D, and hence, was associated with more R&D. The contrast between low-tech electrical lighting (SIC 3640) and high-tech semiconductors (SIC 3674) was similar.

Instead of identifying high-tech companies by the U.S. government classification, an alternative would be to use R&D intensity. Accordingly, using all of the manufacturers in Compustat (not limited to those in the estimation sample), while excluding each of the sample companies in turn, I calculated the R&D intensity for each 4-digit SIC industry
excluding the particular company. This procedure sought to avoid any endogeneity from the company itself being used to calculate the R&D intensity.

Table 3, column (4), reports an estimate including the index of trade secrets law as well as the interaction of the index with company sales revenue, and the interaction of the index with the industry R&D intensity (measured as the difference from its sample mean). Consistent with the estimate of the specification using the high-technology indicator, the coefficient of the interaction of the index of trade secrets law with industry R&D intensity, 0.287(±0.056), was positive and significant. Apparently, stronger trade secrets protection was associated with higher R&D in R&D-intensive industries.16 Between the two specifications of R&D intensity, I preferred to use the U.S. government classification, as it was clearly exogenous to the estimation sample.

Cohen et al. (2000) found significant differences in the purpose of patents between companies applying “discrete” vis-a-vis “complex” technologies. In complex industries such as semiconductors and telecommunications, new products and processes combine multiple separately patentable elements. Hence, businesses use patents in negotiations to license the complementary innovations.

With new products and processes that require multiple elements, innovators can choose to patent some elements and keep others secret. It would be important to understand the effect of trade secrets law on complex industries. Accordingly, I estimated a specification including the index of trade secrets law as well as its interaction with an indicator of a complex industry (Cohen et al. 2000).

Owing to the limited industry coverage of Cohen et al.’s (2000) survey, the sample was reduced by more than half. Nevertheless, the results were striking. As reported in Table 3, column (5), the coefficient of the interaction of the index of trade secrets law with the complex indicator, 0.298(±0.151), was positive and significant. Apparently, increases in trade secrets protection were associated with larger changes in R&D among companies in complex relative to discrete industries.

These estimates reveal subtle nuances in the relation between the strength of trade

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16In Table 3, column (4), the coefficient of the index of trade secrets law (the main effect), 0.318 (±0.079), was positive and significant. This arose from the difference between identifying R&D-intensive companies by the high-tech indicator and a continuous measure of R&D intensity. In the sample, the difference in mean R&D intensity between high-tech and low-tech companies was 0.0813 - 0.0215 = 0.0598. Hence, by Table 3, column (4), the semi-elasticity of R&D with respect to the index of trade secrets law for high-tech companies would be 0.0598 × 0.287 = 0.40(±0.08). This is close to the corresponding estimate of 0.495(±0.135) from Table 3, column (3).
secrets protection and R&D. Apparently, stronger protection was associated with more R&D among larger companies and less R&D among smaller ones. Further, stronger protection was associated with more R&D among companies in high-tech and complex industries, but no significant change in R&D among companies in low-tech and discrete industries.

Robustness

To check the robustness of my findings, I considered alternative characterizations of the state trade secrets law, alternative constructions of the sample, and omission of possibly relevant variables. Table 5 reports the robustness checks, and, for easy reference, column (1), reproduces the preferred estimate from Table 4, column (3).

In constructing the index of trade secrets law, I stipulated that the law on each issue was unknown if there was no relevant case or statute. An alternative would be to stipulate that, in the absence of a statute, that the state would follow the Restatement (First) of Torts (1939). This motivated the construction of an alternative index. Table 5, column (2), reports an estimate using this alternative index. The results were quite similar to the preferred estimate.

Another, and very simple, way to construct an index of trade secrets law is to consider whether the state had enacted civil and criminal statutes governing trade secrets. This index would also address any worry of reverse causation in the sense of changes in R&D influencing the direction of case law. Table 5, column (3), reports an estimate using this alternative index. The results were quite similar to the preferred estimate.

In the next two robustness checks, I addressed the sensitivity of the results to construction of the sample. One possible issue is the identification of the state-wise locations of the company R&D from patent records. Another way would be to use the company headquarters from filings with the Securities and Exchange Commission. Using Compact Disclosure, I traced the historical locations of companies from 1988 onward. Table 5, column (4), reports an estimate associating the company R&D to the state containing the company headquarters. The results were quite similar to the preferred estimate, except that the coefficient of the interaction of the index of trade secrets law with the high-technology indicator, 0.531 (±0.301), was only marginally significant ($p = 0.078$).

17 In an earlier version of this paper, I confirmed that state enactment of civil trade secrets statutes was not related to R&D. Further, there has been no suggestion that enactment of criminal statutes was related to R&D (Connelly 1986-87).
Another possible issue with the sample is the dominance of California, which accounted for 13.7% of the sample. In case that California was somehow special, Table 5, column (5), reports an estimate excluding that state. The results were quite similar to the preferred estimate.

In the next two robustness checks, I addressed the sensitivity of the results to omission of other widespread state policies that possibly influenced R&D. Besides the inherent impact of the two policies, Biderman et al. (2010) suggest that checking observable policies also helps to check for unobservable policies as it is likely that governments implement both observable and unobservable policies in tandem.

The case study of biotechnology suggested that trade secrets law might affect R&D by regulating the mobility of employees and the consequent flow of information. Employee mobility is also regulated through covenants not to compete (Garmaise 2011). Table 5, column (6), reports an estimate including Garmaise’s (2011) index of state law on covenants not to compete. The sample was reduced as Garmaise’s (2011) index mostly varied across states rather than over time, so identification depended on companies with locations in different states.18 Even with the inclusion of the index on covenants not to compete, the estimated effects of trade secrets law were quite similar to those in the preferred estimate. The index of covenants not to compete was not significant.

The only widespread state policy directly targeting R&D was the R&D tax credit (Wilson 2007; Wilson 2009). Table 5, column (7), reports an estimate including an indicator of a state R&D tax credit in effect. With the inclusion of the state R&D tax credit, the estimated effects of trade secrets law were almost identical to those in the preferred estimate. The index of the state R&D tax credit was not significant.

To summarize, the central finding that stronger trade secrets law was associated with more R&D among larger and high-tech companies and less R&D among smaller companies was robust to multiple checks for the characterization of state trade secrets law, sample construction, and omission of possibly relevant variables.19

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18 A minor reason was that the index was available only from 1980 onward.
19 I conducted other robustness checks, unreported for brevity. One checked for lagged effects, with the trade secrets index and its interaction with company sales revenue and industry R&D intensity lagged by one year. The results were quite similar to the preferred estimate. Another checked the sensitivity of the results to omission of state educational policies, which might also possibly influence company-level R&D. The results were quite similar to the preferred estimate, and the education measures were not significant.
Falsification

As a further check of the validity of my findings, I conducted a set of validation and falsification exercises to test the impact of trade secrets law on other company-level expenditures. For brevity, I report just one, which tested the impact of trade secrets law on selling, general, and administrative (SG&A) expenses. Two elements of SG&A – general and administrative expenses – are overhead items. There would be little reason for trade secrets law to affect overhead expenses. On the other hand, trade secrets law encompasses marketing innovation, and one of most commonly litigated subjects in trade secrets is customer lists (Almeling et al. 2010). Hence, trade secrets law might affect expenditure in selling to new customers, and thus, affect SG&A.

Table 5, column (8), reports a regression on SG&A. The coefficient of the interaction of the index of trade secrets law with company sales revenue, 0.046(±0.025), was positive and marginally significant. Importantly, it was less than one-third the magnitude of the corresponding coefficient in the preferred estimate with a regression on R&D. The coefficient of the interaction of the index of trade secrets law with high-technology was small and not significant. The results of this falsification exercise were in line with theory and intuition.

7 Results – Patents

Much of the existing analytical and empirical literature on trade secrets has focused on the substitution between patents and secrecy in appropriating innovation (Anton and Yao 2004; Denicolo and Franzoni 2004; Kultti et al. 2007; Moser 2005; Moser 2010). By contrast, practitioners (Jorda 2008) and some scholars (Ottoz and Kugno 2008) have emphasized that patents and trade secrecy are complementary in appropriating the returns from innovation.

So, empirically, how did changes in state trade secrets laws affect company-level patenting? The number of patents is a count variable. With Poisson estimation, the coefficients are consistent if the mean specification is correct and the robust standard errors are consistent even if the distribution is misspecified (Wooldridge 2002: 646-649). Accordingly, following Hall and Ziedonis (2001), I used the Poisson model with robust standard errors clustered by state.

I first estimated a background specification, regressing patent applications on sales
revenue, market-book ratio, EBITDA, and company and year fixed effects.\textsuperscript{20} I did not include R&D expenditure as, being itself affected by changes in trade secrets law, it would have been a “bad control” (Angrist and Pischke 2008: Section 3.2.3). As reported in Table 6, column (1), the coefficient of sales revenue was positive and significant, which is consistent with economies of scale in patenting. Neither the market-book ratio nor EBITDA was significant.\textsuperscript{21}

Next, I included the index of trade secrets law. As Table 6, column (2), reports, the coefficients of the controls were similar to those in the background estimate. Interestingly, the coefficient of the index of trade secrets law, \(-0.336(\pm0.169)\), was negative and significant. To appreciate the implications of this estimate, consider an increase in the index of trade secrets law by 0.30, which was the increase in California between 1978-84 and 1990-98. This would be associated with a change in the expected number of patents to \(\exp(0.30 \times -0.336) = 0.90\), or a 10\% reduction, which is substantial. The result suggests that companies treated patents and trade secrets as substitutes.

Table 6, column (3), reports the estimate including the index of trade secrets law, the interaction of the index with company sales revenue (measured as the difference from its sample mean), and the interaction of the index with the high-technology indicator. The coefficient of the index of trade secrets law was larger than in the previous estimate. However, neither of the interactions was significant.

Next, to strengthen the identification of the impact of trade secrets law on patenting, I drew on Cohen et al.’s (2000) survey of technology managers, and specifically, the percentage of managers in the survey reporting that patents were effective in appropriating returns to innovation in products and processes. The survey covered a limited number of manufacturing industries, and so, with the inclusion of this variable, the sample was reduced by more than 40\%.

Table 6, column (4), reports an estimate including the interaction of the index of trade secrets law with the percentage of managers in Cohen et al.’s (2000) survey reporting that patents were effective in appropriating returns to \textit{process} innovation (measured as the difference from its sample mean). The coefficient of the interaction, \(-1.428(\pm0.554)\), was negative and significant. This is consistent with companies treating patents and trade secrets as substitutes in protecting process innovations. With the additional covariate,\textsuperscript{21}

\textsuperscript{20}I focused on patent applications rather than patent grants, since the issue is how businesses seek to appropriate the returns from their innovations. In practice, most patent applications are eventually granted, so applications and grants are highly correlated (Jaffe and Lerner 2004).
\textsuperscript{21}All patent regressions were estimated with the STATA routine, XTPQML (Simcoe 2008).
the main effect of the index of trade secrets law was still negative, but imprecisely estimated.

In addition, Table 6, column (5), reports an estimate including the interaction of the index of trade secrets law with the percentage of managers in Cohen et al.’s (2000) survey reporting that patents were effective in appropriating returns to product innovation (measured as the difference from its sample mean). The coefficient of the interaction, $-2.069(\pm 0.498)$, was negative and significant, which is consistent with companies treating patents and trade secrets as substitutes in protecting product innovations. The main effect of the index of trade secrets law was still negative and marginally significant.

In summary, I interpret these results as showing that companies treated patents and trade secrets as substitutes both overall, and specifically, in safeguarding both product and process innovations.\footnote{In unreported estimates, I replicated all of the regressions in Table 6 including R&D expenditure as an additional control. The results on the effect of changes in trade secrets law were even stronger than those reported in Table 6. However, I preferred the specifications in Table 6 as R&D expenditure was a “bad control” (Angrist and Pischke 2008: Section 3.2.3).}

8 Concluding Remarks

Through various empirical tests, I have robustly shown that changes in state trade secrets law were associated with a nuanced effect on company-level innovation. At the investment stage, stronger trade secrets protection was associated with more R&D among large and high-tech companies, and less R&D among small companies in low-tech industries. I interpret these results as showing that, among small companies in low-tech industries, own and spillover R&D were complements. By reducing spillovers among manufacturers, stronger trade secrets protection reduced the expected return from R&D, and so, led to less R&D. The interpretation is less clear for large and high-tech companies. It could be that the increase in appropriability, which would increase R&D, was sufficiently strong to outweigh the complementarity between own and spillover R&D. Or, it could be that, among these companies, own and spillover R&D were substitutes, so, stronger trade secrets protection, by reducing spillovers, raised the expected return from R&D, and hence, led to more R&D.

At the exploitation stage, stronger trade secrets protection was associated with significantly less patenting, with the negative effect increasing in the extent to which technology managers reported patenting to be an effective means of appropriating the returns
to innovation. These results suggest that companies treated patents and trade secrets as substitutes.

My results imply that trade secrets law matters for investment in R&D and for the decision whether to patent technical innovations. These findings are significant for public policy and managerial practice. Policy-makers concerned about technical innovation should look beyond patents, and give more attention to trade secrets. Managers should pay attention to the nuanced impact of secrecy – differing between small and large companies, between low- and high-tech industries, and between complex and discrete technologies.

The present study points to and enables a new research agenda – the impact of trade secrets law on (i) entrepreneurship and venture capital, (ii) collaboration, (iii) business and marketing innovation, and (iv) international trade and investment. Just as Garmaise’s (2011) index has been used in studies of the effect of state law on covenants not to compete on various aspects of innovation, the index of state trade secrets law can be applied to study the effect of trade secrets protection on other business and economic outcomes beyond R&D and patenting.

Gilson (1999) famously argued that California is more entrepreneurial than Massachusetts because it does not enforce non-competition agreements. However, the laws of the two states differ with respect to the protection of trade secrets as well as the enforceability of non-competition agreements. So, does entrepreneurship thrive in California in spite or because of a tougher trade secrets regime? This is a question that is obviously deserving of further investigation.

It is worth emphasizing that stronger trade secrets law would not necessarily affect entrepreneurship in a negative way. Stronger trade secrets law might reduce spillovers of knowledge, and so reduce entrepreneurship. On the other hand, stronger trade secrets law would increase security of property rights, and so facilitate agreements for collaboration and spin-off businesses.

Related to the above, the second important direction for future research is the impact of trade secrets law on collaboration between businesses. A major risk in any business or technical collaboration is that one party might steal the ideas of the other. By providing security of property rights over work in progress, trade secrecy may foster collaboration and sharing of information. Secrecy is the only available protection for innovation which has not reached the stage to qualify (if at all) for patent or trademark protection. To the extent that the law strengthens protection of trade secrets, it might foster collaboration.
A third useful direction for future research is the impact of trade secrets law on business and marketing innovation. One of the most common subjects of trade secrets litigation is customer lists (Almeling et al. 2010). The challenge to this research would be to procure the relevant data on investment in business and marketing innovation. One possible proxy is advertising expenditure, which is reported by Compustat. However, it is imperfect to the extent that the advertising copy and media placement are public, hence only the planning and resource allocation are secret.

Finally, trade secrets law possibly affects international trade and investment. The multilateral Agreement on TRIPS (Trade-Related Aspects of Intellectual Property Rights) came into effect on January 1, 1995. TRIPS, in Article 39.2, specifically provides for protection of trade secrets. However, just as trade secrets law varies within the United States, it varies across countries. Even the European Union, which has energetically sought to harmonize patent, copyright, and trademark laws, has not done so with trade secrets. Given the international variation of trade secrets law (and enforcement), it would be very useful to study their impact on international trade and investment.
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Notes: Estimation by ordinary least squares with fixed effects. Dependent variable: Index of state trade secrets law. Robust standard errors clustered by state in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
Table 2. Summary statistics

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<td>(1) Company</td>
<td>(2) Index</td>
<td>(3) Size &amp; hi-tech</td>
<td>(4) Size &amp; R&amp;D intensity</td>
<td>(5) Size &amp; complex</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------</td>
<td>-----------</td>
<td>--------------------</td>
<td>--------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Revenue (ln)</td>
<td>0.754***</td>
<td>0.755***</td>
<td>0.666***</td>
<td>0.658***</td>
<td>0.717***</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.045)</td>
<td>(0.041)</td>
<td>(0.040)</td>
<td>(0.042)</td>
</tr>
<tr>
<td>Market/ book value ('000)</td>
<td>0.169</td>
<td>0.181</td>
<td>-0.427</td>
<td>-0.508</td>
<td>-0.451</td>
</tr>
<tr>
<td></td>
<td>(1.997)</td>
<td>(1.992)</td>
<td>(1.946)</td>
<td>(1.970)</td>
<td>(2.241)</td>
</tr>
<tr>
<td>EBITDA (ln)</td>
<td>-0.046**</td>
<td>-0.047**</td>
<td>-0.050***</td>
<td>-0.052***</td>
<td>-0.091***</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.020)</td>
<td>(0.019)</td>
<td>(0.019)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Secrecy index x revenue</td>
<td>-0.057</td>
<td>-0.084</td>
<td>0.315***</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.051)</td>
<td>(0.063)</td>
<td>(0.082)</td>
<td>(0.118)</td>
<td></td>
</tr>
<tr>
<td>Secrecy index x hitech</td>
<td>0.160***</td>
<td>0.172***</td>
<td>0.161***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.030)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>Secrecy index x R&amp;D intensity</td>
<td>0.495***</td>
<td></td>
<td></td>
<td>(0.135)</td>
<td></td>
</tr>
<tr>
<td>Secrecy index x complex</td>
<td>0.303***</td>
<td></td>
<td></td>
<td></td>
<td>0.298**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.151)</td>
</tr>
<tr>
<td>Company f.e.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year f.e.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
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<td>23,457</td>
<td>23,457</td>
<td>23,061</td>
<td>11,133</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.421</td>
<td>0.421</td>
<td>0.426</td>
<td>0.424</td>
<td>0.461</td>
</tr>
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<td>4,080</td>
<td>4,080</td>
<td>4,016</td>
<td>1,956</td>
</tr>
</tbody>
</table>

Notes: Estimation by ordinary least squares with company and year fixed effects. Dependent variable: logarithm of R&D expenditure. Column (1): Company characteristics; Column (2): Including index of trade secrets law; Column (3): Including index of trade secrets law x logarithm of company revenue (measured as difference from sample mean) and index of trade secrets law x high tech, with high-tech industries as classified by U.S. Department of Commerce (1983) and refined by Brown et al. (2009), but including aerospace (SIC 372 and 3760) and excluding software computer and data processing services (SIC 737); Column (4): Including index of trade secrets law x logarithm of company revenue (measured as difference from sample mean) and index of trade secrets law x industry R&D intensity (measured as difference from sample mean); Column (5): Including index of trade secrets law x logarithm of company revenue (measured as difference from sample mean) and index of trade secrets law x complex, with complex industries as classified by Cohen et al. (2000). Robust standard errors clustered two-way, by state and company, in parentheses (** p<0.05, * p<0.1).
Table 4. Counterfactuals

<table>
<thead>
<tr>
<th>SIC</th>
<th>Industry</th>
<th>Sales revenue ($ billion)</th>
<th>High-tech</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>2810</td>
<td>Industrial inorganic chemicals</td>
<td>3.13</td>
<td>No</td>
<td>-0.049***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.064)</td>
</tr>
<tr>
<td>2834</td>
<td>Pharmaceutical preparations</td>
<td>8.67</td>
<td>Yes</td>
<td>0.148***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.037)</td>
</tr>
<tr>
<td>3640</td>
<td>Electric lighting and wiring equipment</td>
<td>1.92</td>
<td>No</td>
<td>-0.072***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.020)</td>
</tr>
<tr>
<td>3674</td>
<td>Semiconductors and related devices</td>
<td>2.05</td>
<td>Yes</td>
<td>0.079**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.034)</td>
</tr>
</tbody>
</table>

Note: Impact of increase in index of trade secrets law by 0.30 (the increase in California between 1978-84 and 1990-98) on company with average revenues in the respective industry.
<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Preferred specification</th>
<th>(2) Index (fill Restatement)</th>
<th>(3) Index (only statutes)</th>
<th>(4) HQ locations</th>
<th>(5) Excl CA</th>
<th>(6) Non-compete</th>
<th>(7) R&amp;D tax credit</th>
<th>(8) SG&amp;A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue (ln)</td>
<td>0.666*** (0.041)</td>
<td>0.660*** (0.041)</td>
<td>0.718*** (0.040)</td>
<td>0.698*** (0.060)</td>
<td>0.638***</td>
<td>0.674*** (0.040)</td>
<td>0.666*** (0.048)</td>
<td>0.841*** (0.041)</td>
</tr>
<tr>
<td>Market/ book value (mill)</td>
<td>-0.427 (1.946)</td>
<td>-0.611 (1.934)</td>
<td>-0.191 (1.983)</td>
<td>-0.373*** (0.111)</td>
<td>0.679</td>
<td>-0.552 (1.895)</td>
<td>-0.441 (1.821)</td>
<td>0.448</td>
</tr>
<tr>
<td>EBITDA (ln)</td>
<td>-0.050*** (0.019)</td>
<td>-0.051*** (0.019)</td>
<td>-0.050*** (0.019)</td>
<td>-0.071*** (0.010)</td>
<td>-0.034*</td>
<td>-0.057*** (0.019)</td>
<td>-0.050*** (0.019)</td>
<td>-0.071*** (0.012)</td>
</tr>
<tr>
<td>Secrecy index</td>
<td>-0.084 (0.063)</td>
<td>-0.098 (0.089)</td>
<td>-0.084 (0.094)</td>
<td>-0.064 (0.197)</td>
<td>-0.070</td>
<td>-0.139** (0.065)</td>
<td>-0.073 (0.070)</td>
<td>0.039</td>
</tr>
<tr>
<td>Secrecy index x revenue</td>
<td>0.160*** (0.030)</td>
<td>0.170*** (0.034)</td>
<td>0.141*** (0.029)</td>
<td>0.207*** (0.060)</td>
<td>0.146***</td>
<td>0.146*** (0.030)</td>
<td>0.160*** (0.028)</td>
<td>0.046*</td>
</tr>
<tr>
<td>Secrecy index x hitech</td>
<td>0.495*** (0.135)</td>
<td>0.596*** (0.138)</td>
<td>0.474*** (0.126)</td>
<td>0.531* (0.301)</td>
<td>0.514***</td>
<td>0.529*** (0.142)</td>
<td>0.494*** (0.135)</td>
<td>0.085</td>
</tr>
<tr>
<td>CNC index</td>
<td>-0.143 (0.215)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D tax credit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.021 (0.033)</td>
<td></td>
</tr>
<tr>
<td>Company f.e.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year f.e.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Observations</td>
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<td>23,457</td>
<td>23,434</td>
<td>12,527</td>
<td>20,055</td>
<td>10,395</td>
<td>14,889</td>
<td>22,985</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.426</td>
<td>0.428</td>
<td>0.425</td>
<td>0.662</td>
<td>0.395</td>
<td>0.389</td>
<td>0.375</td>
<td>0.356</td>
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<td>4,080</td>
<td>4,077</td>
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<td>3,611</td>
<td>2,989</td>
<td>4,002</td>
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<tr>
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<td></td>
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</tr>
</tbody>
</table>

Notes: Estimation by ordinary least squares with company and year fixed effects. Dependent variable: ln R&D expenditure. Column (1): Preferred specification including primary index of trade secrets law; Column (2): Including alternative index of trade secrets law filling in with Restatement for years before trade secrets act; Column (3): Including alternative index of trade secrets law based on enactment of civil and criminal trade secrets law; Column (4): Company locations specified by headquarters using historical data from Compact Disclosure; Column (5): Excluding California; Column (6): Including Garmaise’s (2011) index of covenants not to compete; Column (7): Including indicator of whether state enacted R&D tax credit; Column (8): Falsification with dependent variable being selling, general, and administrative expenses. Robust standard errors clustered two-way, by state and company, in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Revenue (ln)</th>
<th>(2) Market/ book value (000)</th>
<th>(3) EBITDA (ln)</th>
<th>(4) Secrecy index x revenue</th>
<th>(5) Secrecy index x hitech</th>
<th>(6) Secrecy index x patent eff product</th>
<th>(7) R&amp;D exp (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.860***</td>
<td>-2.208</td>
<td>0.090</td>
<td>-0.336**</td>
<td>0.348</td>
<td>-1.428***</td>
<td>-2.069***</td>
</tr>
<tr>
<td></td>
<td>(0.117)</td>
<td>(7.195)</td>
<td>(0.061)</td>
<td>(0.169)</td>
<td>(0.075)</td>
<td>(0.227)</td>
<td>(0.554)</td>
</tr>
<tr>
<td></td>
<td>0.867***</td>
<td>-2.214</td>
<td>-0.092</td>
<td>-0.473**</td>
<td>0.225</td>
<td>-1.88*</td>
<td>-0.217**</td>
</tr>
<tr>
<td></td>
<td>(0.115)</td>
<td>(7.160)</td>
<td>(0.060)</td>
<td>(0.225)</td>
<td>(0.102)</td>
<td>(0.224)</td>
<td></td>
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<tr>
<td></td>
<td>0.878***</td>
<td>-2.225</td>
<td>-0.088</td>
<td>-0.422</td>
<td>0.064</td>
<td>(0.245)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.129)</td>
<td>(7.175)</td>
<td>(0.059)</td>
<td>(0.275)</td>
<td>(0.098)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.939***</td>
<td>-7.893</td>
<td>-0.071</td>
<td>-0.450*</td>
<td>0.211</td>
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</tr>
<tr>
<td></td>
<td>(0.136)</td>
<td>(6.171)</td>
<td>(0.067)</td>
<td>(0.265)</td>
<td>(0.989)</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.963***</td>
<td>-5.404</td>
<td>-0.072</td>
<td>-0.217**</td>
<td>(0.245)</td>
<td></td>
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<tr>
<td></td>
<td>(0.128)</td>
<td>(6.717)</td>
<td>(0.066)</td>
<td>(0.217)</td>
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<td>2,401</td>
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</table>

Notes: Estimation by Poisson regression with company and year fixed effects. Dependent variable is number of patent applications by company and year. Column (1): Company characteristics; Column (2): Including index of trade secrets law; Column (3): Including index of trade secrets law x logarithm of company revenue (measured as difference from sample mean) and index of trade secrets law x high tech, with high-tech industries as classified by U.S. Department of Commerce (1983) and refined by Brown et al. (2009), but including aerospace (SIC 372 and 3760) and excluding software computer and data processing services (SIC 737); Column (4)-(5): Including index of trade secrets law x Cohen et al.'s (2000) percentage of technology managers reporting that patents were effective in appropriating process/product innovations (measured as difference from sample mean). Robust standard errors clustered by state in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
Figure 1. Index of trade secrets law

Figure 2. Innovation stages

**Trade secrets law:**

- **Affects R&D spillovers**
- **Affects exclusivity**

Stage 1: Investment
- Decide R&D spending

Stage 2: Exploitation
- Patent or keep secret