The Sarbanes-Oxley Act, industrial innovation, and real option creation

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19 August 2013

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WORKING PAPER – COMMENTS WELCOME

19 August, 2013

ABSTRACT

We look at the effect of the US Sarbanes-Oxley (SOX) financial regulation on industrial innovation. Our theoretical framework shows it creating immediate uncertainty about its costs and future resolution of cost and managerial performance uncertainty. Real option value is created for investment delay. We construct a panel of patenting data and fit our model to it. We find a dip in patenting after SOX and subsequent medium term recovery, with larger dips for small, risky, and new companies. In the medium term, these companies continue to have relatively lower patenting. Like SOX, the dynamic behaviour is found only to apply to US companies. Our results have implications for policy and analysis.

Keywords

Innovation
Patents
Sarbanes-Oxley
Regulation
Real options

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1. Introduction

Following the Enron bankruptcy and other financial scandals (Coates, 2007), the US Government enacted the Sarbanes-Oxley Act (Sarbanes-Oxley (2002), hereafter SOX) in 2002. The Act aims to protect investors by improving the quality of information disclosed by companies publicly quoted in the US. It set up a body to oversee the auditing of public companies, it increased restrictions on the activities of auditors, company insiders, and analysts, it expanded disclosure requirements, and it increased penalties for malfeasance.

SOX is costly for companies through direct charges and compliance costs. Direct charges are incurred through levies to fund the auditing oversight body. Compliance costs are incurred by hiring auditors and officers able to implement the regulations and bear the risk of increased punishment, and through allocation of time to meet the extended internal review and disclosure requirements. These costs will ultimately be carried by investors in the companies. On the other hand, SOX offers a number of benefits to investors. They receive better information and so can make more informed decisions with lower uncertainty. Plausibly, corporate insiders and auditors will change their behaviour to avoid illegal behaviour, so reducing risk as well as revealing it.

Prior work has examined the net effects of SOX on various measures of corporate activity and performance, including profitability (Ahmed, 2010; Li et al, 2008; Zhang 2007) and choice of executives and their compensation (Cohen, 2013; Linck, 2009). Some papers have identified a shift against investment and related measures in the years immediately after SOX. For instance, Bargeron et al (2010) find that capital expenditures and research and development spending fell, Cohen et al (2013) determine that some types of risky expenditures decreased, and in Kang et al (2010) investment discount rates are found to have increased.

This paper looks at changes in innovation outputs after SOX. We examine whether the declines in industrial inputs indicated in the literature translate to declines in outputs. A focus is the dynamics of the changes, and how short term and medium term changes differ.

We start by giving a theoretical model of how investors respond to SOX's passage. SOX's effect is on investor costs and uncertainty. The costs arise through SOX's direct charges, and through risk costs. SOX creates uncertainty in the level of costs and resolves uncertainty relating to managerial competence. The cost uncertainty and the managerial uncertainty both decline over the period of SOX's implementation. The uncertainty decline creates a real option value of waiting to invest.

We use the model to deduce hypotheses on investor behaviour before SOX, in the short run after it, and in the medium term. The model implies that investment in small, risky, and new companies will decline immediately after SOX, and then rise in the medium term. The finding is specific to investment in US public companies, and investment in non-US companies should not exhibit such a fall and rise. The persistent effect of SOX is not determined in the model and is left for empirical determination.

Testing of the hypotheses then follows. We use US patent data as a measure of industrial output following long precedent in the literature (Jaffe and Trajtenberg, 2002). A panel of patents is constructed, with industrial classes as the cross-section and monthly patenting in the time dimension. Statistics on class size, risk, and newness are derived and included. The model's estimating equations describe patents driven by common time trends and industrial class dummies with parameter breaks immediately after SOX and then in the medium term, where the size of the breaks depend on class characteristics. The equations are fitted under panel negative binomial stochastic assumptions, with both fixed and random effects.

We find that our model's predictions hold. With various degrees of significance, small, risky, and new classes (and by extension, companies) experience patent declines immediately after SOX, and then recover in the medium term. The behaviour is not replicated by non-US companies, indicating a US specific cause like SOX.

We make a number of contributions to analysis of SOX. Our theoretical contribution is in representing the Act in terms of its effect on uncertainty and the creation of real option value for investment delay. We provide a theoretical connection between the prior SOX empirical work on investment rates (Bargeron et al, 2010; Cohen et al, 2013; Kang et al, 2010), on information revelation and improved investment practice (Ashbaugh-Skaife et al, 2009; Cheng et al, 2013; Kalelkar and Nwaeze, 2011; Singer and You, 2011), and risk dynamics (Akhigbe and Martin, 2008; Akhigbe et al, 2008).

An empirical contribution is to demonstrate the existence of a temporary dip in SOX response and subsequent recovery, consistent with our theory. Previous empirical work has generally examined the post-SOX period as subject to a common generating function, rather than subject to variation (Ahmed et al, 2010; Kang et al, 2010; Leuz et al, 2008; Linck et al, 2009). We further find an industrial output change attributable to SOX. Existing work has examined changes in industrial inputs (Bargeron et al, 2010; Cohen et al, 2013), or looked at financial quantities like profit (Ahmed, 2010; Li et al, 2008). We supplement the literature on SOX's effect on these variables by demonstrating that there is a medium term reduction in patenting following SOX.

A more general contribution is to the literature on the effect of finance on innovative outcomes. General frameworks for looking at finance's effect on innovation are given in Hall (2002), and the effect of financial crises on innovation is given in Paunov (2012) and Archibugi (2013). We are not aware of any precursors in the literature looking at financial regulation's effect on innovative outputs.

Section 2 presents our theoretical model, section 3 describes the data, section 4 has our estimation method, section 5 presents results, and section 6 concludes.

2. Theoretical framework

In this section we describe the options faced by an investor who can invest in a project leading to innovation. Their investment criteria are given prior to SOX, immediately following its introduction, and in the long run. After solving the criteria, we use them to formulate a testable hypothesis and a means of inferring SOX's persistent effect.

An investor is profit maximising and earns income from investing in a company and receiving profits from their investment. They discount future income at a rate d. The investor is risk averse and incurs costs of K_R when they receive a random income drawn from distribution function R; this cost may arise from extra capital being advanced to protect against loss exposure and so not being available for higher yielding projects elsewhere. When R is concentrated at a single point, $K_R = 0$. Investors have funds available for immediate investment in the company, or can choose to delay for m time periods and then reassess their options.

The company requires investment of C. If the company receives the investment, it is spent on an innovative project that is non-reversible and there are no resale opportunities at a value above the investment return. Innovation results in intellectual property and a one-off income from it of r_t. Because of difficulties in observing the company's managerial quality, the investor perceives r_t as unknown prior to investment and treats it as a random variable drawn from a distribution R_t. The company protects its intellectual property by patenting, with the number of patents increasing in r_t.

Prior to SOX, the distribution R_t is unchanging over time, so $R_0 = R_m$. When SOX is introduced, the income generated after investment decreases by a one-off cost of s_t. We call this extra term "cost" by reference to the additional auditing and other expenses incurred through SOX, but it may be negative and so increase the investor's income if the changes improve the ongoing performance of the company. Investors are initially unsure about the size of s_t, and treat it as drawn from a distribution S_t. They have assumptions about how they will update their prior distribution of the effect as information emerges over time. Companies anticipate that they will have sufficient information to form stable judgements of SOX's effect by time m, so that the support for S_m will be a single point within the support for S_0. We denote by Q_t the distribution of the sum $q_t = r_t - s_t$.

Before SOX's introduction, the investor loses from delay in making their investment decision or not. The distribution function of returns is stable over time, so the same undiscounted expected return will be earned from immediate or delayed investment, and the latter return is subject to discounting. So investment will be made if and only if the expected returns from immediate investment net of risk costs are positive, or

$$\int_{I(R_0)} r\, dR_0 - K(R_0) + e_1 > 0 \tag{1}$$

where $I(R_0)$ is the support of R_0 and e_1 is an error term with distribution function F. The probability of (immediate) investment is thus

$$1 - F(-\int_{I(R_0)} r\, dR_0 + K(R_0)). \tag{2}$$

Immediately after SOX's introduction, the returns from investment change over time so a choice not to invest immediately does not imply a permanent commitment. Thus, investors choose whether to invest straightaway or delay for \$m\$ periods until they are fully informed about SOX costs and managerial quality. Delay occurs if and only if

$$\int_{I(Q_0)} q \; dQ_0 - K(Q_0) + e_2 < \frac{1}{(1+d)^m} \int_{I(Q_+)} q \; dQ_0 \tag{3}$$

where $I(Q_0)$ is the support of Q_0, $I(Q+) = \{q \in I(Q_0) : q > 0\}$, and e_2 is an error term.

The left hand side is the expected value from immediate investment, and the right hand side is the expected value from waiting and only investing if the revealed managerial quality net of costs gives a positive profit. We can decompose the integral on the left hand side and rearrange to give

$$(1 - \frac{1}{(1+d)^m}) \int_{I(Q_+)} q \; dQ_0 + \int_{I(Q_-)} q \; dQ_0 - K(Q_0) + e_2 < 0 \tag{4}$$

where $I(Q-) = I(Q_0) \setminus I(Q+)$, which is the set of SOX costs and managerial qualities that result in a loss if they occur after m periods. If e_2 has distribution function F, then the probability of immediate investment is

$$1 - F(-(1 - \frac{1}{(1+d)^m}) \int_{I(Q_+)} q \; dQ_0 - \int_{I(Q_-)} q \; dQ_0 + K(Q_0)) . \tag{5}$$

Comparison with the probability of immediate investment before SOX shows that whether it rises or falls depends on SOX and company characteristics affecting SOX's costs, benefits, and risks. We consider some company features that are liable to reduce immediate investment in favour of delayed investment.

Many papers find that SOX was more costly for small companies (Ahmed et al, 2010; Chhaochharia and Grinstein, 2007; Kamar et al, 2007; Kang, 2010; Litvak, 2007b; Wintoki, 2007). If companies have high costs, then $\int_{I(Q_+)} q \; dQ_0$ will tend to be smaller and positive while $\int_{I(Q_-)} q \; dQ_0$ will tend to be larger and negative. The probability of immediate investment then declines. Moreover, for a small company the risk compensation term $K(Q_0)$ is likely to be more significant relative to other components of the expression including the error term, so the probability of immediate investment would also decline. Thus we have the following hypotheses:

H1a: Investment by small companies will fall immediately after SOX.
H1b: Investment by small companies will rise in the medium term after SOX.

Some research finds that SOX penalised risk-taking and was followed by shifts out of risk taking activities (Bargeron et al, 2010; Cohen et al, 2013). Kang et al (2010) find that riskier firms used higher discount rates after SOX, consistent with increased risk aversion. We look at how investment in risky companies responded dynamically after SOX, where risk is measured by dispersion in income. If the dispersion in q increases, then $\int_{I(Q_+)} q \, dQ_0$ and $\int_{I(Q_-)} q \, dQ_0$ increase in magnitude by the same amount since any extra expected profits will be offset by extra expected losses. Thus, their net contribution to the probability of immediate investment is unchanged. The risk compensation term $K(Q_0)$ will rise. We can rewrite the probability as

$$1 - F(-\int_{I(Q_+)} q \, dQ_0 - \int_{I(Q_-)} q \, dQ_0 + \frac{1}{(1+d)^m} \int_{I(Q_+)} q \, dQ_0 + K(Q_0)) \qquad (6)$$

where the first two terms in the distribution function make no net contribution, while the last two terms become more positive. Thus, the probability of immediate investment declines. Intuitively, the extra risk increases the value of waiting to see and the risk disutility of immediate investment. Hypotheses H3 and H4 follow:

H2a: Investment by risky companies will fall immediately after SOX.
H2b: Investment by risky companies will rise in the medium term after SOX.

Wintoki (2007) determines that newer companies had lower abnormal returns during the passage of SOX than older companies. New companies may be both smaller and riskier than average, and so their response will reflect these characteristics. For our model, their patenting will tend to fall and rise after SOX. A further dynamic is introduced by the information revelation associated with investors and regulators learning about a new company from experience. When a new company undertakes an investment project and is immediately subject to SOX, lack of publicly available information will likely make disclosure about the project more onerous and costly. Instead, the new company could avoid immediate investment and allow information about itself to emerge at a lower cost through continued operations. We represent the lower cost by a reduction of c to the disclosure cost s_t, so that the revenue from waiting is $q_t + c = r_t - (s_t - c)$. The revised delay criterion is

$$\int_{I(Q_0)} q \; dQ_0 - K(Q_0) + e_2 < \frac{1}{(1+d)^m} \int_{I(Q_+)} (q+c) \; dQ_0 \tag{7}$$

with probability of immediate investment given by

$$1 - F(-(1 - \frac{1}{(1+d)^m}) \int_{I(Q_+)} q \; dQ_0 + \frac{c}{(1+d)^m}) \int_{I(Q_+)} dQ_0 - \int_{I(Q_-)} q \; dQ_0 + K(Q_0)). \tag{8}$$

The expression in the distribution function differs by the positive term $\frac{c}{(1+d)^m}) \int_{I(Q_+)} dQ_0$, so the probability of immediate investment declines. The intuitive reason is that immediate investment incurs a disclosure cost through SOX that is not required for actual disclosure, so is more costly relative to waiting. Hence we have

H3a: Investment by new companies will fall immediately after SOX.
H3b: Investment by new companies will rise in the medium term after SOX.

SOX applies only to companies publicly quoted in the US. We would therefore not expect to see all of the behaviours proposed in hypotheses H1-3 exhibited by other innovative organisations if SOX is their cause. In particular, non-US residents would not be directly affected by SOX, although they may be indirectly affected, for example if they sell to US public companies. The following hypothesis captures our expectations:

H4: Investment in non-US residents will not exhibit all the behaviours proposed in hypotheses H1-3.

After *m* periods, investors are aware of SOX's costs and managerial quality and face no further uncertainty. They therefore face a problem of investing if and only if $r_m - s_m > 0$ where r_m and s_m are realisations from the returns distribution R_0 and the SOX cost distribution S_0 respectively.

Comparing with the investment criterion before SOX given in inequality (1), we see that the expected long run value of investment will increase if and only if

$$r_m - s_m > \int_{I(R_0)} r \, dR_0 - K(R_0) + e_1 \tag{9}$$

which says that the observed returns net of the observed SOX costs exceed the expected returns net of the risk premium. Generally the left hand side and right hand side will differ in value, and SOX will induce a persistent change in investment and innovation. At the time of SOX's implementation the two left hand values will not be known, and their expected values can be taken to determine whether SOX is expected to increase investment. Putting the error term as zero mean and taking expectations, cancelling out the terms for expected returns, and rearranging, we have

$$K(R_0) > \int_{I(S_0)} s \, dS_0 \tag{10}$$

where $I(S_0)$ is the support of S_0.

So SOX is expected to increase investment if and only if the risk premium from ignorance about managerial quality (which vanishes after SOX) exceeds the expected SOX costs (which appear after SOX). If investors are not risk averse and SOX is expected to be costly, then the left hand side will be zero and the right hand side will be positive, so the value of investment will tend to fall after SOX.

There is evidence in the literature on the types of company which have large costs relative to their size. Many papers find that small companies are disproportionately burdened (for example, Ahmed et al (2010)) and Wintoki (2007) indicates that new companies are too. Some papers find that companies were avoiding risky behaviour (for example, Bargeron et al (2010)), consistent with lower net income from it. On the other hand, investors may be expected to be relatively ignorant about managerial quality at small, new, and risky companies or such companies may be particularly susceptible to internal control weaknesses (Doyle, 2007), and so investors would benefit disproportionately from disclosure about them. Research indicates that investment allocation does respond to SOX disclosures (Cheng, 2013; Singer and You, 2011).

Given SOX's ambiguous persistent effects, we test the following competing hypotheses:

H5a: Investment by small, risky, and new companies will fall in the medium term after SOX relative to the pre-SOX period.
H5b: Investment by small, risky, and new companies will rise in the medium term after SOX relative to the pre-SOX period.

3. Empirical procedure

Our theoretical model looks at innovative investment in companies. We will test its hypotheses using aggregated output data. To connect the model with the data, we make the assumption that aggregate characteristics reflect the characteristics of the individual input investments. Thus, if the individual investments are small and volatile, the aggregate output will also tend to be small and volatile and vice versa. Similarly, if component investments undergo a change in behaviour, then the change will be manifested in aggregate output and vice versa. We perform aggregation to the level of industrial sector, and provide more detail in Section 4 on data.

Patents are used as our measure of outputs of industrial innovation, for which there is long precedent (Hausman et al, 1984; Hall et al, 1986; Jaffe and Trajtenberg, 2002). The expected level of patenting has an unobserved, class specific component and a common time trend. The time trend will not capture different long term trends across industries, but will describe more short term drifts such as that due to broad business cycles. The formula for expected patents $y_{i,t}$ in class i at time t is then assumed to be given by $\exp(\alpha t + \beta x_{i,t} + \ln \delta_i)$ where α is a constant, t is time, β is a vector of parameters, $x_{i,t}$ is a vector of class and time specific variables, and δ_i is a class specific positive constant.

Our theoretical model indicates that there is a change in patenting immediately after SOX and then in the medium term. Moreover, the change is affected by company size, risk, and age. We infer aggregate changes are induced by the characteristics of the industrial sectors in which the companies patent. Two possible changes are considered, in the level of patenting and in its trend. $\beta x_{i,t}$ in the former case is given by $\beta x_{i,t} = d \times (\beta_0 + \beta_1 size + \beta_2 risk + \beta_3 new)$ where d is a dummy equal to one for the change period and zero otherwise, the β_js are constants, *size* is the size of the industrial sector, *risk* is the risk in the sector, and *new* measures its newness. For the trend change, $\beta x_{i,t}$ is given by $\beta x_{i,t} = d \times t \times (\beta_0 + \beta_1 size + \beta_2 risk + \beta_3 new)$. Our estimations compare patenting before SOX with patenting immediately after it, then patenting immediately after it with the medium term, then patenting before SOX with the medium term. In each case the later period has the time dummy *d* equal to one.

The stochastic distribution of patenting in each class is assumed to be negative binomial following the NB1 specification so the variance is proportional to the mean. The probability of $y_{i,t}$ patents occurring in class *i* and time *t* is then

$$P(y_{i,t} \mid x_{i,t}, \delta_i) = \frac{\Gamma(\lambda_{i,t} + y_{i,t})}{\Gamma(\lambda_{i,t})\Gamma(y_{i,t}+1)} \left(\frac{1}{1+\delta_i}\right)^{\lambda_{i,t}} \left(\frac{\delta_i}{1+\delta_i}\right)^{y_{i,t}} \quad (11)$$

where $\lambda_{i,t} = \exp(\alpha t + \beta x_{i,t})$. We consider both fixed effects and random effects models. In the former, the δ_i are unknown deterministic parameters, while in the latter they are independent, identically distributed, random variables with $1/(1+\delta_i) \sim Beta(p_1, p_2)$ for unknown deterministic parameters p_1 and p_2. The observed patent data is estimated as a panel across class and time using maximum likelihood estimation (Hausman et al, 1984; Cameron and Trivedi, 1998, ch. 9). The estimations are implemented in STATA code forthcoming on the author's website.

4. Data

We test our hypotheses on US patent data. Our source for the data and supporting material is the US Patent and Trademark Organization (USPTO) website at www.uspto.gov. The data was extracted in July and August 2013. We use the patent data as the output and to derive determinant statistics. Other data from the website is used as a source of determinant variables.

4.1 Innovation

Patent data at the USPTO is multiply subdivided. The divisions include the record type (application, publication of application, or issue), date of event, industrial patent class, the country of residence of the applicant, and the name of the assignee. We examine applications made between April 2001 and December 2007 and aggregate the data by the application month. The data is grouped by patent class. There are 473 classes recorded by the USPTO, and we randomly select 67 of them. The selection is done to make data collection more manageable. The classes are shown in Appendix 1, Table A1. We split the data depending on whether the patenter's country of residence is the US or not.

4.2 Size

The size of the patent class is measured by the mean number of monthly patents applied for in the class between April 2001 and March 2002. The statistics are calculated for US and non-US residents' patents. The country means are shown by patent class in Appendix 1, Table A2. There is quite a wide variation in the mean numbers by class, from 283.5 per month (US residents) and 120.3 (non-US residents) in the data processing class 707 down to zero per month for the smokers' supplies class D27. The between class standard deviation in the within class means is 44.6 (US) and 19.5 (non-US).

4.3 Risk

Patent class risk is measured by the standard deviation of monthly patent applications in the class between April 2001 and March 2002. The risk is calculated for the US and non-US data. Appendix 1, Table A2 shows the standard deviations by patent class. The maximum standard deviation for US residents is 41.6 while for non-US residents it is 12.4, with zero minima.

4.4 Newness

We use the patent class establishment date to measure class newness. The establishment date is available directly from the USPTO website, and is shown in Appendix 1, Table A2. It is moderately correlated with the other determinants, US patent mean (0.31), US standard deviation (0.29), non-US patent mean (0.29), and non-US standard deviation (0.24). Thus, there is some tendency for newer classes to be larger and more volatile.

4.5 Timing for SOX's effects

We have to decide on the dates to allocate to the pre-SOX period, the period immediately after, and the medium term. Patent application data is only published by the USPTO website from March 2001, and the financial crisis of 2008-9 plausibly affected innovation investment (Paunov, 2012). Thus, between these natural breaks we have seven years to allocate to the three periods.

SOX was signed into law on July 30th 2002 following a legislative procedure that had started at the beginning of the year (Chhaochharia and Grinstein, 2007; Litvak, 2007a). The implementation of its measures was staggered over the next decade, with longer delays for small firms (Gao et al, 2009). The expectation of SOX linked costs may have reasonably arisen from early 2002 with actual implementation costs from the middle of the year onwards, depending on the firm size.

Patents measure new investment with a lag to allow for product development, so the full effect of SOX on patenting would be expected to act with a delay (Griffin (1997) reports average product development cycle times of 15.3 months across five industries when development systems are in place). Some early impact may be expected as patents emerge during the development process. Moreover, the act of patenting is in itself costly as it reveals the existence of an innovation and part of its process to the market, so would be sensitive to operating conditions and hence SOX. But the major effect would plausibly not be instantaneous. Taking into account the date of SOX's signing and implementation and the delays in investment output response, we take the years 2001-2 as the pre-SOX period for patenting. We omit the year 2003 from our analysis as it is difficult to classify patents emerging then as broadly belonging to investment from the pre-SOX or immediate post-SOX era.

We take January 2004 as marking the start of the immediate post-SOX period. The theoretical model characterises this period as being one of corporate uncertainty, so to find a suitable end point we look for evidence from the literature on when uncertainty substantially reduced. Public and private measures to increase information and certainty were undertaken from SOX's inception (Prentice and Spence, 2007, p.54). However, the Securities and Exchange Commission's interpretative guidance on internal controls was only issued in 2007 (Kamar et al, 2007), and industry bodies reported uncertainty about implementation at that time (Biotechnology Industry Organization, 2007b). Hartman (2007) quantifies the level of SOX costs and corporate ability to predict them from 2001 to 2006, using raw financial data and a survey of firms. Audit costs and the general costs of being a public company stabilise after 2004 for both large and small businesses. The percentage of senior corporate directors and officers who reported being better able to predict SOX costs rose from 38 percent in 2004 to 66 percent in 2006. On balance, we take the end of 2005 as the end of the immediate post-SOX period of highest uncertainty, and thus consider 2006 and 2007 as the medium term after SOX.

5. Results

5.1 Changes in patenting by US patenters

We start the presentation of results by looking at patenting by US residents before and after SOX. The tables show random effects estimates in their first section and fixed effects estimates in their second section. As the estimates are very similar, we only comment on the former.

5.1.1 Changes in patenting immediately after SOX for US patenters

Table 1a: Patenting and coefficient shifts for time-invariant variables between 2001/2 and 2004/5 - random effects estimates

	1	2	3	4
Time	0.00443***	0.00446***	0.00454***	0.00452***
	0.00103	0.00103	0.00101	0.00101
D	0.0815**	0.0878**	5.85***	5.74***
	0.0382	0.0438	0.936	0.94
D * mean		0.00362***	0.00144***	0.00372***
		0.00112	0.000214	0.00112
D * s.d.		-0.0214**		-0.0172**
		0.00833		0.00829
D * date estd.			-0.00298***	-0.00291***
			0.00048	0.000483

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 1b: Patenting and coefficient shifts for time-invariant variables between 2001/2 and 2004/5 – fixed effects estimates

	1	2	3	4
Time	0.00443***	0.00446***	0.00454***	0.00451***
	0.00104	0.00103	0.00101	0.00101
D	0.0815**	0.0909**	5.85***	5.74***
	0.0382	0.0439	0.938	0.942
D * mean		0.0037***	0.00142***	0.0038***
		0.00113	0.000215	0.00112
D * s.d.		-0.0222***		-0.0179**
		0.00835		0.00831
D * date estd.			-0.00298***	-0.00291***
			0.000481	0.000484

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 1a shows the estimated coefficients allowing for changes immediately after SOX in coefficients on time-invariant variables. The first column shows that there was a general tendency for patenting to increase within groups over time. Immediately after SOX, there was a level shift upwards in the patent rate. The shift is significant at five percent. Column two includes the post-

SOX dummy interacted with the mean of the number of early patents and the standard deviation. Classes with larger mean numbers of early patents have a greater upwards shift, while greater standard deviation of patenting is associated with a lower shift. The coefficients are significant at one percent and five percent respectively. Column three shows the model with post-SOX interaction with the patent mean and the year the patent class was established. The patenting increase is again greater for larger classes. Newer classes have a lower shift. The coefficients on both are highly significant. The fourth column has mean, standard deviation, and establishment date interactions. Again, the patenting increase after SOX is greater for bigger classes. Increased standard deviation of early patenting and later class introduction both are associated with reduced patenting. The coefficients are all significant, at one, five, and one percent respectively.

Table 2a: Patenting and coefficient shifts for trends between 2001/2 and 2004/5 – random effects estimates

	1	2	3	4
Time	0.0014	0.00139	0.00141	0.0014
	0.00166	0.00166	0.00163	0.00163
D * time	0.00412***	0.00404***	0.122***	0.12***
	0.00132	0.00139	0.0199	0.02
D * mean * time		0.0000657***	0.0000309***	0.0000682***
		0.0000239	0.00000455	0.0000238
D * s.d. * time		-0.000366**		-0.000281
		0.000177		0.000176
D * date estd. * time			-0.0000608***	-0.0000597***
			0.0000102	0.0000103

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 2b: Patenting and coefficient shifts for trends between 2001/2 and 2004/5 – fixed effects estimates

	1	2	3	4
Time	0.0014	0.00139	0.00141	0.00139
	0.00167	0.00166	0.00164	0.00164
D * time	0.00412***	0.0041***	0.122***	0.12***
	0.00132	0.00139	0.02	0.02
D * mean * time		0.0000675***	0.0000305***	0.0000699***
		0.000024	0.00000457	0.0000239
D * s.d. * time		-0.000382**		-0.000297*
		0.000178		0.000177
D * date estd. * time			-0.0000608***	-0.0000596***
			0.0000102	0.0000103

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

In Table 2a we see coefficient shifts for trend terms after the introduction of SOX. The first column looks at a time trend and a change in the trend after SOX's introduction. There is a positive but insignificant time trend. The time trend after SOX's introduction is positive and highly significant. Column two includes the post-SOX time trend interacted with the mean and standard deviation of early patents in the class. Classes with more early patents had a greater trend increase after SOX, while classes with more volatility had a lower increase. The former effect is one percent significant, and the latter is five percent significant. Column three interacts the post-SOX trend with the mean and the year of class establishment. Classes with higher patent mean have a greater trend increase, while later established classes have lower increase. Both effects are one percent significant. In column four, the post-SOX trend change is interacted with the class mean, standard deviation, and establishment date. The mean increases the trend change at one percent significance. The standard deviation decreases the trend change but is insignificant, while the establishment date decreases it with a significance of one percent.

In summary, there is evidence from estimates from Tables 1 and 2 of shifts in the level and trend of patenting following SOX. The average effect was an increase in the patenting rate, and the increase was greater in classes with many patents. It was smaller for more volatile and newer classes. We find evidence hypotheses H1a, H2a, and H3a, that a downward shift would be expected after SOX for smaller, newer, and riskier companies patenting in classes more exposed to uncertainty.

5.1.2 Changes in patenting in the medium term after SOX for US patenters

Table 3a shows how the effect of time-invariant factors on patenting changes between the immediate period after SOX (2004/5) and the medium term (2006/7). The first column has a time trend and dummy for the 2006/7 period as determinants. The trend is positive and highly significant. There is a fall in the level of patenting within groups in the second period which is significant at five percent. Column two includes dummy interactions with the early patent mean and standard deviation. Classes with larger numbers of patents had a larger decline in patenting in the second period, while classes with greater standard deviation had a reduced decline. The third column has dummy interactions with the class mean and establishment date. The mean interaction has an entirely insignificant effect. Classes established later have a smaller patent decline in 2006/7, and the effect is highly significant. The fourth column has dummy interactions with the mean, standard deviation, and establishment date. The mean makes the patenting reduction larger while the standard deviation makes it smaller. Neither interaction is significant. Later establishment dates make the patenting reduction smaller, and is five percent significant.

Table 3a: Patenting and coefficient shifts for time-invariant variables between 2004/5 and 2006/7 – random effects estimates

	1	2	3	4
Time	0.00773***	0.00772***	0.00772***	0.00773***
	0.000948	0.000945	0.000944	0.000942
D	-0.0563**	-0.098***	-1.92**	-1.85**
	0.0263	0.0332	0.878	0.877
D * mean		-0.00137	0.0000657	-0.00141
		0.00114	0.000219	0.00113
D * s.d.		0.0124		0.0111
		0.00837		0.00833
D * date estd.			0.000951**	0.000904**
			0.000451	0.000451

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 3b: Patenting and coefficient shifts for time-invariant variables between 2004/5 and 2006/7 - fixed effects estimates

	1	2	3	4
Time	0.00773***	0.00772***	0.00773***	0.00773***
	0.000949	0.000947	0.000945	0.000944
D	-0.0563**	-0.0958***	-1.93**	-1.87**
	0.0263	0.0333	0.879	0.878
D * mean		-0.00129	0.000047	-0.00134
		0.00114	0.00022	0.00113
D * s.d.		0.0118		0.0104
		0.00839		0.00835
D * date estd.			0.000956**	0.000911**
			0.000452	0.000452

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

We see in Table 4a how patenting trends changed between 2004/5 and 2006/7. In column one, the determinant variables are time and time interacted with a 2006/7 dummy. The time trend is positive and highly significant. The trend reduces in the second period, and the reduction is significant at ten percent. Column two has interactions of the mean and standard deviation with the 2006/7 time trend change. The mean decreases the trend and higher standard deviation increases it, but the effects are insignificant. In column three the class establishment date is introduced beside the mean as an interaction with the trend change. The mean interaction has an entirely insignificant effect. Later class establishment date increases the trend change with five percent significance. The fourth column has the trend change interacted with the mean, standard deviation, and establishment date. The mean increases the change, the standard deviation reduces it, and neither is significant. The establishment date increases the trend with ten percent significance.

Table 4a: Patenting and coefficient shifts for trends between 2004/5 and 2006/7 – random effects estimates

	1	2	3	4
Time	0.00773***	0.00772***	0.00772***	0.00772***
	0.00114	0.00113	0.00113	0.00113
D * time	-0.00076*	-0.00131**	-0.0261**	-0.0252**
	0.000446	0.000531	0.0124	0.0124
D * mean * time		-0.00002	0.000000283	-0.0000207
		0.0000161	0.00000311	0.000016
D * s.d. * time		0.000176		0.000158
		0.000119		0.000118
D * date estd. * time			0.0000129**	0.0000123*
			0.00000639	0.00000638

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 4b: Patenting and coefficient shifts for trends between 2004/5 and 2006/7 – fixed effects estimates

	1	2	3	4
Time	0.00773***	0.00772***	0.00772***	0.00773***
	0.00114	0.00114	0.00113	0.00113
D * time	-0.00076*	-0.00128**	-0.0262**	-0.0254**
	0.000446	0.000532	0.0125	0.0124
D * mean * time		-0.0000189	0.0000000198	-0.0000197
		0.0000161	0.00000312	0.000016
D * s.d. * time		0.000166		0.000148
		0.000119		0.000118
D * date estd. * time			0.000013**	0.0000124*
			0.0000064	0.00000639

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

To summarise the results from Tables 3 and 4, patenting fell within classes in the 2006/7 period relative to the immediate post-SOX period. The decline was heterogeneous across patenting classes. The decline was larger for classes with large mean and less for those with large standard deviation. Classes established later declined less, and the effect was always significant. We find evidence of a patenting rise in the medium term after SOX in classes that are smaller, riskier, or newer. By extension to companies, we find support for hypotheses H1b, H2b, and H3b.

5.1.3 Changes in patenting between the pre-SOX period and the medium term for US patenters

We now turn to look at what SOX's effect was once we allow to pass the temporary change in patenting that followed it. Table 5a looks at the shifts in the effect of time invariant variables on patenting between the pre-SOX period (2001/2) and the medium term (2006/7). The first column has a time trend and a 2006/7 dummy variable only. The time trend is significant. There is a decline in the level of patenting in the later period, but it is not significant. The second column introduces the early patent mean and standard deviation interaction with the dummy. The dummy again has a negative, insignificant effect. Larger patent classes have a smaller reduction in their patenting level, and the effect is five percent significant. More volatile classes have a larger decline between the two periods, but without significance. In column three, the mean and class introduction date interact with the dummy. The post-SOX dummy becomes positive and highly significant. Larger classes have a greater increase and more volatile classes have a smaller increase, both at one percent significance. The fourth column includes the dummy interacted with patent standard deviation. The mean interaction is positive and five percent significant, while the standard deviation interaction is negative and insignificant. Newer classes have reduced patenting, with one percent significance.

Table 5a: Patenting and coefficient shifts for time-invariant variables between 2001/2 and 2006/7 – random effects estimates

	1	2	3	4
Time	0.00651***	0.00645***	0.00643***	0.00643***
	0.00111	0.0011	0.0011	0.0011
D	-0.0276	-0.0461	3.85***	3.8***
	0.0665	0.0699	1.02	1.02
D * mean		0.00267**	0.00151***	0.00276**
		0.00126	0.000245	0.00127
D * s.d.		-0.0123		-0.00942
		0.00927		0.00935
D * date estd.			-0.00202***	-0.00198***
			0.000523	0.000525

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 5b: Patenting and coefficient shifts for time-invariant variables between 2001/2 and 2006/7 – fixed effects estimates

	1	2	3	4
Time	0.00651***	0.00645***	0.00643***	0.00643***
	0.00111	0.0011	0.0011	0.0011
D	-0.0278	-0.0427	3.85***	3.79***
	0.0666	0.07	1.02	1.03
D * mean		0.00279**	0.00148***	0.00288**
		0.00126	0.000246	0.00127
D * s.d.		-0.0134		-0.0105
		0.0093		0.00938
D * date estd.			-0.00202***	-0.00197***
			0.000524	0.000527

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 6a looks at changes in patenting trends and their determinants between 2001/2 and 2006/7. Column one has a time trend and a dummy for a trend change in 2006/7. The time trend is positive but not significant in 2001/2. In the later period the trend is positive and significant at five percent. The second column includes trend change interacted with early patent means and standard deviations. The trend change remains positive and ten percent significant. Larger classes have a higher trend change, while more volatile classes have a lower change. The former effect is significant at five percent, while the latter isn't significant. The third column has trend change interactions with the patent mean and establishment date. The time trend change in 2006/7 is positive and highly significant. The trend change increases for larger classes but is smaller for riskier ones. Both interactions are significant at one percent. In column four, we see interactions between the trend change dummy and the patent mean, the standard deviation, and the establishment date. The trend change coefficient is positive and one percent significant, its mean interaction is positive and five percent significant, and its standard deviation interaction is negative and insignificant. Later established classes have a lower, highly significant trend change.

Table 6a: Patenting and coefficient shifts for trends between 2001/2 and 2006/7 – random effects estimates

	1	2	3	4
Time	0.00205	0.00201	0.00199	0.00199
	0.00189	0.00189	0.00188	0.00189
D * time	0.00345**	0.00321*	0.0591***	0.0584***
	0.00161	0.00164	0.0145	0.0145
D * mean * time		0.0000363**	0.0000204***	0.0000379**
		0.0000178	0.00000347	0.0000179
D * s.d. * time		-0.00017		-0.000132
		0.000131		0.000132
D * date estd. * time			-0.0000289***	-0.0000284***
			0.00000739	0.00000742

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 6b: Patenting and coefficient shifts for trends between 2001/2 and 2006/7 – fixed effects estimates

	1	2	3	4
Time	0.00204	0.002	0.00199	0.00199
	0.0019	0.00189	0.00189	0.00189
D * time	0.00345**	0.00326**	0.059***	0.0583***
	0.00162	0.00165	0.0145	0.0146
D * mean * time		0.000038**	0.00002***	0.0000397**
		0.0000178	0.00000348	0.000018
D * s.d. * time		-0.000186		-0.000148
		0.000131		0.000133
D * date estd. * time			-0.0000289***	-0.0000283***
			0.00000741	0.00000744

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

The findings from tables 5 and 6 shows that there was a patenting increase within patent classes in 2006/7 relative to 2001/2. An increase in patenting between the two periods is greater for large classes and smaller for newer classes. There is less significant evidence that riskier classes had lower patenting increases. By extending the results to companies operating in the classes, we find evidence supporting hypothesis H5a that smaller, newer, and riskier companies patented less in the medium term after SOX's passage, and evidence against H5b.

5.2 Changes in patenting by non-US patenters

In this section we examine patenting by non-US resident patenters following SOX's passage. Fixed effects models had difficulties in numerical convergence, so we report only random effects estimates. As noted in section 5.1, for the US patenters the fixed and random effect estimates were very close.

5.2.1 Changes in patenting immediately after SOX for non-US patenters

Table 7 shows changes in the effect of time-invariant influences on patenting between 2001/2 and 2004/5. The first column has only a time trend and a level dummy for the 2004/5 period. The dummy has a positive effect and is highly significant. The second column has the dummy interacted with the early patent mean and standard deviation. Larger classes benefit more in the later period, while more volatile classes benefit less. Both relations are one percent significant.

The third column interacts the dummy with the mean and class establishment date. Larger classes have higher patenting with one percent significance. The establishment date is not significant. In column four, the mean, standard deviation, and establishment date are interacted. The mean has a positive effect on patenting, the standard deviation has a negative effect, and both are one percent significant. The establishment date is entirely insignificant.

Table 7: Patenting and coefficient shifts for time-invariant variables between 2001/2 and 2004/5 – random effects estimates

	1	2	3	4
Time	0.00369***	0.00379***	0.00372***	0.00379***
	0.00106	0.00106	0.00106	0.00106
D	0.402***	0.472***	0.852	0.595
	0.0399	0.0498	1.02	1.03
D * mean		0.00538***	0.00187***	0.0054***
		0.00099	0.00059	0.00101
D * s.d.		-0.0401***		-0.04***
		0.00936		0.0094
D * date estd.			-0.000255	-0.0000635
			0.000527	0.000529

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

We can compare the results with those from Table 1a to see relative effects of SOX on patenting by US and non-US residents. The first columns show that the increase in the patenting level was much lower for US residents. The second columns show that the difference is not explained by differences in the effect of the mean and standard deviation. These have a statistically similar effect on the patenting shift for US and non-US patenters (we do not have cross-panel covariances from the two count panel estimates, so cannot perform formal statistical testing; neglecting the covariance and treating the standard errors as accurate we obtain a normal statistic of $(0.00538-0.00362)/(0.00112^2+0.00099^2)^{0.5} = 1.18$ with a two sided p-value of 0.24 for the mean, for example). In the third columns we see that the establishment date explains the difference in patenting shift between US and non-US patenters. For the US patenters, it has a large and significant negative effect which is missing from non-US patenting. The fourth columns confirm the same distinction.

Table 8: Patenting and coefficient shifts for trends between 2001/2 and 2004/5 – random effects estimates

	1	2	3	4
Time	0.0057***	0.00569***	0.00566***	0.00569***
	0.0019	0.00189	0.0019	0.00189
D * time	0.00636***	0.00801***	0.0278	0.0219
	0.00151	0.00163	0.0219	0.0219
D * mean * time		0.00012***	0.0000443***	0.000123***
		0.0000212	0.0000127	0.0000216
D * s.d. * time		-0.000896***		-0.000884***
		0.0002		0.000201
D * date estd. * time			-0.0000115	-0.00000717
			0.0000113	0.0000113

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 8 shows trend changes in patenting after SOX for non-US residents. The first column shows that there is a highly significant trend increase after SOX. Column two shows that the trend change is increased by in large patent classes and reduced in volatile classes, with high significance. From column three we can see that the establishment date has an insignificant effect on the trend change. The fourth column confirms the findings from the two previous columns.

By comparison with Table 2a, we can see from the first columns that the trend change for US and non-US patenters is similar. However the pre-SOX trend is not significantly different from zero for the US patenters whereas it is significantly positive for the non-US patenters. In columns two, we can compare between the US and non-US patenters the magnitudes of the base post-SOX increase and the effects of the patent class size and standard deviation on the trend change. The magnitudes are all around twice as large for non-US patenters. Columns three indicate that the class establishment date has a significant negative effect on the trend change, but only for US patenters. Columns four finds that the patent mean and establishment date have significant positive and negative effects respectively on the patenting trend for US patenters, while for non-US patenters the mean and standard deviation have the significant positive and negative effects.

We can summarise the differences between US and non-US patenting between 2001/2 and 2004/5. The difference primarily arises from the highly significant reduction in US patenting for newer patent classes in the later period. The difference is observable in both the level and trend change. This result is consistent with hypothesis H4, in that the inferred immediate post-SOX behaviour for newer US and non-US companies differs.

5.2.2 Changes in patenting in the medium term after SOX for non-US patenters

Table 9: Patenting and coefficient shifts for time-invariant variables between 2004/5 and 2006/7 – random effects estimates

	1	2	3	4
Time	0.00293***	0.00294***	0.00294***	0.00294***
	0.000917	0.000917	0.000915	0.000915
D	-0.0434*	-0.0451	-1.96**	-1.99**
	0.0253	0.0365	0.861	0.863
D * mean		0.000641	-0.000151	0.000258
		0.000895	0.000517	0.000911
D * s.d.		-0.00281		-0.00451
		0.00825		0.00829
D * date estd.			0.000983**	0.001**
			0.000442	0.000444

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

We now look at changes in patenting for non-US patenters between the immediate post-SOX period (2004/5) and the medium term (2006/7). Table 9 shows estimates of level changes in patenting and their determinants between the two periods. The first column shows the existence of a ten percent significant downward correction in the level. In column two, the introduction of patent class size and volatility renders all level shift variables insignificant. Column three has the 2006/7 dummy interacted with the patent mean and establishment date. The effect of the mean is insignificant, while later established patent classes have a smaller decline. In column four we see a similar outcome when the mean, standard deviation, and establishment date are all included. Only the establishment date has a significant effect on the patenting level change, and the effect is positive.

By comparison with US resident patenting in Table 3a, the first columns demonstrate no significant difference between the within class downward shift in patenting between 2004/5 and 2006/7. The second columns show that the patent class mean and standard deviation both had insignificant impacts for US and non-US patenters, while the third columns show that the shifts were explained for both patenters by establishment date with no explanatory power from the mean. Moreover, the effect of the establishment date on the medium term effect is almost the same for both US and non-US residents. Column four confirms the same findings, with no significant effect of volatility on the patenting level shift.

Table 10: Patenting and coefficient shifts for trends between 2004/5 and 2006/7 – random effects estimates

	1	2	3	4
Time	0.00248**	0.00249**	0.00249**	0.00249**
	0.00109	0.00109	0.00109	0.00109
D * time	-0.000394	-0.000404	-0.0266**	-0.0271**
	0.000428	0.000569	0.0123	0.0123
D * mean * time		0.00000935	-0.00000198	0.00000415
		0.0000128	0.00000739	0.000013
D * s.d. * time		-0.000044		-0.0000677
		0.000117		0.000118
D * date estd. * time			0.0000134**	0.0000137**
			0.0000063	0.00000633

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 10 shows changes in patent trends between 2004/5 and 2006/7 for non-US residents. The first column indicates that there is no significant change in the trend between the two periods in the absence of other covariates. The second column introduces class size and standard deviation as determinants of the trend change. Both are entirely insignificant. In column three, the class size and establishment date are interacted with the 2006/7 dummy. The dummy itself becomes negative and significant at five percent. The mean is insignificant in its effect, but the later established classes are found to have a lower patent decline with five percent significance. From column four, we can see the same findings when mean, standard deviation, and establishment date are all interacted.

Comparison with Table 4a is informative about the relative trend changes for US and non-US patenters. The first columns show a slight decline in the trends of within class patenting in 2006/7. However, it is only ten percent significant for US patenters and insignificant for non-US patenters.

The second columns indicate that the mean and standard deviation did not affect the trend changes significantly for either patenters. For the third columns we see that the trend change was negative, but the decline was less for later established classes. The magnitudes of the effects were very similar for US and non-US residents. The fourth columns confirm the comparative results.

In summary of the findings, for both US and non-US patenters the establishment date for the patent class is the only significant determinant of the patent change between 2004/5 and 2006/7. Later established classes have an increased patent change (or reduced decline) between the two periods. However, for smaller and riskier classes there are upwards corrections for US patenters which are close to significance, whereas for non-US patenters these corrections are not demonstrated with numerical or statistical significance. Thus, we find further evidence in support of hypothesis H4, that the inferred behaviour of US and non-US patenters differs in the medium term after SOX.

5.2.3 Changes in patenting between the pre-SOX period and the medium term for non-US patenters

Table 11: Patenting and coefficient shifts for time-invariant variables between 2001/2 and 2006/7 – random effects estimates

	1	2	3	4
Time	0.00785***	0.00784***	0.00784***	0.00784***
	0.00107	0.00107	0.00107	0.00106
D	0.0954	0.17**	-1.49	-1.81*
	0.0649	0.0715	1.04	1.04
D * mean		0.00589***	0.00159***	0.0055***
		0.001	0.000596	0.00102
D * s.d.		-0.0428***		-0.0445***
		0.0095		0.00956
D * date estd.			0.000788	0.00102*
			0.000531	0.000533

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 11 shows the changes in the level of patenting between the pre-SOX period (2001/2) and the medium term after SOX (2006/7) for non-US patenters. The first column shows that there was a statistically insignificant upward shift in the later period. The second column finds that larger classes had more patenting increase and more volatile classes had less. Both are one percent significant. In column three the patent mean and establishment date are interacted with the 2006/7 dummy. The large classes have a greater patent increase with one percent significance, while the newer classes also have a larger increase but without significance. In the fourth column the mean increases the patent increase, the standard deviation reduces it, and the establishment date raises it. All are significant (at one, one, and ten percent).

We can compare with the patenting changes by US residents in Table 5a. Columns one indicate that there was no significant shift in patenting in the second period in the absence of the covariates. From columns two we see that the larger classes increase patenting for both US and non-US residents. Greater volatility reduces patenting, but the effect is only significant for non-US residents. Columns three show that later establishment dates reduce patenting for US residents but increase it for non-US residents. Only the reduction is statistically significant. The fourth column finds that class size has a common positive effect, volatility has a significant negative effect for non-US residents only, and the establishment date significantly reduces US patenting and significantly increases non-US patenting.

Table 12: Patenting and coefficient shifts for trends between 2001/2 and 2006/7 – random effects estimates

	1	2	3	4
Time	0.0114***	0.0113***	0.0114***	0.0113***
	0.00196	0.00195	0.00195	0.00195
D * time	-0.00171	-0.000648	-0.0222	-0.0267*
	0.00166	0.00171	0.0146	0.0146
D * mean * time		0.0000813***	0.0000222***	0.0000763***
		0.0000141	0.00000839	0.0000144
D * s.d. * time		-0.000593***		-0.000616***
		0.000134		0.000135
D * date estd. * time			0.0000102	0.0000135*
			0.00000746	0.00000749

The dependent variable is the number of patents. D is the later period dummy. Standard errors are shown below the coefficients. * denotes significance at ten percent, ** at five percent, and *** at one percent.

Table 12 examines non-US resident patenting trend changes in the medium term after SOX compared with the pre-SOX period. The first column shows that the trend fell within classes in 2006/7, but the decline is not significant. From the second column we can see that the patent mean increases the trend change, while patent volatility decreases it. Both are highly significant. The third column looks at the mean and establishment date as influences on the trend change. Larger companies and newer companies both have a greater trend change, with the former effect significant at one percent but the latter effect insignificant. The fourth columns shows that when considered together, size increases trend change, volatility decreases it, and newness increases it. All are significant (at one percent, one percent, and ten percent).

By comparison with US resident patenting in Table 6a, we see from the first columns that trends in US resident patenting tend to increase significantly between the two periods within classes, while trends for non-US resident patenting tend to fall but without significance. Columns two show that the trend change is greater for larger classes. It is smaller for more volatile classes, but only significantly so for non-US residents. From columns three, the trend change is again bigger for larger classes. Newer classes have significantly reduced trend changes for US residents, but they have insignificantly higher trend changes for non-US residents. The fourth columns show that size significantly increases the trend change and volatility reduces it. Newness significantly lowers the trend change for US companies, and significantly increases it for non-US companies.

We can summarise the findings from Tables 11 and 12. Larger classes tended to have an increased patent change between 2001/2 and 2006/7, for patents from both US and non-US residents. More volatile classes tended to have a reduced (or negative) change for both sources. Newer classes had a reduced (or negative) change for US residents' patenting, but an increased change for non-US residents. As there was a differential effect of newness between US and non-US residents, we find evidence in support of hypothesis H4 that their behaviour differs in the medium term after SOX.

6. Conclusion

This paper has examined the dynamic effects of SOX on innovation by US companies. We presented a model showing investors will reduce their investment in smaller, riskier, and newer companies in the immediate period after SOX and increase it subsequently due to the creation of real option value from waiting. Empirical data on patenting by US residents shows behaviour consistent with our model, and non-US residents do not show such behaviour indicating that a US explanation, such as SOX, is most plausible. A reduction in patenting for these residents persists in the medium term.

The approach adopted in this paper indicates general patenting patterns, affected parties, and US specificity all consistent with SOX as a cause. The results moreover show coherence with other econometric studies and corporate surveys. There remain other possible causes. Bargeron et al (2010) briefly consider and reject as explanations US economic weakness, stock price decline, business environment uncertainty, and an accounting regulation change on stock options. Waters (2013) examines and rejects six non-SOX causes as explanations for a downturn in patenting in stem cell technologies. Another possibility is that the medium term patenting recovery was due to SOX cost reforms rather than information disclosure. A difficulty arises with separating the two effects in that SOX reforms were often clarification (Gao et al, 2009; Kamar et al, 2007) and involved simultaneous reduction in expenses and uncertainty (see for example a trade body's response to reform at Biotechnology Industry Organization, 2007a). An alternative explanation for the observed patenting variation is that other, non-SOX regulatory and judicial changes were responsible. As these were often coincident with SOX and acted through similar mechanisms, separating the relative effects is problematic (Kamar et al, 2007, p24 and footnote 26).

We have taken the period 2006-7 to be relatively free of uncertainty about SOX's effect. However, substantial guidance was still being issued during the period (Kamar et al, 2007), trade bodies were reporting lack of SOX clarity (Biotechnology Industry Organization, 2007a), and many directors and officers remained uncertain about its effects (Hartman, 2007). It is difficult to use our aggregated data beyond 2007 to infer SOX effects because of the impact of the 2008-9 financial crisis (Paunov, 2012), and more detailed data would help with identifying SOX effects that persist after 2007.

Our work suggests that uncertainty was responsible for part of the decline in innovation outputs immediately after SOX. A policy implication is that companies should be kept informed about disclosure regulation costs and implementation details, particularly for businesses that would have the highest SOX costs relative to their size. This would mitigate the decline due to cost uncertainty, but would not change the decline due to disclosure's creation of a real option value for waiting. The real option value may be changed by varying the level and incidence of costs, and the speed of implementation. Investigation of such policy changes could form the basis of future work.

We have determined a medium term decline in patenting after SOX for smaller, riskier, and newer industrial classes. Assuming that performance in the 2006/7 period can be considered as representing SOX's persistent effect, it would seem that investors have shifted against investment in these classes. If investment prior to SOX was efficient and made by fully informed investors, then SOX would be an inefficient intervention in the market for these industrial segments and a policy implication would be that smaller, riskier, and newer companies should have their SOX costs reduced. If investment prior to SOX was inefficient, then an explicit regulatory metric connecting investor safeguards and corporate performance could be established to determine the relative efficiency of the market before and after SOX.

A final implication relates to the analysis of SOX. Most research treats the post-SOX era as subject to a homogeneous effect from it. Our research shows that the effect is dynamic, and immediate corporate performance is likely to be influenced by SOX's creation of real option value for investment delay. Analysis of SOX's costs and benefits in the immediate post-SOX period that attributes them to a persistent effect is misleading and probably too pessimistic. SOX's persistent effects should be examined at later dates instead.

Appendix 1.

Table A1: Patent classes selected

Class	Description
28	Textiles: manufacturing
30	Cutlery
36	Boots, shoes, and leggings
38	Textiles: ironing or smoothing
42	Firearms
48	Gas: heating and illuminating
56	Harvesters
62	Refrigeration
63	Jewelry
65	Glass manufacturing
74	Machine element or mechanism
86	Ammunition and explosive-charge making
91	Motors: expansible chamber type
102	Ammunition and explosives
122	Liquid heaters and vaporizers
147	Coopering
168	Farriery
171	Unearthing plants or buried objects
181	Acoustics
184	Lubrication
186	Merchandising
193	Conveyors, chutes, skids, guides, and ways
208	Mineral oils: processes and products
216	Etching a substrate: processes
221	Article dispensing
227	Elongated-member-driving apparatus
235	Registers
244	Aeronautics and astronautics
260	Chemistry of carbon compounds
267	Spring devices
270	Sheet-material associating
283	Printed matter
290	Prime-mover dynamo plants
293	Vehicle fenders

Table A1 (continued): Patent classes selected

Class	Description
307	Electrical transmission or interconnection systems
322	Electricity: single generator systems
323	Electricity: power supply or regulation systems
355	Photocopying
373	Industrial electric heating furnaces
374	Thermal measuring and testing
400	Typewriting machines
406	Conveyors: fluid current
412	Bookbinding: process and apparatus
431	Combustion
432	Heating
441	Buoys, rafts, and aquatic devices
472	Amusement devices
503	Record receiver having plural interactive leaves or a colorless color former, method of use, or developer therefor
508	Solid anti-friction devices, materials therefor, lubricant or separant compositions for moving solid surfaces, and miscellaneous mineral oil compositions
518	Chemistry: fischer-tropsch processes; or purification or recovery of products thereof
524	Synthetic resins or natural rubbers -- part of the class 520 series
532	Organic compounds -- part of the class 532-570 series
600	Surgery
606	Surgery
623	Prosthesis (i.e., artificial body members), parts thereof, or aids and accessories therefor
700	Data processing: generic control systems or specific applications
706	Data processing: artificial intelligence
707	Data processing: database and file management or data structures
800	Multicellular living organisms and unmodified parts thereof and related processes
902	Electronic funds transfer
968	Horology
976	Nuclear technology
D11	Jewelry, symbolic insignia, and ornaments
D14	Recording, communication, or information retrieval equipment
D27	Tobacco and smokers' supplies
D99	Miscellaneous
PLT	Plants

Table A2: Patent classes summary for US and non-US patenters

		US		Non-US	
Class	Estd	Mean	SD	Mean	SD
28	1922	3.5	2.0	3.1	2.0
30	1937	18.1	5.2	17.2	3.4
36	1900	16.8	3.3	11.6	4.6
38	1936	0.8	1.2	1.5	1.2
42	1902	8.5	3.3	3.1	1.7
48	1903	3.8	2.0	3.2	2.1
56	1919	12.8	3.9	6.6	3.3
62	1958	33.9	6.1	31.2	7.6
63	1908	4.6	3.6	1.6	1.1
65	1962	18.1	8.6	18.1	6.6
74	1934	20.2	4.3	38.4	10.0
86	1901	0.8	0.8	0.1	0.3
91	1963	4.1	1.9	4.7	2.2
102	1902	7.9	2.6	6.8	3.1
122	1911	2.4	1.2	2.5	1.6
147	1899	0.0	0.0	0.0	0.0
168	1906	0.8	0.8	0.1	0.3
171	1957	0.3	0.5	0.8	2.1
181	1900	9.0	3.2	8.6	2.9
184	1907	4.4	2.5	3.8	1.5
186	1909	1.0	1.0	0.5	0.5
193	1922	1.3	1.1	0.4	0.7
208	1958	14.2	5.1	6.5	2.5
216	1995	25.2	6.9	18.8	4.5
221	1954	12.7	4.1	4.9	1.9
227	1965	5.2	1.9	4.9	2.7
235	1901	41.3	8.3	25.0	4.3
244	1936	21.6	7.1	11.7	4.9
260	1938	0.3	0.6	0.0	0.0
267	1919	7.6	2.6	11.8	2.8
270	1916	1.8	1.2	2.3	1.4
283	1918	10.5	4.1	3.5	2.2
290	1918	8.4	3.6	5.6	2.2
293	1918	2.5	1.7	2.0	1.8

Table A2 (continued): Patent classes summary for US and non-US patenters

		US		Non-US	
Class	Estd	Mean	SD	Mean	SD
307	1952	16.5	3.3	13.2	2.8
322	1947	1.8	0.8	3.3	2.8
323	1947	10.1	2.8	15.6	6.0
355	1968	9.3	3.5	21.7	5.3
373	1982	1.0	0.7	1.8	2.2
374	1982	14.9	3.8	12.8	5.2
400	1978	10.8	3.4	14.6	3.3
406	1979	2.8	1.7	0.9	0.9
412	1982	1.4	1.2	1.5	1.9
431	1968	13.0	2.2	8.0	3.7
432	1972	3.5	2.2	7.3	4.3
441	1982	5.3	2.1	2.1	1.3
472	1992	3.2	2.0	1.4	1.4
503	1987	1.5	1.4	5.2	2.4
508	1996	8.1	2.8	6.2	2.9
518	1981	4.8	1.6	1.8	1.1
524	1982	63.0	9.5	61.5	9.8
532	1984	0.0	0.0	0.0	0.0
600	1988	144.0	17.5	68.4	7.4
606	1989	166.2	23.7	36.3	7.7
623	1985	85.8	15.7	19.3	3.8
700	1999	67.1	13.0	47.0	8.2
706	1998	18.8	8.0	8.6	3.9
707	1997	283.5	41.6	120.3	12.4
800	1986	77.9	11.3	20.6	4.5
902	1988	0.4	0.7	0.2	0.6
968	1992	0.0	0.0	0.0	0.0
976	1991	0.0	0.0	0.1	0.3
D11	1976	0.1	0.3	0.0	0.0
D14	1976	0.0	0.0	0.1	0.3
D27	1975	0.0	0.0	0.0	0.0
D99	1967	0.0	0.0	0.0	0.0
PLT	1963	14.1	7.1	23.7	9.5

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