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Equity Regulation and U.S. Venture Capital Investment

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Abstract

There is a growing consensus that the long-run per capita growth rate of the U.S. economy has drifted lower since the early 2000s, consistent with a perceived slowdown in business dynamism. One factor that may have contributed to this is a downshift in venture capital investment and its failure to recover in line with stock prices, as pre-2003 patterns would suggest. Critics have argued that this is associated with the increased regulatory burden for publically traded firms to comply with the Sarbanes-Oxley Act of 2002 (SOX). There is inconclusive evidence of SOX deterring firms from becoming publically traded as indicated by IPO activity, a proxy reflecting several factors that may not be as tied to innovation as venture capital. Earlier tests of SOX's impact on venture capital activity, which tended to focus on cross-sectional evidence, were hampered by a short time-series sample following the Internet-stock bust of the early 2000s. Taking advantage of the large-sized rise, fall, and recovery in stock prices since then, this study assesses whether the time-series behavior of venture capital investment shifted following SOX. We find evidence of a time-series break in the middle of our sample, consistent with the passage of SOX. Estimates indicate that the slower post-SOX pace of venture capital investment is mainly attributed to a reduced elasticity of such investment with respect to stock prices rather than to a simple downshift in the level of investment. Our estimates suggest that a cost-benefit analysis of SOX could be worthwhile, especially given concerns that the long-run growth rate of U.S. productivity and GDP has been unusually sluggish and the emerging consensus that excessive debt financing—not equity financing—is more tied to the subset of financial crises associated with severe macroeconomic downturns.

JEL codes: G24, 047

Key words: venture capital, Sarbanes-Oxley, regulatory costs, long-run growth

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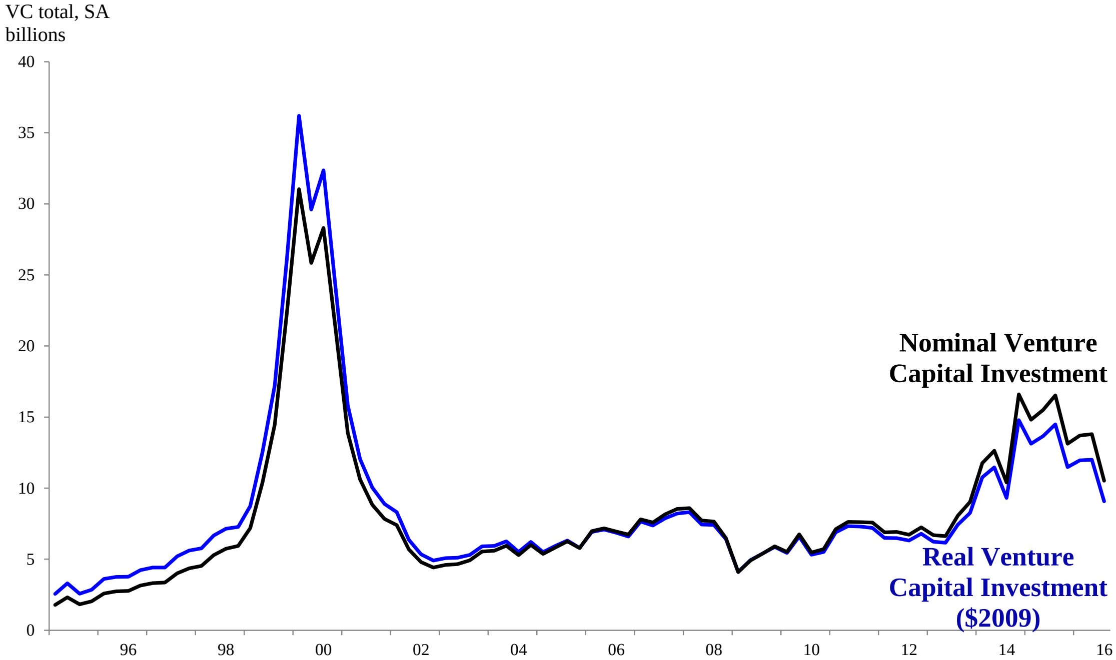
1. Introduction

There is growing concern that the long-run growth rate of the U.S. economy has slowed so far this century—even apart from slower workforce growth—perhaps reflecting an end to large technical revolutions (e.g., Gordon, 2012), a lesser pace of innovation (Cette, et al., 2015), slower capital formation, and declining business creation (e.g., Decker, et al. 2016a).[1] In the past and even predating the high-tech boom of the late-1990s, high rates of entry have been positively correlated with rates of innovation (Acs and Audretsch, 1990, and Geroski, 1989, 1995). Diminished business creation (or dynamism) since 2000 has been concentrated in high-tech industries that has coincided with a measured slowdown in innovation in this sector. Likely compounding the impact of reduced entry rates on innovation and economic growth is the marked decrease in the share of new firms that have subsequently grown rapidly (Decker, et al. 2016b). These patterns are consistent with the critical role that the high-tech industry played in the productivity mini-boom of the late 1990s (Oliner, et al., 2007), which has since ebbed.

Coincident with the post-2000 slowdown in tech firm creation has been a marked downshift in the range in which venture capital investment has fluctuated (*Figure 1*). In particular, venture capital investment has failed to recover in line with stock prices (a signal of potential returns) as much as pre-2003 patterns would suggest, as illustrated in Figure 2. It plots total venture capital investment and the Nasdaq, both scaled by GDP. Some (Zhang, 2007) have found that subdued venture capital investment is associated with the increased regulatory burden for publically traded firms to comply with the Sarbanes-Oxley Act of 2002 (SOX). This is consistent with analysis of discontinuities in the requirements to comply with Section 404 of SOX, indicating that the costs

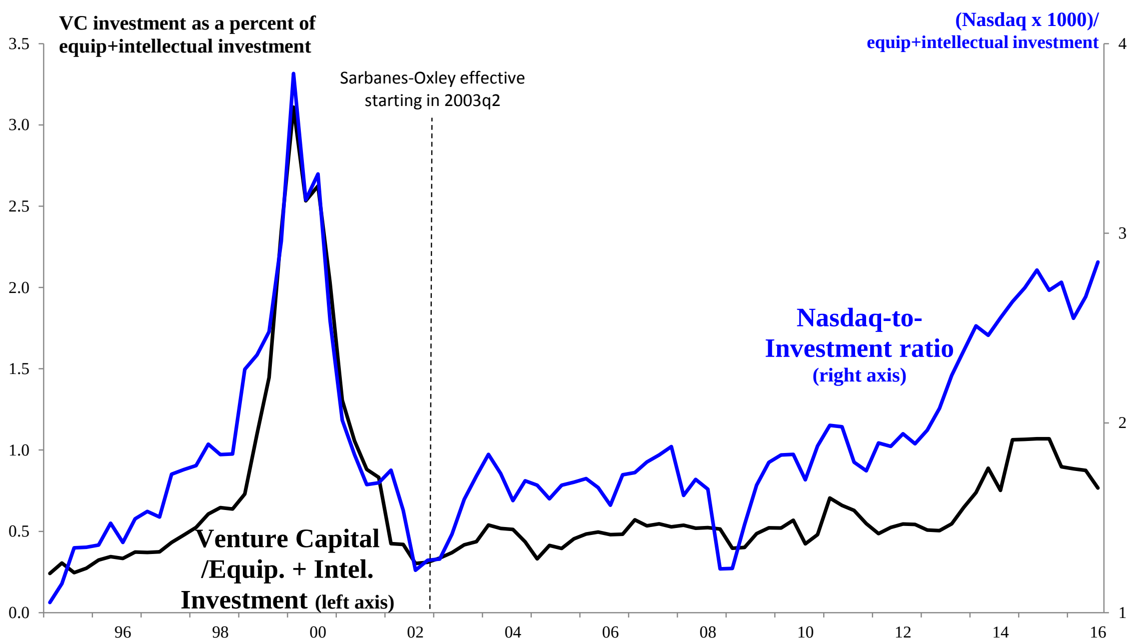
[1] Nevertheless, the slowdown in productivity growth has coincided with a notable slowing in the pace of new firm creation and subpar job creation since 2000 (see Decker, et al., 2014, *inter alia*).

Figure 1: Inflation-Adjusted Venture Capital Investment Above Pre-Great Recession Levels, but not Above Late 1990s



Sources: PWC Moneytree, Bureau of Economic Analysis, and authors' calculations (including seasonal adjustment). Recessions denoted by shaded areas.

Figure 2: Venture Capital Investment Less Correlated With Nasdaq Stock Prices Since the Passage of Sarbanes-Oxley



Sources: PWC Moneytree, Bureau of Economic Analysis, and author's calculations (including seasonal adjustment). Recessions denoted by shaded areas.

of compliance outweigh its benefits (Iliev, 2010).[2] While 2007 reforms, which lowered compliance costs for smaller firms, arguably removed this factor, venture investment is substantially driven by the returns of rapidly growing companies that one day would need to fully comply with SOX. By raising compliance costs, thereby reducing the potential value of a start-up becoming a publicly owned company, SOX has arguably lowered capitalists' valuations of start-ups and expanding young firms. This, in turn, has had the unintended consequence of inducing lower venture capital investment in such firms (see Fletcher and Miles, 2004, p. 74). Indeed, rapidly growing small firms have been notably scarce since 2000, as Decker, et al. (2016b) have found, which could be related to the downshift in venture capital investment since many leading public companies received funding from venture capital early in their development (see Gornall and Strebulaev, 2015). That said, there is inconclusive evidence of whether SOX has deterred firms from becoming publicly traded as evidenced by IPO activity (e.g., see Engel, et al., 2007, 2007, and Gao, et al., 2013). However, initial public offerings reflect several factors and may not be as tied to innovation as venture capital. Earlier tests of SOX's impact on venture capital were hampered by a short time-series sample—the period following the Internet-stock bust of the early 2000s—and tended to focus on cross-sectional evidence.

Taking advantage of the large-sized rise of stock prices in the mid-2000s, their fall during the Great Recession, and full recovery since then, this study assesses whether the time-series behavior of venture capital investment shifted following SOX's passage. We find statistically significant evidence of a time-series break near the passage of SOX, consistent with the argument that regulation created by SOX has deterred venture capital investment. Estimates indicate that the slower post-SOX pace of venture capital investment is mainly attributed to a reduced elasticity

[2] Among SOX's many provisions, Section 404 requires management to implement procedures to monitor internal systems that ensure the accuracy of financial reports.

of such investment with respect to stock prices rather than to a simple downshift in the level of investment. These findings relate to two broad concerns regarding growth and financial stability; namely, that long-run growth has downshifted to an undesirably slow pace in the U.S. and that equity financing poses less risk to financial stability than debt financing.[3] To establish our empirical results, the next section briefly outlines the role played by stock prices as a factor affecting venture capital investment and the data used. Section 3 presents the empirical findings, while Section 4 concludes.

2. Stock prices as an incentive to undertake venture capital investment

There are several important roles that venture capitalists play, key among them are supplying needed managerial talent to supplement scientific or technical expertise in developing products and overcoming asymmetric information problems in research and development when firms have intangible capital and a need for external finance (Gompers and Lerner, 2004, *inter alia*). Venture capitalists do so in several ways, particularly through monitoring equity investors as firm directors, requiring key employees and other stakeholders to have some state-contingent payouts, and providing new investment in stages (Gompers and Lerner, 1999). Venture capitalists' main payoff comes from selling their formerly illiquid investment stakes, usually after initial public offerings, to paraphrase Gompers and Lerner (1999). If stock prices are roughly a random walk owing to difficulties in out-forecasting fundamentals or discount rates, then stock prices provide a signal of the prospective returns from venture capital investments. By implication, swings in stock prices are likely positively correlated with swings in the equilibrium level of

[3] There is evidence that the downshift in long-run total factor productivity (TFP) growth predated the Great Recession, and was concentrated in IT industries (see Fernald 2015). This timing downplays the role of the Great Recession in the productivity slowdown, and is consistent with the plausible role of venture capital investment, which slowed down a few years before the deceleration in TFP growth and which historically had been an important source of equity funding for IT firms (see Gornall and Strebulaev, 2015).

venture capital investment, *ceteris paribas*. This is consistent with the empirical cross-section results of Miloud, et al. (2012), who examine the determinants of venture capitalist valuations of firms ("pre-money" or prior to a subsequent IPO), which critically affect the volume of venture capital investment. In particular, Miloud, et al. (2012) find that venture capitalist valuations of firms in which they invest are significantly affected by stock prices, controlling for a myriad of other factors (e.g., firm-specific and industry-specific influences).

The venture capital industry initially was slow to develop, partly because the nature of its investments required long-run patient investors (e.g., funding from institutional investors) and sufficient R&D related investment outside of large firms. It received some inducement in 1979 when Congress reformed pension laws (ERISA, 1979) to clarify implicit "Prudent Man Rule" restrictions on corporate pension funds and explicitly permit the funds to invest up to 10 percent of their capital in venture capital funds (Gompers, 2004). This liberalization occurred just before back-to-back recessions hurt investment between 1979 and 1982, which also delayed the impact of easing investment rules. While venture capital expanded in the 1980s, it did not really take off until the 1990s, particularly in funding the emerging Internet-related high-tech industry that was particularly in need of long-run, initially illiquid investments in intangible product development. Indeed, tech-related venture capital investment is larger than non-tech related investment, according to PriceWaterhouseCooper's database. For these reasons, large stock price movements coupled with a surge in research and development of the high-tech industry beginning in the 1990s enabled a relationship between venture capital and stock prices to notably emerge.

Our main data source, PriceWaterhouseCooper's MoneyTree report, begins during this period and covers the subsequent post-SOX era.[4] By raising the compliance cost of a firm

[4] The National Venture Capital Association has a similar database, but their sample begins in 2004.

becoming publicly traded (see, e.g., Fletcher and Miles, 2004), SOX arguably introduced a wedge between a firm's valuation if it remained private, and the stock price at which it could trade after becoming a publicly owned company. In this way, SOX plausibly reduced the incentive for venture capital investment implied by a given level of real stock prices for existing public firms that already incur the costs of complying with SOX. By implication, the likely positive relationship between an index of stock prices and the aggregate level of venture capital investment should experience a statistical break near the advent of SOX and display a smaller-sized positive correlation thereafter.

3. Empirical approach to testing for long-run and short-run relationships

To test these two implications, an error-correction framework is used to estimate long-run (equilibrium) and short-run movements in venture capital investment. This approach is suited to our purposes for at least two reasons. First, it can model nonstationary variables as a function of one another, provided that the variables are cointegrated—that is the deviation between actual and equilibrium levels are themselves stationary. Second, the error-correction approach explicitly allows the time for stock price signals to affect venture capital investment. If this approach works well for modeling venture capital, the estimated equilibrium level of investment will move slightly ahead of the actual level, with a statistically significant tendency for short-run changes to narrow (correct) the gap between the actual and equilibrium levels, proxied by the prior period's gap (or error). Thus, one can use cointegration tests to see if long-run relationships are valid and estimate short-run models to see if there is evidence of correction toward the long-run equilibrium in the short-run.

Our main variables are nonstationary and are integrated of order 1, meaning that they have trends that can complicate statistical analysis and that the first differences of these variables are stationary (Table 1). We use the Johansen-Juselius approach rather than the DOLS approach to estimate the long-run relationships, as the latter's use of future changes in variables seems implausible given that expectations of making venture capital investments in the future would move overall stock price indexes in advance and to a substantial degree.

Cointegration analysis is amenable to testing whether right-hand side variables are exogenous to the dependent variable, providing evidence on whether stock prices drive venture capital investment or the reverse. We use vector-error correction models (VECMs) to jointly estimate the long-run relationship between two variables, Y_1 and $Y_{2,}$ in a cointegrating vector and short-run effects in first difference equations, respectively:

$$\ln(Y_1) = \alpha_0 + \alpha_1 \ln(Y_2)$$

$$\Delta\ln(Y_1) = \beta_1[\ln(Y_1) - \alpha_0 + \alpha_1\ln(Y_2)]_{t-1} + \Sigma_{i=1}\gamma_i\Delta\ln(Y_1)_{t-i} + \Sigma\delta_i\Delta\ln(Y_2)_{t-i} + \lambda_1 X_t + \varepsilon_{1t}$$

$$\Delta\ln(Y_2) = \beta_1[\ln(Y_1) - \alpha_0 + \alpha_1\ln(Y_2)]_{t-1} + \Sigma_{i=1}\gamma_i\Delta\ln(Y_2)_{t-i} + \Sigma\delta_i\Delta\ln(Y_1)_{t-i} + \lambda_2 X_t + \varepsilon_{2t} \quad (1)$$

where the lags of first difference endogenous variables minimize the AIC, X is a vector of exogenous factors, ε_{it} are residuals, and the λ_i, γ_i, and $\delta_{i\ v}$ are row vectors of coefficients.

Each of our specifications include the level of venture capital investment, either total (*VCTot*) or tech related (*VCTech*), and the NASDAQ stock price index (*Nasdaq*).[5] These enter as logs, and are detrended either by business equipment and intellectual property investment or GDP, denoted by superscripts *inv* and *GDP*, respectively. The detrending should clean-up any breaks in the cointegrating relationship driven by long-term demographic or productivity growth trends. Detrending by scaling with business investment additionally limits the influence of cycles in investment that may differ from movements in GDP, especially during periods of high unused capacity, such as the Great Recession and the subsequent recovery from it.

[5] Tech-related venture capital investment includes the sectors Computer Hardware & Services, Internet, Mobile & Telecommunications and Software.

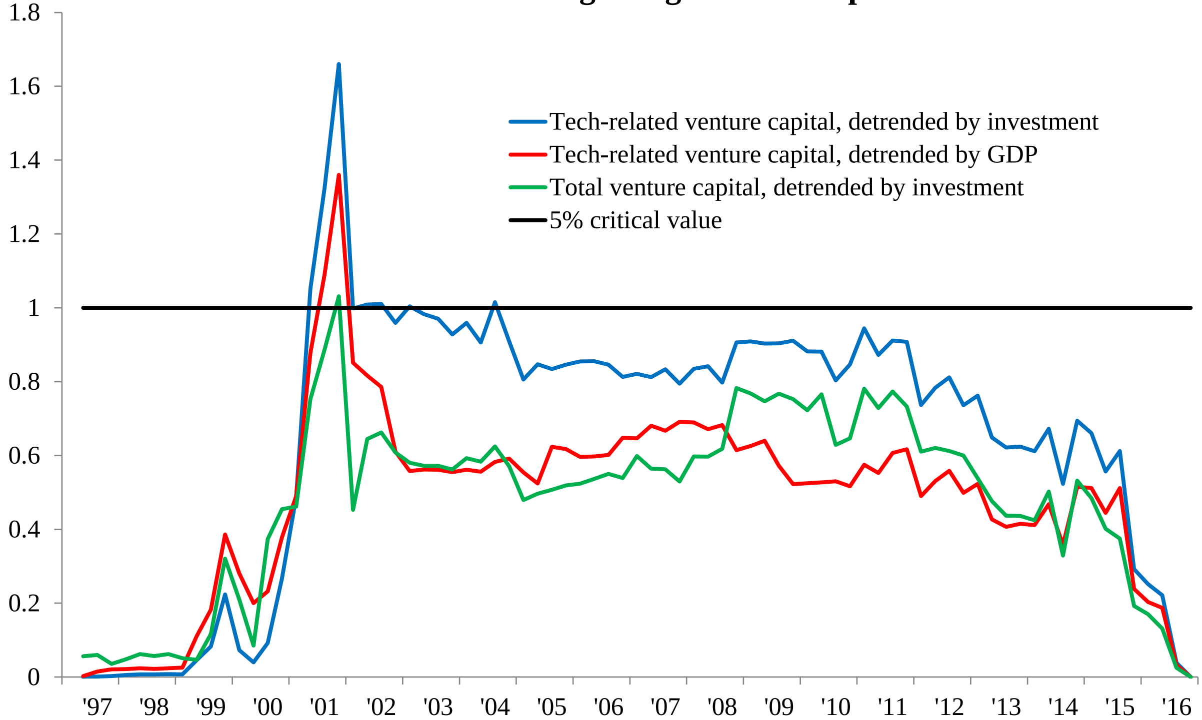
3.1 Tests of a break in the long-run relationship between venture capital investment and stock prices

Table 2 displays the results of our baseline specification, using tech-related venture capital investment and detrending by business investment. Model 1 only includes the two endogenous variables with no consideration for a break in the relationship. The tests allow for trends in the variables and a constant in the cointegrating vector, but not a time trend in the vector. The usual Johansen test for cointegration does not provide evidence of a single cointegrating relationship. If there were a break in the relationship, this test would be unreliable.

The Gregory-Hansen (1996) test for cointegration allows for an unknown break in the constant and slope in the cointegrating relationship. These tests, shown in Table 5, provide statistically significant evidence of a cointegrating relationship. The breakpoint identified by the procedure is typically in 2002, consistent with the timing of the passing of SOX. However the Gregory-Hansen test assumes a breakpoint and then tests for cointegration; it is not intended to be a test for the existence of a breakpoint or the timing of a breakpoint.

The graphical tests of Hansen and Johansen (1999) are more appropriate for assessing the stability of cointegrating relationships and identifying any potential breakpoints. Figure 3 shows the Max Test of Beta Constancy. The estimation is repeated recursively to test for constancy in the cointegrating parameters as the sample expands. Values above 1 reject the hypothesis of constancy. All three specifications reject constancy in 2001 and the baseline also rejects constancy in 2002. This is suggests a break in the parameters, and the time is roughly consistent with the timing of the debate over—and passage of—SOX, as documented in the table timeline in Zhang (2008), corroborating the results of the Gregory-Hansen test. The timing of the break also coincides with the quarter following the September 11, 2001, terrorist attacks. The impact of that shock is unlikely

Figure 3. Hansen-Johansen (1999) Max Test of Beta Constancy Indicates a Break in the Cointegrating Relationship



Note: Value above one indicates that coefficients in the cointegrating relationship are not constant across the sample. The alpha (speed of adjustment) parameters are re-estimated at every recursive estimation rather than once for the whole sample. The specifications come from Model 1 in Tables 1,2 and 3.

to be long lived and predates the official introduction of SOX legislation in early 2002 (see Zhang, 2007).

The existence of a break in the relationship and its timing in late-2001 are also supported by the Kejriwal and Perron (2010) tests for structural change in cointegrated regression model, as shown in Table 7. This test is similar to the Bai and Perron (2003) multiple break point test, but with critical values that account for cointegration. The UDMax test statistic rejects the null hypothesis of no breaks versus the alternative hypothesis of one or more breaks.

The sequential method of adding one break at a time and checking for the statistical significance of an additional break, conditional on the previously specified break, identifies a single break in late-2001, at the 1% critical value. (This break occurs just before Congressman

Oxley formally introduced a precursor to SOX in 2002q1.) There is wide uncertainty around the timing however, with the 90% confidence interval of the timing of the break including 2003q1 in all three specifications. The Kejriwal and Perron tests also reject the null hypothesis of no breaks versus the alternative hypothesis of two breaks, timing the breaks in early 1999 and early 2003. This is notable because it moves the post-bust break point soon after the passage of SOX in July 2002, and also that it does not indicate a break in the Great Recession and recovery period.

In the remaining analysis, a single break is used in 2002q4, to illustrate the potential effect of the passage and implementation of SOX on venture capital. This is within the confidence interval of the single estimated break, so it is not rejected by the data, and lines up with the second break when two are allowed. We do not include a second break to avoid over-fitting the data with breaks in the relationship. In fairness, these tests would also support a break caused by the terror attacks of September 11, 2001, or the stock market bust of 2000-2001. The important point is that the slowdown in venture capital started around 2001-2003, and is not a recent phenomenon.

3.2 Estimates of long-run relationships between venture capital investment and stock prices

Break variables are then introduced into Models 2 and 3 in Tables 2-4. Specifically, model 2 adds a shift in the constant (*SOXShift*) that equals 0 before 2002q4 and 1 thereafter. In addition to *SOXShift*, model 3 in each table adds *SOXShift* interacted with the scaled *Nasdaq* stock index. The latter tests whether the responsiveness of venture capital investment to scaled stock prices has changed post-SOX.

The upper-panels of Tables 2-4 report tests and estimates of long-run relationships, and several patterns emerge. For each version of scaling and for the two categories of venture capital investment, a significant, unique cointegrating vector could not be found for the baseline model that omits the two SOX shift variables. This is consistent with the break test results in Table 5. Interestingly, a significant unique cointegrating relationship could be identified for the baseline model when it is estimated through a pre-SOX sample, as in Model 4 in Tables 2-4. In each case, the long-run coefficient on scaled stock prices is positive and significant, consistent with the incentives of venture capitalists to later sell their equity stakes in venture investments. Note that the long-run coefficient estimates are reported to show the long-run equilibrium relationship such that a positive sign reflects a positive long-run relationship.

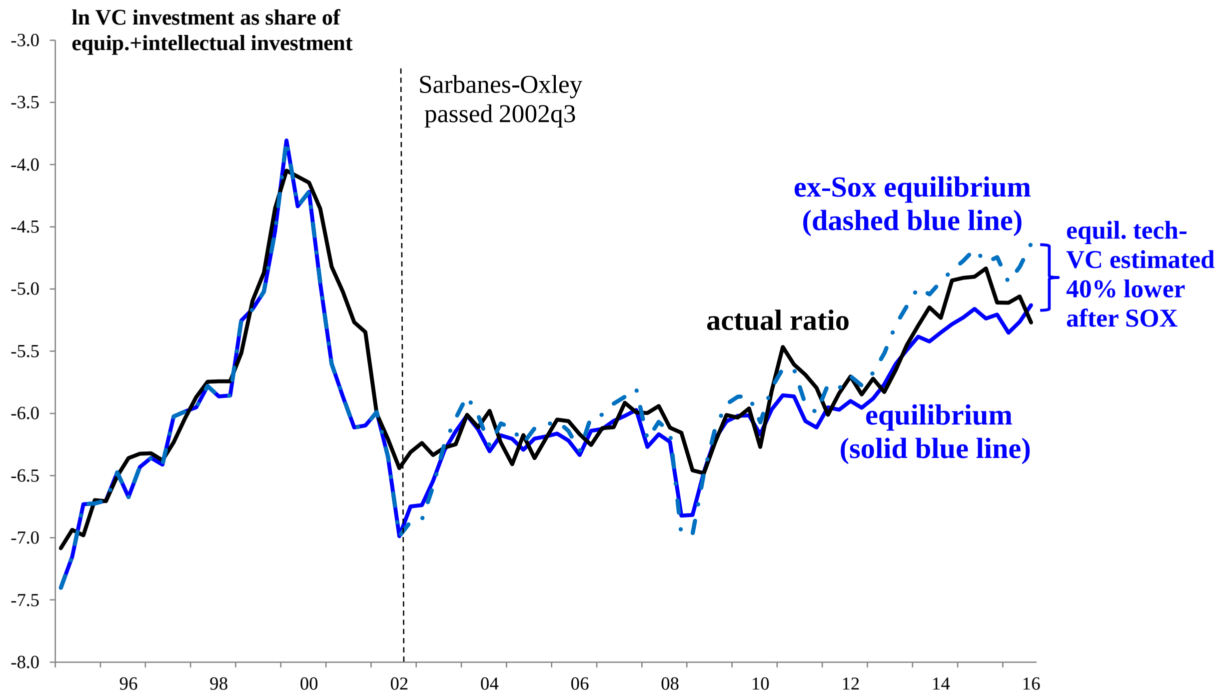
Turning to the specifications allowing for SOX-related shifts, the evidence favors the view that SOX had more of an effect on damping the responsiveness of venture capital investment to stock prices. Of the models that just allow a shift in the constant (Model 2 in Tables 2-4), only for the case of tech-related venture investment scaled by business investment (Table 2) is a unique long-run relationship in which *SOXShift* is statistically significant. When tech-related venture investment is scaled by GDP, a significant and unique cointegrating vector is identified, but the *SOXShift* variable is insignificant as shown in Model 2 of Table 3. And when total venture capital is scaled by investment, a significant unique cointegrating vector could not be identified, as shown in Model 2 of Table 4.

In contrast, when SOX is allowed to affect the responsiveness of venture capital investment to stock prices as well as having a non-interactive effect, a unique, significant cointegrating vector is found in every case for Model 3 in Tables 2-4. And in each instance, the non-interactive scaled stock variable (ln*Nasdaq)* is positive and statistically significant, while the variable interacting *SOXShift* with stock prices is negative and statistically significant. In each case, the absolute magnitude of the positive coefficient on non-interacted stock prices is larger than the absolute size of the negative coefficient on the SOX-interacted stock price variable, with the sum of the coefficients statistically significant. This pattern implies that stock prices still have a positive effect on venture capital investment post-SOX, but that venture capital investment has become less responsive to stock prices post-SOX.

The non-interactive *SOXShift* variable is significant in every version of Model 3 in Tables 2-4. In each case, the sign is positive, which may seem counter-intuitive at first glance. However, the net effect of SOX in the Model 3 specification combines the non-interactive effect of *SOXShift* and its interactive effect on the responsiveness of stock prices. And the net effect in every case is negative. This is illustrated in Figure 4, which plots the actual tech-related venture capital investment with the estimated equilibrium level from Model 3 in Table 2 and with the estimated equilibrium level omitting the effects of *SOXShift* and *SOXShift*lnNasdaq*. As the figure shows, the equilibrium relationship nicely tracks the actual log-level of tech-related venture capital, and that absent both SOX effects, the equilibrium relationship would have predicted higher levels of venture capital investment, particularly in the mid-2010s when stock prices had largely recovered from their Great Recession lows. Indeed, accounting for the scaling in natural logs, estimates indicate that equilibrium tech-related venture capital investment would have been 40 percent higher in 2016q4 if pre-SOX behavior had prevailed (or 1.0 percent the size of equipment plus intellectual investment instead of 0.6 percent).

In each table, the coefficient on ln*Nasdaq* is similar in Model 3 to that in Model 4, which omits the SOX variables but is estimated over a pre-SOX sample. Because of this, the equilibrium path of venture capital based on pre-SOX relationships from Model 4 are virtually identical to the counterfactual equilibrium levels from Model 3 plotted in Figure 4. Thus, Models 3 and 4 in each table imply that venture capital investment has been lower post-SOX than scaled stock prices would suggest based on pre-SOX relationships.

Figure 4: Estimated Equilibrium Tracks Venture Capital Investment, Implies SOX Lowered Post-2002 Investment



Sources: PWC Moneytree, Bureau of Economic Analysis, and author's calculations (including seasonal adjustment). Recessions denoted by shaded areas.

3.3 Estimates of short-run relationships between venture capital investment and stock prices

The lower panels of Tables 2-4 report results for modeling the change in scaled venture capital investment. In each case, reflecting that the long-run results favor the specification allowing for both non-interactive and stock price-interactive effects of SOX for the full sample, the error-correction coefficients are more significant and larger in magnitude for Model 3 than in Model 2 or Model 1. And in each case, Model 3 has a better fit, as reflected in its lower standard error. The negative error-correction coefficient reflects that changes in venture capital investment tend to be negative when the actual log-level of venture capital investment exceeds its estimated equilibrium log-level. It is also encouraging that the size of the error-correction coefficient in the preferred Model 3 specification implies that venture capital investment changes in quarter t to close 40 to 42 percent of the gap between actual and equilibrium venture capital investment in the prior quarter.

3.4 Tests of weak exogeneity

The results also provided evidence on the direction of long-run feedback between stock prices and venture capital investment. Each model was estimated as a vector error-correction model that contained separate equations for changes in venture capital investment, stock prices, *SOXShift*, and *SOXShift* interacted with stock prices. These equations were regressed on the same error-correction term, the same lags of changes in the long-run variables, and the same sets of short-run variables. If the error-correction term is significant in the model of venture capital investment but is insignificant in the model of stock prices, then formal econometric evidence would indicate that stock prices are 'weakly exogenous' to venture capital investment, as discussed in Urbain (1992), and that venture capital investment is temporally "caused," in a long-run sense, by the stock prices, according to Granger and Lin (1995). In every case for Model 3, the non-interactive and stock price-interacted SOX variables are weakly exogenous to venture capital (not reported), while venture capital investment is not weakly exogenous to those variables, as implied by the significant error-correction coefficients reported in Tables 2-4.

As reported in Table 6, while venture capital investment is not weakly exogenous to non-interacted stock prices and the other variables, the latter are weakly exogenous to venture capital in two of three cases: tech-related venture capital scaled by GDP and total venture capital scaled by business investment. For tech-related venture capital investment scaled by business investment, there is some evidence that venture capital investment may have some feedback on stock prices. Nevertheless, the t-statistic on the error-correction term for venture capital (4.12) is notably higher and more significant than the t-statistic on the error-correction term for non-interactive stock prices (2.19). This suggests that there is more feedback from stock prices to venture capital investment than the reverse, as intuition would suggest. In addition, note that the test for whether non-interacted stock prices are exogenous to all the other variables, includes stock prices interacted with the SOX shift variable. Consistent with this point, the error-correction terms on stock prices and stock prices interacted with the *SOXShift* variable are jointly insignificant in this case, implying that over the full sample, on net, stock prices are weakly exogenous to venture capital.

4. Conclusion

Venture capital investment has not recovered to levels seen in the late 1990s, despite a recovery in stock prices to around then-prevailing levels. This study provides statistical time-series evidence of diminished responsiveness of venture capital investment to stock prices following the introduction of SOX legislation in early 2002. This is consistent with the view that the regulatory burdens associated with SOX and perhaps higher levels of overall regulation since then have deterred investment, including venture capital investment, in research and development. It is important to note that movements in venture capital investment do not always coincide with swings in overall IPO activity, reflecting that the latter includes non-venture capital related activity motivated by other factors.

From a broader perspective, the findings are related to the emerging literature on the financial stability need to regulate debt and the shadow banking industry. There is an emerging consensus of an imperative to regulate shadow banking-funded debt, owing to the negative externalities posed by debt financing (see Duca, et al., forthcoming, and Turner, 2015) and the regulatory arbitrage induced by unequal treatment of banks and nonbank debt providers that has fueled the rise of shadow banking (Duca, 2016) and played a role in fueling the U.S. subprime housing boom and bust (Duca, et al., 2016). Other studies also find that only a subset of financial crises are linked to severe macroeconomic distress, namely those associated with excessive investment in real estate (Bordo and Haubrich, 2017), which are often funded with excessive reliance on debt (see *inter alia*, Jorda, Schularik, and Taylor, 2015 and Turner, 2015). Debt-funded booms are problematic partly because of the correlated macroeconomic downside risks to which they can lead during busts when borrower purchases are constrained by debt overhangs and when financial intermediaries' ability to lend is impaired by loan losses (see Duca and Muellbauer, 2014; *inter alia*). However, there is less evidence of negative externalities posed by excessive equity financing, owing in part to incentives arising from asymmetric information and the repricing features of equity relative to debt financing.[6] These concerns raise issues for calculating the benefits of regulating equity markets.

With respect to the costs from equity regulation, one potential downside appears to be that SOX has possibly curtailed venture capital investment, consistent with this study's estimates that tech-related venture investment is 40 percent below what pre-SOX relationships would imply. This amounts to about 0.4 percentage points of total business equipment plus intellectual property investment and may help account for why there has been a notable decline in the share of new businesses that have grown rapidly, as documented by Decker, et al. (2016b). These patterns coupled with the downshift in U.S. productivity growth since the mid-2000s suggest that greater

[6] Indeed, bank reform proposals (Calomiris and Herring, 2013) and regulatory changes (Federal Reserve Board, 2016) call for large banks that pose systemic risk to issue convertible debt that can convert (reprice) into equity when they suffer severe losses, especially during crises when their ability to raise new capital is impaired.

equity regulation entails some downside risk to long-run growth. To some extent regulatory-induced declines in venture capital investment may have also induced a greater share of firms to remain privately held. Although the latter type of firms do not have as much access to broad capital sources as publicly traded firms, this substitution towards privately-held companies could limit the net macroeconomic effects of weaker venture capital investment. Clearly, a welfare analysis is beyond the scope of this paper and would need to account for such substitution effects in assessing the cost of regulation, versus its benefits from limiting fraud and other deleterious behavior. With this caveat in mind, our findings suggest that a review of the costs and benefits of SOX could be worthwhile.

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Table 1: Unit Root Tests

	ln*VCTech*^{inv}	ln*VCTech*^{gdp}	ln*VCTot*^{inv}	ln*Nasdaq*^{inv}	ln*Nasdaq*^{gdp}
ADF					
Level	-2.18	-2.16	-3.03	-2.44	-2.23
1st diff.	-7.10**	-6.17**	-7.32**	-7.05**	-6.92**
I(1)	Yes**	Yes**	Yes**	Yes**	Yes**
Phillips-Peron					
Level	-2.34	-2.30	-2.48	-2.48	-2.27
1st diff.	-7.25**	-6.93**	-7.54**	-7.48**	-6.96**
I(1)	Yes**	Yes**	Yes**	Yes**	Yes**
KPSS					
Level	0.12^{+}	0.12^{+}	0.10	0.14^{+}	0.14^{+}
1st diff.	0.19	0.09	0.07	0.09	0.10
I(1)	Yes^{+}	Yes^{+}	No	Yes^{+}	Yes^{+}

Notes: $^{+,\,*}$ and ** denote 90%, 95%, and 99% significance levels, respectively. A trend and intercept is allowed in every speciation. Augmented Dickey-Fuller (ADF) and Phillips-Peron tests have a null hypothesis of a unit root. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test has a null hypothesis of stationarity. The number of lags in the ADF test is selected using SIC.

Table 2: Models of Tech-Related Venture Capital Investment and Nasdaq Scaled by Investment

(Quarterly data, 1995q1-2016q4, Sample estimation period 1995:q3 – 2016:q4)

Long-Run Relationship: $lnVCTech^{inv}_t = \lambda_0 + \lambda_1 lnNasdaq^{inv}_t + \lambda_2 SOXShift_t{*}lnNasdaq^{inv} + \lambda_3 SOXShift_t$

Sample:	1995:q3 – 2016:q4			1995:q3-2002:q3
	Model 1	**Model 2**	**Model 3**	**Model 4**
Constant	-7.425	-7.281	-7.548	-7.600
ln$Nasdaq^{inv}_t$	2.636**	2.680**	3.087**	3.122**
	(11.93)	(18.06)	(20.38)	(16.59)
$SOXShift_t$*ln$Nasdaq^{inv}$			-0.876**	
			(3.96)	
$SOXShift_t$		-0.262**	0.308*	
		(3.51)	(2.08)	
Trace (1 vector)	23.68**	39.27**	58.19**	18.92*
Trace (2 vectors)	6.26*	9.58	17.93	2.88
MaxEigen (1 vector)	17.43*	29.69**	40.25**	16.04*
MaxEigen (2 vectors)	6.26*	7.74	12.90	2.88
Unique Coint. Vector?	No	Yes**,**	Yes**,**	Yes*,*
Gregory-Hansen Break?	Yes, 2002:q2			

Short-Run: $\Delta lnVCTech^{inv}_t = \alpha_0 + \alpha_1(EC)_{t-1} + \beta_i\Delta(lnNasdaq^{inv})_{t-i} + \theta_i\Delta(SOXShift_t{*}lnNasdaq^{inv})_{t-i} + \delta\Delta(SOXShift_t)$

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Constant	0.013	0.012	0.012	0.004
	(0.69)	(0.64)	(0.23)	(0.10)
EC_{t-1}	-0.265**	-0.351**	-0.409**	-0.270^{+}
	(3.29)	(3.95)	(4.12)	(1.74)
$\Delta(lnNasdaq^{inv})_{t-1}$	0.326	0.188	-0.013	-0.146
	(1.24)	(0.70)	(0.04)	(0.32)
$\Delta(SOXShift)_{t-1}$		0.242	0.143	
		(1.35)	(0.73)	
$\Delta(SOXShift{*}lnNasdaq^{inv})_{t-1}$			0.258	
			(0.63)	
$\Delta lnVCTech^{inv}_{t-1}$	0.120	0.117	0.124	0.374*
	(1.15)	(1.14)	(1.19)	(2.01)
Adjusted R^2	.255	.284	.287	.395
S.E.	0.172	0.169	0.168	0.196
VECLM(1)	0.88	4.01	23.20	4.57
VECLM(4)	3.00	6.80	22.42	3.40

Notes: first differences of lagged variables omitted in the short-run results section to conserve space (full results are available). "v." denotes vector, while $^{+,*}$ and ** denote 90%, 95%, and 99% significance levels, respectively. Absolute t-statistics are in parentheses. Significance indicators for a unique cointegrating vector refer to trace then max-eigen statistics. The AIC selected a lag length of 1 quarter for each model. The significance level of VECLM statistics accounts for size of the vector.

Table 3: Models of Tech-Related Venture Capital Investment and the Nasdaq Scaled by GDP

(Quarterly data, 1995q1-2016q4, Sample estimation period 1995:q3 – 2016:q4)

Long-Run Relationship: $lnVCTech^{GDP}_t = \lambda_0 + \lambda_1 lnNasdaq^{GDP}_t + \lambda_2 SOXShift_t{*}lnNasdaq^{GDP} + \lambda_3 SOXShift_t$

Sample:	1995:q3 – 2016:q4			1995:q3-2002:q3
	Model 1	**Model 2**	**Model 3**	**Model 4**
Constant	-4.039	-3.908	-3.357	-3.373
$\ln Nasdaq^{GDP}_t$	2.396**	2.434**	2.780**	2.788**
	(15.48)	(17.36)	(19.98)	(18.48)
$SOXShift_t{*}\ln Nasdaq^{GDP}$			-0.764**	
			(3.73)	
$SOXShift_t$		-0.101	1.366**	
		(1.23)	(3.89)	
Trace (1 vector)	26.96**	35.16*	53.54*	19.11*
Trace (2 vectors)	6.48*	10.13	18.47	3.30
MaxEigen (1 vector)	20.48*	25.03*	35.07*	15.82*
MaxEigen (2 vectors)	6.48*	8.18	13.19	3.30
Unique Coint. Vector?	No	Yes*,*	Yes*,*	Yes*,*
Gregory-Hansen Break?	Yes, 2002:q3			

Short-Run: $\Delta\ln VCTech^{GDP}_t = \alpha_0 + \alpha_1(EC)_{t-1} + \beta_i\Delta(\ln Nasdaq^{GDP})_{t-1} + \theta_i\Delta(SOXShift_t{*}\ln Nasdaq^{GDP})_{t-1} + \delta\Delta(SOXShift_t)$

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Constant	0.013	0.011	0.011	0.005
	(0.68)	(0.57)	(0.57)	(0.13)
EC_{t-1}	-0.328**	-0.344**	-0.416**	-0.354*
	(3.68)	(3.80)	(4.11)	(2.14)
$\Delta(\ln Nasdaq^{GDP})_{t-1}$	0.322	0.305	0.068	0.089
	(1.24)	(1.17)	(0.21)	(0.20)
$\Delta(SOXShift)_{t-1}$		0.194	0.804	
		(1.10)	(0.95)	
$\Delta(SOXShift{*}\ln Nasdaq^{GDP})_{t-1}$			0.304	
			(0.79)	
$\Delta\ln VCTech^{GDP}_{t-1}$	0.134	0.126	0.137	0.355^{+}
	(1.30)	(1.23)	(1.32)	(1.94)
Adjusted R^2	.318	.317	.328	.464
S.E.	0.170	0.170	0.168	0.193
VECLM(1)	1.21	3.90	21.83	3.96
VECLM(4)	3.18	5.51	16.17	3.34

Notes: first differences of lagged variables omitted in the short-run results section to conserve space (full results are available). "v." denotes vector, while $^{+,*}$ and ** denote 90%, 95%, and 99% significance levels, respectively. Absolute t-statistics are in parentheses. Significance indicators for a unique cointegrating vector refer to trace then max-eigen statistics. The AIC selected a lag length of 1 quarter for each model. The significance level of VECLM statistics accounts for size of the vector.

Table 4: Models of Total Venture Capital Investment and Nasdaq Scaled by Investment

(Quarterly data, 1995q1-2016q4, Sample estimation period 1995:q3 – 2016:q4)

Long-Run Relationship: $lnVCTot^{inv}_t = \lambda_0 + \lambda_1 lnNasdaq^{inv}_t + \lambda_2 SOXShift_t * lnNasdaq^{inv} + \lambda_3 SOXShift_t$

Sample:	1995:q3 – 2016:q4			1995:q3-2002:q3
	Model 1	**Model 2**	**Model 3**	**Model 4**
Constant	-6.361	-6.152	-6.712	-6.657
ln$Nasdaq^{inv}_t$	1.978**	1.933**	2.764**	2.686**
	(6.42)	(8.49)	(20.67)	(18.62)
$SOXShift_t$*ln$Nasdaq^{inv}$			-1.557**	
			(7.96)	
$SOXShift_t$		-0.277*	0.765**	
		(2.41)	(5.85)	
Trace (1 vector)	15.30	23.14	56.56**	23.10**
Trace (2 vectors)	6.32*	9.93	16.99	2.33
MaxEigen (1 vector)	8.98	13.21	39.56**	20.77**
MaxEigen (2 vectors)	6.32*	8.04	11.49	2.33
Unique Coint. Vector?	No	No	Yes**,**	Yes**,**
Gregory-Hansen Break?	Yes, 2002:q3			

Short-Run: $\Delta lnVCTot^{inv}_t = \alpha_0 + \alpha_1(EC)_{t-1} + \beta_i\Delta(lnNasdaq^{inv})_{t-i} + \theta_i\Delta(SOXShift_t * lnNasdaq^{inv})_{t-i} + \delta\Delta(SOXShift_t)$

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Constant	0.004	0.003	0.004	-0.005
	(0.22)	(0.17)	(0.23)	(0.13)
EC_{t-1}	-0.204**	-0.254**	-0.404**	-0.414*
	(2.69)	(2.99)	(3.94)	(2.28)
$\Delta(lnNasdaq^{inv})_{t-1}$	0.432+	0.374	-0.007	-0.073
	(1.87)	(1.60)	(0.02)	(0.15)
$\Delta(SOXShift)_{t-1}$		0.102	-0.088	
		(0.64)	(0.51)	
$\Delta(SOXShift * lnNasdaq^{inv})_{t-1}$			0.443	
			(1.22)	
$\Delta lnVCTot^{inv}_{t-1}$	0.108	0.126	0.150	0.311
	(0.99)	(1.14)	(1.39)	(1.54)
Adjusted R^2	.213	.220	.270	.261
S.E.	0.157	0.157	0.152	0.211
VECLM(1)	3.38	12.51	19.13	4.63
VECLM(4)	2.68	5.28	15.58	6.65

Notes: first differences of lagged variables omitted in the short-run results section to conserve space (full results are available). "v." denotes vector, while +, * and ** denote 90%, 95%, and 99% significance levels, respectively. Absolute t-statistics are in parentheses. Significance indicators for a unique cointegrating vector refer to trace then max-eigen statistics. The AIC selected a lag length of one quarter for each model. The significance level of VECLM statistics accounts for size of the vector.

Table 5: **Gregory-Hansen Cointegration Test While Allowing for Unknown Break**
(Quarterly data, 1995q1-2016q4)

	ADF	**Zt**	**Za**
Tech-Related Venture Capital, Nasdaq Scaled by Investment	-5.00* [2002q2]	-5.03* [2002q2]	-40.11 [2002q2]
Tech-Related Venture Capital, Nasdaq Scaled by GDP	-4.87+ [2001q1]	-4.83+ [2001q1]	-37.37 [2001q1]
Total Venture Capital, Nasdaq Scaled by Investment	-3.79 [2001q1]	-5.32* [2002q3]	-43.17* [2002q3]

Notes: +, * and ** denote 90%, 95%, and 99% significance levels, respectively. Dates of break in relationship are in brackets. A break is allowed in both the constant and slope. Number of lags is selected with AIC.

Table 6: Weak Exogeneity Tests

Testing Whether Venture Capital Investment is Weakly Exogenous to Non-Interacted Stock Prices

Estimate Short-Run Model: $\Delta \ln VC_t = \alpha_0 + \alpha_1(EC)_{t-1} + \beta_i \Delta(\ln Nasdaq)_{t-1} + \theta_i \Delta(SOXShift_t * \ln Nasdaq)_{t-1} + \delta \Delta(SOXShift_t)$

Test whether α_1 is equal to zero: resoundingly rejected in Model 3 in Tables 2-4, implying that venture capital is not weakly exogenous to the other variables, including stock prices.

Variable and Scaling:	**VCTech^{inv}** (Model 3, Table 2)	**VCTech^{GDP}** (Model 3, Table 3)	**VCTot^{inv}** (Model 3, Table 4)
EC_{t-1}	-0.409**	-0.416**	-0.404**
	(4.12)	(4.11)	(3.95)

Testing Whether Non-Interacted Stock Prices are Weakly Exogenous to Venture Capital Investment

Estimate Short-Run Model: $\Delta \ln Nasdaq_t = \alpha_0 + \alpha_1(EC)_{t-1} + \beta_i \Delta(\ln VC)_{t-1} + \theta_i \Delta(SOXShift_t * \ln Nasdaq)_{t-1} + \delta \Delta(SOXShift_t)$

Variable and Scaling:	**Nasdaq^{inv}** (Model 3, Table 2)	**Nasdaq^{GDP}** (Model 3, Table 3)	**Nasdaq^{inv}** (Model 3, Table 4)
EC_{t-1}	-0.117*	-0.091	-0.086
	(2.19)	(1.62)	(1.38)

Notes: $^{+}$, * and ** denote 90%, 95%, and 99% significance levels, respectively.

Table 7: Kjriwal-Perron Test for Multiple Structural Changes in Cointegrated Regression Models
(Quarterly data, 1995q1-2016q4)

	$lnVCTech^{inv}$ $lnNasdaq^{inv}$	$lnVCTech^{GDP}$ $lnNasdaq^{GDP}$	$lnVCTot^{inv}$ $lnNasdaq^{inv}$
UDMax	24.40^{**}	18.15^{**}	44.99^{**}
Sequential method			
$SupF_t$(0 vs 1)	18.08^{**}	17.72^{**}	44.99^{**}
$SupF_t$(1 vs 2)	14.14^{+}	1.88	8.52
$SupF_t$(2 vs 3)	1.80	2.60	0.98
$SupF_t$(3 vs 4)	3.09	0.37	1.13
Break dates	2001q4	2001q2	2001q4
90% C.I.	[99q2-04q3]	[99q2-03q3]	[00q4-03q1]
Two break points			
$SupF_t$(0 vs 2)	24.40^{**}	17.04^{**}	33.24^{**}
Break dates 1	1999q2	1999q2	1998q3
90% C.I.	[98q4-00q2]	[98q4-00q2]	[98q1-99q3]
Break dates	2003q1	2003q1	2001q4
90% C.I.	[02q3-03q4]	[02q2-04q1]	[01q2-02q3]

Notes: $^{+,\,*}$ and ** denote 90%, 95%, and 99% significance levels, respectively. Test statistics are calculated from Bai and Perron (2003) and all critical values are taken from Kjriwal and Perron (2010) which account for cointegration. Both the constant and slope are allowed to change. Trimming percentage is 15%. The Liu-Wu-Schwarz Information Criterion selected two breaks in all three models, while the BIC selected three breaks in the first two models and two breaks in the third.