The Impact of Privacy Policy Changes on Venture Capital Investment in Online Advertising Companies

By Josh Lerner[1]

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1. Introduction

This paper examines the effect of electronic privacy policy changes on venture capital (VC) investment in online advertising companies. To do this, we analyze the effect of the European Union (EU) Privacy and Electronic Communications Directive (2002/EC/58), hereafter referred to as the EU e-Privacy Directive, on VC investment in such companies generally, and in online advertising, specifically.

Our hypothesis is that the EU e-Privacy Directive, which regulates the electronic collection and use of personal data in the EU more tightly than in other countries, has reduced VC investment in EU-based businesses that lend themselves to the use of such data. This hypothesis is based on a substantial literature which suggests that increased legal and regulatory certainty can have significant effects on innovation and investment.[2] For example, clearly defined property rights have been found to be strongly associated with increased innovation,[3] and countries with strong and clearly defined property rights receive more foreign direct investment.[4] More recently, a wide variety of aspects of legal regimes have been shown to be associated with innovation on a cross-national basis.[5]

Our hypothesis is also based on the findings of Goldfarb and Tucker (2011), which examines how the EU e-Privacy Directive affected the performance of online advertising in the European countries that enacted it, relative to other countries that had no such laws. It finds that in those countries that enacted the EU e-Privacy Directive, internet banner ads experienced an

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2 See, for example, Busse and Hefeker (2005) and Dumludag (2009).
3 See, for example, Mansfield (1986), Anand and Galetovic (2000), and Chen and Puttitanun (2005).
4 See, for example, Mansfield (1994), Besley (1995), Maskus (2000), and Rodrik, Subramanian, and Trebbi (2002).
5 See, for example, Acharya and Subramanian (2009) and Acharya, Subramanian, and Baghai (2010).

average reduction in effectiveness of 65 percent. Thus, we anticipate that VC investment in online advertising declined in the EU as a result of its decreased effectiveness.

Our findings suggest that decisions around the scope of electronic personal data usage can have significant impacts on investment and innovation. We find that VC investment in online advertising companies decreased significantly in the EU relative to the U.S. after passage of the EU e-Privacy Directive. Our results suggest that the EU e-Privacy Directive has led to an incremental decrease in investment in EU-based online advertising companies of approximately $249 million over the approximately eight-and-a-half years from passage through the end of 2010. When paired with the findings of the enhanced effects of VC investment relative to corporate investment, this may be the equivalent of approximately $750 million to $1 billion in traditional R&D investment.

2. Background

2.1. Academic Research Examining Impact of Policy on Venture Financing

To understand the impact of the enactment of the EU e-Privacy Directive on the willingness of venture capitalists to invest in online advertising companies, we employ a difference-in-difference approach, hypothesizing that policy shifts affect investments in different geographies and years in varying ways. While such analyses are widely employed in the economics literature, this paper is very similar in spirit to the work of Goldfarb and Tucker (2011), which examines how the EU e-Privacy Directive affected the performance of online advertising in the European countries that enacted it, relative to other countries that had no such laws.

This topic is important due to the relationship between venture capital (VC), innovation, and job growth. It might be thought that it would not be difficult to address the question of the

impact of venture capital. For instance, one could look at regressions across industries and time, and examine whether, controlling for R&D spending, venture capital funding has an impact on various measures of innovation. But, even a simple model of the relationship between venture capital, R&D, and innovation suggests that this approach is likely to give misleading estimates.

Both venture funding and innovation could be positively related to a third unobserved factor such as the arrival of technological opportunities. Thus, there could be more innovation at times that there was more venture capital, not because the venture capital caused the innovation, but rather because the venture capitalists reacted to some fundamental technological shock which was sure to lead to more innovation. To date, only a handful of papers have attempted to address these challenging issues.

Hellmann and Puri (2000), for instance, examines a sample of 170 recently formed firms in Silicon Valley, including both venture-backed and non-venture-backed firms. Using questionnaire responses, they find empirical evidence that venture capital financing is related to product market strategies and outcomes of startups. They find that firms that are pursuing an "innovator strategy" (a classification based on the content analysis of survey responses) are significantly more likely and faster to obtain venture capital. The presence of a venture capitalist is also associated with a significant reduction in the time taken to bring a product to market, especially for innovators. Furthermore, firms are more likely to list obtaining venture capital as a significant milestone in the lifecycle of the company as compared to other financing events.

The results suggest significant interrelations between investor type and product market dimensions, and a role of venture capital in encouraging innovative companies. Given the small size of the sample and the limited data, they can only modestly address concerns about causality,

and as a result, the possibility remains that more innovative firms select venture capital for financing, rather than venture capital causing firms to be more innovative.

Kortum and Lerner (2000), by way of contrast, examines whether these patterns can be discerned on an aggregate industry level, rather than on the firm level. They address concerns about causality in two ways. First, they exploit the major discontinuity in the recent history of the venture capital industry: in the late 1970s, the U.S. Department of Labor clarified the Employee Retirement Income Security Act, a policy shift that freed pensions to invest in venture capital. This shift led to a sharp increase in the funds committed to venture capital. This type of exogenous change should identify the role of venture capital, because it is unlikely to be related to the arrival of entrepreneurial opportunities. They exploit this shift in instrumental variable regressions. Second, they use R&D expenditures to control for the arrival of technological opportunities that are anticipated by economic actors at the time, but that are unobserved to econometricians. In the framework of a simple model, they show that the causality problem disappears if they estimate the impact of venture capital on the patent-R&D ratio, rather than on patenting itself.

Even after addressing these causality concerns, the results suggest that venture funding has a strong positive impact on innovation. The estimated coefficients vary according to the techniques employed, but on average a dollar of venture capital appears to be three to four times more potent in stimulating patenting than a dollar of traditional corporate R&D. The estimates, therefore, suggest that venture capital, even though it averaged less than three percent of corporate R&D from 1983 to 1992, is responsible for a much greater share—perhaps ten percent—of U.S. industrial innovations in this decade. Moreover, the venture-backed firms'

patents are more frequently cited and litigated, which suggests that the results are not being driven by patenting for its own sake.

There also appears to be a strong relationship between venture capital and job creation. There are several ways to see this relationship. Perhaps the most straightforward way is to take a snapshot of the public markets. By late 2011, venture-backed firms that had gone public made up over 11 percent of the total number of public firms in existence in the U.S. at that time. Those public firms supported by venture funding employed six percent of the total public-company workforce—many of which were high-salaried, skilled positions in the technology sector.[6]

Puri and Zarutskie (2010), in a more academically rigorous analysis, looks at job creation by venture-backed firms. They highlight that many of the firms that receive venture backing for the first time have no revenues and very modest employment. They compare the evolution of venture-backed and non-venture-backed firms using the records of the U.S. Census's Longitudinal Business Database, which tracks both public and private entities. After venture financing, they find very rapid growth in the employment of venture-financed firms relative to non-venture-financed firms. While the venture-backed firms (and by construction, the matching entities) have an average of about 20 employees at the time of the initial financing, five years later the venture-financed firms have on average about 80 employees, while non-venture-financed firms have grown to around 30 employees. Beyond the fifth anniversary of the financing, they continue to see greater employment growth by venture-financed firms relative to non-venture-financed firms.

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[6] Lerner, Josh, 2012, *The Architecture of Innovation*, Boston: Harvard Business School Press (*forthcoming*)

2.2. EU Privacy Policy

The EU has a stricter, more comprehensive privacy policy than the U.S.[7] The origins of these regulatory efforts lie in the 1995 Data Protection Directive (95/46/EC), which guaranteed rights to individuals pertaining to the processing of their personal data. While this directive covered information processed by "automated" as well as "non-automated" means, it was unclear how and to what extent these guidelines applied to internet and electronic communications.[8]

The EU e-Privacy Directive built on the 1995 EU Data Protection Directive by setting clear guidelines for the use of personal data of internet users. The e-Privacy Directive guarantees confidentiality of communications and regulates treatment of traffic and location data. It stipulates that web-tracking software ("cookies") are legitimate as long as users are provided with clear and precise information about their use, and given the ability to opt out at any time. Similarly, it restricts the use of spyware, web bugs, and hidden identifiers unless express consent is given by the user.

The restrictions in the e-Privacy Directive clearly limit the collection and use of personal information helpful to online advertisers in serving targeted ads. Prior research by Goldfarb and Tucker indicates a drop in the effectiveness of online advertising in the EU subsequent to passage of the e-Privacy

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[7] The following quotes are illustrative. "Whereas US policy makers have been reluctant to legislate privacy, European countries have done so more frequently and more broadly." [Strauss, Jared & Rogerson, Kenneth, "Policies for online privacy in the United States and the European Union," *Telematics and Informatics* 19 (2002): 173-192, p. 176.] "…the EU has a significantly more robust regulatory foundation for consumer privacy and data protection than the U.S." [King, Nancy J. & Jessen, Pernille Wegner, "Profiling the Mobile Customer – Privacy Concerns when Behavioral Advertisers Target Mobile Phones – Part I," *Computer Law and Security Review* (Sept. 2010), p. 11.]

[8] See for example: Strauss, Jared & Rogerson, Kenneth, "Policies for online privacy in the United States and the European Union," *Telematics and Informatics* 19 (2002): 173-192; Debussere, Frederic, "The EU E-Privacy directive: A Monstrous Attempt to Starve the Cookie Monster?" *International Journal of Law and Information Technology* Vol. 13 No. 1 (2005): 70-97.

Directive would lead to a decrease in VC investment in online advertising companies in the EU relative to in other countries with no such restrictions.[9]

Complicating the empirical assessment of the e-Privacy Directive is that its implementation has been fairly protracted. The deliberative process began in July 2000, and the e-Privacy Directive was signed in July 2002. Though the transposition deadline for Member States was October 2003, the e-Privacy Directive was implemented at various dates between 2003 and 2006. The four largest European economies—France, Italy, Germany, and the United Kingdom—implemented the act between December 2003 and June 2004. As Goldfarb and Tucker point out, implementation of the e-Privacy Directive was far from a single event—a number of nations passed subsequent amendments or clarifications—but we will follow them by focusing on the initial adoption and implementation of the legislation.

A further complication is introduced by the fact that the volume of venture capital activity varies considerably over time due to factors that are largely exogenous to the issues being studied here. To cite one notable example, the volume of venture investment fell by almost 90 percent between 2000 and 2002; this decline was driven primarily by the collapse in the public valuations for Internet and telecommunications stocks in 2000, and the subsequent inability of venture funds to exit many of their investments at attractive prices. In other cases, funds have flowed to particular sectors, such as cleantech, potentially crowding out investment elsewhere. As a result, the bulk of our analyses examine VC investments in the key sectors as a share of all VC investments, though we also analyze the levels of venture investment in a robustness check.

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[9] To the extent that EU-based firms also do business in the rest of the world, or non-EU-based firms do business in the EU, such international activity will dampen the hypothesized effect. In the presence of such dampening influences, any estimates of the hypothesized effect, should one be found, are likely to be conservative.

3. Data

3.1. Venture Capital Funding Data

Our analysis focuses on how VC investment in online advertising companies varies between the U.S. and EU, and over time. In order to examine these differences, we construct a data set that draws on historical investment figures captured by VentureXpert.[10] VentureXpert is one of the two most widely-used databases of venture capital investments in the U.S.[11] It contains data on approximately 1.2 million global private companies and over 25,000 venture, buyout, and mezzanine funds.[12]

The dataset is seeded with all private equity investments in the Thomson database from the beginning of 1995 through the end of 2010 classified as "Venture Capital Deals"[13] involving a portfolio company with a business description including the terms "online" and any permutation of the term "advertise."[14] These criteria yielded data on investments in 349 companies.

107 companies were removed from the dataset based on manual review of the 349 companies' business descriptions in VentureXpert, Bloomberg, and in some cases company websites and additional research. This manual screening was performed to remove companies whose primary business did not appear to be online advertising that may involve the use of personal data.

35 companies were added to the list based on manual review of information on an additional 1,072 companies identified by searching the business descriptions of portfolio

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[10] More specifically, the Thomson ONE's Private Equity module powered by VentureXpert was used.

[11] Maats, Frederike, Metrick, Andrew, Hinkes, Brian, Yasuda, Ayako & Vershovski, Sofia, "On the Consistency and Reliability of Venture Capital Databases," (2009).

[12] "Private Equity Module: ThomsonONE.com Investment Banking," Thomson Reuters factsheet, 2011.

[13] Includes start-up, seed, and early, expansion, and later stage deals; excludes buyout and "MoneyTree" deals.

[14] More specifically, the following Boolean logic search string was used: "online AND advertis*", where "advertis*" picks up the term "advertis" with any suffix, e.g., "advertising" or "advertiser".

companies in VentureXpert using other search strings designed to capture other e-privacy related businesses. Our final dataset thus consists of 277 online advertising companies.[15]

Given the judgment involved in the manual review process described above, we tested the sensitivity of our results reported below to the list of companies included in the dataset. Results reported below based on our final dataset of 277 companies are similar to those obtained using a dataset consisting of our original 349 companies identified from the first string search before the subtractions or additions.[16]

The unit of observation in the data extracted from VentureXpert is an investment by a particular venture capital fund into a particular portfolio company on a particular date. Our investment data on online advertising companies contains 1,824 observations on investments by 702 distinct funds into the 277 companies on 602 different dates, totaling approximately $5 billion.

Appendix A summarizes the investment data discussed above, by quarter, for both the U.S. and EU. As Appendix A shows, total VC investment in the identified EU online advertising companies from the beginning of 1995 to the end of 2010 amounted to $235.8 million. This reflects average quarterly investment of $3.7 million in the EU over that time period. In the period immediately preceding the e-Privacy Directive (Q1 2000 through Q2 2002), average quarterly VC investment in EU-based online advertising companies was approximately $4.2 million. In the period of, and immediately following, the e-Privacy Directive (Q3 2002 through Q4 2006) ruling, average quarterly VC investment in EU-based online advertising companies was approximately $1.1 million. Thus, average quarterly investment in EU online advertising

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[15] 349 - 107 + 35 = 277

[16] Business descriptions in VentureXpert, Bloomberg, and company websites change over time as companies' business models and focus change. Our analysis is based on the business description s available from these sources at the time of our research.

decreased by approximately 73 percent after the e-Privacy Directive. Appendix A further depicts that VC investment in the identified U.S. online advertising companies from the beginning of 1995 through the end of 2010 amounted to approximately $4.8 billion. This reflects average quarterly investment of $74.9 million over that time period. In the period immediately preceding the e-Privacy Directive ruling (Q1 2000 through Q2 2002), the average quarterly VC investment in U.S.-based online advertising companies was $77.9 million, and subsequent to the ruling, that figure amounted to approximately $58.9 million. Thus, average quarterly VC investment in U.S. online advertising companies decreased by approximately 24 percent, as compared with 73 percent in the EU, after passage of the e-Privacy Directive.

3.2. Supplemental Data

We augment the VC funding data with data on other factors that could influence investors' decisions to invest in online advertising businesses specifically, and in other electronic personal data usage intensive sectors more generally. Such factors include macroeconomic conditions reflected in gross domestic product (GDP) measures and the feasibility of intensive electronic personal data collection and use as enabled by internet usage.

Our GDP data are quarterly growth rates of real, seasonally adjusted GDP as a percent change over the previous quarter from the OECD.[17] These data are available for the U.S. from Q1 1995 through Q2 2011, and for the EU (27 countries) from Q2 1995 through Q2 2011.

The GDP data are summarized in Appendix A. As the summary statistics show, quarterly GDP growth in the EU over the period 1995 through 2010 was lower on average than in the U.S (means of 0.5 and 0.6 percent, respectively) and less volatile than in the U.S. (standard deviations of 0.6 and 0.7 percent, respectively). In the period immediately preceding the EU e-

[17] Data accessed through http://stats.oecd.org.

Privacy Directive ruling (Q1 2000 through Q2 2002), quarterly GDP growth in the EU was approximately the same on average but less volatile than in the U.S. (means of 0.5 and 0.5 percent, respectively; standard deviations of 0.3 and 0.6 percent, respectively). In the period including and immediately following the Directive (Q3 2002 through Q4 2006), quarterly GDP growth in the EU was lower on average than in the U.S. and less volatile (means of 0.6 and 0.7 percent, respectively; standard deviations of 0.3 and 0.4 percent, respectively).

Our internet usage data are the total number of internet users per 100 individuals, available on an annual basis for the U.S. and the EU (27 countries) from 1995 through 2009.[18] Since these data were only provided annually, we interpolated the data using a cubic spline technique to obtain quarterly data.

The internet usage data are also summarized in Appendix A. As the summary statistics show, there were a higher percentage of internet users in the U.S. as compared to the EU over the period 1995 through 2010 (a mean of 51.5 percent in the U.S. and 32.9 percent in the EU). In the period immediately preceding the EU e-Privacy Directive ruling (Q1 2000 through Q2 2002), 27.6 percent of EU residents used the internet while 51.1 percent of U.S. residents used the internet. In the period including and immediately following the Directive (Q3 2002 through Q4 2006), 48.1 percent of EU residents used the internet while 67.7 percent of U.S. residents used the internet. Thus, while a higher percentage of U.S. residents used the internet both before and after the Directive, the difference between the EU and U.S. diminished somewhat, from 24.5 percent in the pre-Directive period to 19.6 percent in the post-Directive period.

[18] Data accessed through http://data.worldbank.org.

4. Estimation and Results

We have conducted multiple statistical analyses in order to determine whether VC investment in EU-based online advertising companies fell subsequent to the Q3 EU e-Privacy Directive. Each of these analyses are variants of difference-in-difference regression frameworks that rely on historical VC investment levels in both the EU and U.S. as controls in order to identify any statistically significant decrease in VC investment in online advertising companies in the EU subsequent to the issuance of the EU e-Privacy Directive.

Our initial set of regression analyses are variants of the following regression model that accounts for the impact of a variety of factors on quarterly venture-backed investment in online advertising companies:

$$VC\ Ratio_{r,t} = \beta_0 + \beta_1(EU\ Indicator)_r + \beta_2(Q3\ 2002\ or\ After\ Dummy)_t + \beta_3(Effect\ of\ the\ EU\ e\text{-}Privacy\ Directive\ on\ EU\ VC\ Investment)_{r,t} + \theta X_{r,t} + \varepsilon_{r,t}. \quad (1)$$

Specifically, the dependent variable, VC $Ratio_{r,t}$, is venture capital (VC) dollars invested in online advertising companies with headquarters in region *r* at quarter *t* divided by venture capital dollars invested in information technology (IT) companies in region *r* at quarter *t*. We normalized our dependent variable this way to control for secular trends in the venture capital market, as discussed in Section 2.2 above.

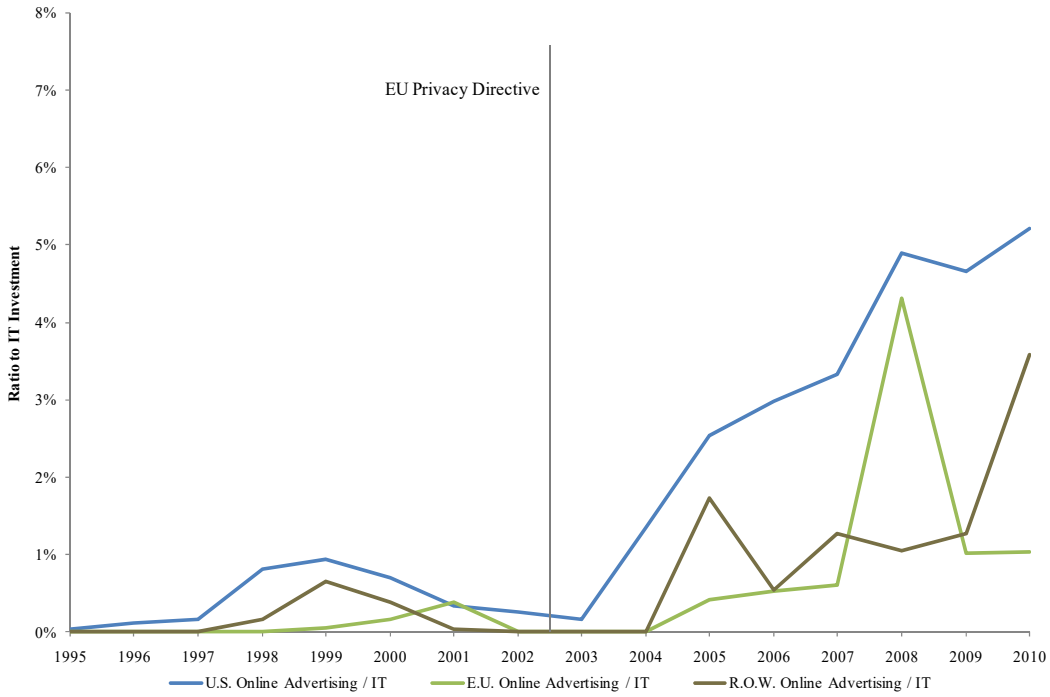
The explanatory variable *EU Indicator* equals one for investment in EU companies and zero for investment in U.S. companies. The explanatory variable *Q3 2002 or After Dummy* equals zero for all quarters before the EU e-Privacy Directive issued in July 2002 and one in Q3 2002 and all quarters thereafter. The explanatory variable, *Effect of the EU e-Privacy Directive on EU VC Investment*, a dummy variable capturing the interaction between the *EU Indicator* and the *Q3 2002 Dummy*, equals one for investment in EU companies in Q3 2002 and thereafter, and

zero otherwise. $X_{r,t}$ is a vector of other explanatory variables including gross domestic product (GDP) and internet usage.

Figure 1 depicts the *VC Ratio* for the U.S. and EU annually from 1995 through 2010 for the online advertising sector.

Figure 1

Ratio of Investment in Online Advertising Companies to Investment in all IT Companies



Source: Private Equity Investment data Jan 1995 - Dec 2010 from Thomson ONE.

This difference-in-difference model is designed to estimate parameter β_3, the effect of the EU e-Privacy Directive on VC investment in the online advertising sector in the EU, controlling for trends in the EU relative to U.S (captured by *EU Indicator*), and trends absent the policy (captured by *Q3 2002 Dummy*).

Our first set of regression results are presented below in Table 1 and show that VC investment in online advertising companies is significantly lower in the EU than in the US after passage of the e-Privacy Directive. The difference-in-difference framework shows that this result

holds after controlling for both differences in levels of investment in EU- vs. U.S.-based online advertising companies and differences in VC investment in online advertising companies before vs. during and after Q3 2002, the quarter in which the EU e-Privacy Directive was passed.

Table 1:
Online Advertising OLS Regression Results: EU vs. U.S.[1]
Dependent Variable: Ratio of Online Advertising VC Dollars to Total IT VC Dollars
Time Period and Data Frequency: 2000 - 2006, Quarterly

	Model	
Independent Variables	(1)	(2)
EU Indicator	-0.0025*	0.0104*
	(0.0014)	*(0.0055)*
2002 Dummy[2]	0.0118***	0.0037
	(0.0035)	*(0.0042)*
Effect of Policy on EU VC Investment	-0.0116***	-0.0142***
	(0.0038)	*(0.0043)*
Percent Change in GDP		-0.0001
		(0.0027)
Number of Internet Users per 100 People		0.0005***
		(0.0002)
Constant	0.0044***	-0.0229**
	(0.0010)	*(0.0100)*
Observations	56	56
Adjusted R-squared	0.328	0.378
Implied Decrease/Increase in EU VC Investment ($ Millions)	**-$203**	**-$249**

Notes:
[1] *** p<0.01, ** p<0.05, * p<0.1.
[2] The EU e-Privacy Directive was signed on July 2002.

More specifically, results for online advertising presented in column 1 of Table 1 can be interpreted as follows.

- The constant term, $\beta_0 = 0.0044$, is an estimate that VC investment in online advertising in the U.S. as a percentage of VC investment in IT in the U.S averaged

approximately 0.44 percent prior to Q3 2002. The standard error of this estimate indicates that it is statistically significant at the 99 percent confidence level.[19]

- The coefficient on the *EU Indicator* variable, β_1 = -0.0025, is an estimate that VC investment in online advertising in the EU as a percentage of VC investment in IT in the EU averaged approximately 0.25 percent lower than the corresponding share in the U.S., or 0.19 percent of VC investment in IT in the EU prior to Q3 2002.[20] The standard error of the β_1 estimate indicates that it is statistically significant at the 90 percent confidence level.
- The coefficient on the *Q3 2002 Dummy*, β_2 = 0.0118, is an estimate that VC investment in online advertising in the U.S. as a percentage VC investment in IT in the U.S. averaged approximately 1.18 percent higher beginning in Q3 2002 than it did prior to Q3 2002, or 1.62 percent of VC investment in IT in the U.S. in that latter time period.[21] The standard error of the β_2 estimate indicates that it is statistically significant at the 99 percent confidence level.
- The coefficient on the *Effect of the EU e-Privacy Directive on EU VC Investment* interaction dummy, β_3 = -0.0116, is an estimate that the fall in average VC investment in online advertising in the EU as a percentage of VC investment in IT in the EU from the period Q1 2000 through Q2 2002 to the period Q3 2002 through Q4 2006 was approximately 1.16 percent less than the corresponding rise in online advertising investment in the U.S., or approximately 0.2 percent overall.[22] This estimate of β_3, statistically significant at the 99 percent confidence level, implies an approximately $203 million decrease in VC investment in EU online advertising companies after passage of the e-Privacy Directive.

Model 2 is similar to Model 1, except that it incorporates variables that control for GDP growth and internet usage. As shown in column 2 of Table 1, the coefficient on internet usage has the expected positive sign and is statistically significant at the 99 percent confidence level,

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[19] Robust standard errors are used throughout.
[20] $\beta_0 + \beta_1 = 0.0044 - 0.0025 = 0.0019$.
[21] $\beta_0 + \beta_2 = 0.0044 + 0.0118 = 0.0162$.
[22] $\beta_2 + \beta_3 = 0.0118 - 0.0116 = 0.002$.

while the coefficient on GDP growth is unexpectedly negative, but statistically insignificant. Interpretation of the other variables remains the same. As shown in the table, the *Effect of the EU e-Privacy Directive on EU VC Investment* remains negative and statistically significant at the 99 percent confidence level, and is roughly 22 percent larger in absolute value, implying a decrease in VC investment in EU online advertising companies of approximately $249 million after passage of the e-Privacy Directive.

To investigate the potential impact of outliers on our analysis, we ran a difference-in-difference quantile regression analysis. Quantile regression analysis allows one to estimate the relationship between a set of independent variables and a specific quantile, or percentile, of the response variable. One advantage of such an analysis is that the influence of large outliers is mitigated. Thus, for our context, it allows us to determine the extent to which our results are sensitive to quarters with very large or very small values of the dependent variable, *VC Ratio*. Results for median (quantile) difference-in-difference regressions are presented in Table 2.

Table 2:
Online Advertising Quantile Regression Results: EU vs. U.S.[1]
Dependent Variable: Ratio of Online Advertising VC Dollars to Total IT VC Dollars
Time Period and Data Frequency: 2000 - 2006, Quarterly

	Model	
Independent Variables	(3)	(4)
EU Indicator	-0.0034**	-0.0033
	(0.0014)	*(0.0081)*
2002 Dummy[2]	0.0133**	0.0131**
	(0.0062)	*(0.0060)*
Effect of Policy on EU VC Investment	-0.0136**	-0.0134**
	(0.0062)	*(0.0054)*
Percent Change in GDP		-0.0001
		(0.0022)
Number of Internet Users per 100 People		0.0000
		(0.0002)
Constant	0.0037***	0.0031
	(0.0010)	*(0.0144)*
Observations	56	56
Implied Decrease/Increase in EU VC Investment ($ Millions)	**-$238**	**-$235**

Notes:
[1] *** p<0.01, ** p<0.05, * p<0.1.
[2] The EU e-Privacy Directive was signed on July 2002.

Column 1 of Table 2 presents the results of Model 3, the quantile regression version of Model 1. These results imply that the rise in median (as opposed to average) VC investment in EU-based online advertising companies, as a percentage of VC investment in EU-based IT companies from the period Q1 2000 through Q2 2002 to the period Q3 2002 through Q4 2006, was approximately 1.36 percent less than the corresponding 1.33 percent rise in VC investment in U.S.-based online advertising companies. This translates into an absolute decline of 0.03 percent in the EU concurrent with an absolute rise of 1.33 percent in the U.S. This estimate, statistically significant at the 95 percent confidence level, implies an approximately $238 million

decrease in VC investment in EU online advertising companies since passage of the e-Privacy Directive.

Results for Model 4, the quantile regression version of Model 2, are presented in column 2 of Table 2. The results for Model 4 are similar to those for Model 3 with an implied decrease in EU online advertising investment of approximately $235 million since passage of the e-Privacy Directive.

4.1. Additional Sensitivity Analyses and Robustness Checks

4.1.1. Alternative Control Group Specifications

We have also estimated a difference-in-difference model comparing investment in the EU to investment in the U.S. and rest of the world (ROW) in order to examine whether the results are sensitive to the use of only U.S. companies as a control group. These results are presented in Table 3.

Table 3:
Online Advertising OLS Regression Results: EU vs. U.S. and ROW[1]
Dependent Variable: Ratio of Online Advertising VC Dollars to Total IT VC Dollars
Time Period and Data Frequency: 2000 - 2006, Quarterly

	Model
Independent Variables	(5)
EU Indicator	-0.0010
	(0.0012)
2002 Dummy[2]	0.0073***
	(0.0024)
Effect of Policy on EU VC Investment	-0.0072**
	(0.0027)
Constant	0.0030***
	(0.0008)
Observations	84
Adjusted R-squared	0.128
Implied Decrease/Increase in EU VC Investment ($ Millions)	**-$126**

Notes:
[1] *** p<0.01, ** p<0.05, * p<0.1.
[2] The EU e-Privacy Directive was signed on July 2002.

As an alternative approach to examining the robustness of our findings, we have examined the extent to which investment levels increased subsequent to the EU e-Privacy Directive for a broad set of "internet-specific" companies,[23] (less the online advertising ones analyzed above) rather than just the electronic personal data intensive ones analyzed above. We anticipate that there will be no effects for this set of internet companies since the e-Privacy Directive should only affect online advertising companies. The results of this analysis are presented in Table 4.

[23] VentureXpert categorized 8,907 companies as being internet-specific. This list includes companies described as "internet communications," "e-commerce technology," "computer hardware," "internet software," "internet programming," "internet ecommerce," "internet content," and "internet services."

Table 4:
Online Advertising OLS Regression Results: EU vs. U.S.[1]
Dependent Variable: Ratio of Internet-Specific VC Dollars to Total IT VC Dollars
Time Period and Data Frequency: 2000 - 2006, Quarterly

	Model	
Independent Variables	(6)	(7)
EU Indicator	0.0421	-0.0832
	(0.0562)	*(0.0961)*
2002 Dummy[2]	-0.1273***	-0.0575
	(0.0354)	*(0.0460)*
Effect of Policy on EU VC Investment	-0.0805	-0.0494
	(0.0605)	*(0.0590)*
Percent Change in GDP		0.0344
		(0.0233)
Number of Internet Users per 100 People		-0.0050*
		(0.0027)
Constant	0.3557***	0.6006***
	(0.0340)	*(0.1490)*
Observations	56	56
Adjusted R-squared	0.432	0.475

Notes:
[1] *** p<0.01, ** p<0.05, * p<0.1.
[2] The EU e-Privacy Directive was signed on July 2002.

The results in Table 4 show VC investment levels in EU internet-specific companies are not statistically different in the time periods before and after the e-Privacy Directive. This suggests that the findings described above are specific to online advertising companies, in particular, and do not reflect general trends associated with venture-backed investment in internet-specific companies.

4.1.2. Stationarity[24]

One assumption made in our regression analyses is that the data are stationary; that is, that the data series do not depend on time and thus, that the mean, variance, and covariance of the data do not vary with time. To examine the extent to which a relative decline in EU investment subsequent to the 2002 e-Privacy Directive reflects an ongoing trend, perhaps attributable to factors not reflected in any of the data we collected, we have conducted a variety of tests. First, we ran a simple ordinary least squares regression on the difference between EU and U.S. investment levels against a time trend. This revealed that EU investment levels relative to U.S. investment levels during the Q1 2000 through Q2 2002 time exhibit no statistically significant time trend.

To more formally test for stationarity, we conducted three well-known tests on our data from Q1 1995 through Q4 2010: the Dickey-Fuller, Phillips-Perron, and Kwiatkowski–Phillips–Schmidt–Shin tests. Using each test, we found no evidence of non-stationarity. As such, our data appear to be stationary, and thus, it is not necessary to adjust our regression equations or data.

4.1.3. Autocorrelation

We also tested for the presence of autocorrelation in our regression analyses by conducting a test proposed by Jeffrey Wooldridge for panel data.[25] This test showed no evidence of autocorrelation.

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[24] A stationary time series is one whose statistical properties such as mean, variance, and autocorrelation, are all constant over time. Most statistical methods are based on this assumption, and violations of stationarity can lead to biased point estimates.

[25] Wooldridge, J.M, *Econometric Analysis of Cross Section and Panel Data*, Cambridge, MA: MIT Press (2002), pp. 282-283.

4.1.4. Investment Levels (vs. Ratios)

We ran additional sensitivities based on an alternate specification of the dependent variable. Specifically, we ran regressions where the dependent variable was total quarterly investment (in the U.S. or EU) measured in dollars, rather than measured in terms of a ratio relative to total IT spending. Total other IT venture capital investment and total other venture capital investment in a given region were controlled for by their inclusion as separate independent variables in the regression analysis. The regressions results are presented in Table 5.

Model 8 implies that EU investment has been, on average, $51.6 million lower each quarter since passage of the e-Privacy Directive (after controlling for U.S. differences), totaling a loss of approximately $929 million in investment in the online advertising sector through the end of 2010. The corresponding figures for Model 9, the Model 2 analog, which incorporates controls for GDP changes and broadband penetration, imply $66.9 million lower investment on a quarterly basis and approximately $1.2 billion in total lost investment in the sector through 2010.

Table 5:
Online Advertising OLS Regression Results: EU vs. U.S.[1]
Dependent Variable: Online Advertising VC Dollars
Time Period and Data Frequency: 2000 - 2006, Quarterly

	Model	
Independent Variables	(8)	(9)
IT U.S. Minus Sector-Specific VC Investment	0.0078*** *(0.0021)*	0.0090*** *(0.0024)*
Total VC Investment Minus IT Minus Sector-Specific VC Investment	0.0349*** *(0.0110)*	0.0294** *(0.0117)*
EU Indicator	60.5244*** *(18.1205)*	88.5649*** *(25.4176)*
2002 Dummy[2]	54.9122*** *(11.8982)*	55.3307*** *(15.1768)*
Effect of Policy on EU VC Investment	-51.6294*** *(12.3857)*	-66.9323*** *(14.6911)*
Percent Change in GDP		-9.9710 *(12.4383)*
Number of Internet Users per 100 People		0.8802 *(0.6218)*
Constant	-94.5658*** *(26.1949)*	-140.2705*** *(40.2624)*
Observations	56	56
Adjusted R-squared	0.683	0.677
Implied Decrease/Increase in EU VC Investment ($ Millions)	**-$929**	**-$1,205**

Notes:
[1] *** p<0.01, ** p<0.05, * p<0.1.
[2] The EU e-Privacy Directive was signed on July 2002.

5. Conclusions

In this paper, we set out to examine the effect of privacy policy changes on venture capital (VC) investment in online advertising companies by analyzing the effect of the EU e-Privacy Directive on VC investment in EU-based online advertising companies. To that end, we constructed a dataset on VC investment in online advertising companies and estimated multiple difference-in-difference regression models designed to test for a statistically significant decrease in VC investment EU online advertising companies after passage of that directive.

Our findings suggest that passage of the EU e-Privacy Decision has led to an incremental decrease in investment in EU-based online advertising companies ranging from approximately $249 million over the approximately eight-and-a-half years from passage through the end of 2010. When paired with the findings of the enhanced effects of VC investment relative to corporate investment, this may be the equivalent of approximately $750 million to $1 billion in traditional R&D investment.

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Appendix A

Summary Statistics for Investment Levels and Regression Variables: Online Advertising

	Q1 1995 - Q4 2010						Pre E.U. Privacy: Q1 2000 - Q2 2002						Post E.U. Privacy: Q3 2002 - Q4 2006					
	Mean	Std Dev	Min	Med	Max	Total	Mean	Std Dev	Min	Med	Max	Total	Mean	Std Dev	Min	Med	Max	Total
VC Investment in E.U. Online Advertising ($ Millions)[1]	$3.7	$12.3	$0.0	$0.0	$94.5	$235.8	$4.2	$7.4	$0.0	$0.2	$20.3	$41.7	$1.1	$2.4	$0.0	$0.0	$7.9	$20.0
VC Investment in E.U. Online Advertising as % of VC Investment in E.U. IT[1]	0.6%	2.1%	0.0%	0.0%	16.7%		0.2%	0.3%	0.0%	0.0%	0.9%		0.2%	0.4%	0.0%	0.0%	1.4%	
VC Investment in U.S. Online Advertising ($ Millions)[1]	$74.9	$74.2	$0.0	$64.3	$292.5	$4,796.1	$77.9	$93.4	$6.7	$47.7	$292.5	$778.6	$58.9	$52.0	$0.1	$53.6	$179.8	$1,060.6
VC Investment in U.S. Online Advertising as % of VC Investment in U.S. IT[1]	1.8%	1.9%	0.0%	0.8%	6.8%		0.4%	0.3%	0.1%	0.3%	1.2%		1.6%	1.4%	0.0%	1.5%	4.8%	
Real E.U. GDP Growth Rate Prior Quarter[2]	0.5%	0.6%	-2.6%	0.5%	1.2%		0.5%	0.3%	0.1%	0.5%	1.1%		0.6%	0.3%	0.2%	0.6%	1.0%	
Real U.S. GDP Growth Rate Prior Quarter[2]	0.6%	0.7%	-2.3%	0.7%	2.0%		0.5%	0.6%	-0.3%	0.4%	2.0%		0.7%	0.4%	0.0%	0.7%	1.6%	
E.U. Percent of Internet Users[3]	32.9%	22.1%	1.6%	35.2%	67.1%		27.6%	5.9%	20.6%	26.4%	36.9%		48.1%	6.6%	38.3%	48.4%	58.7%	
U.S. Percent of Internet Users[3]	51.5%	21.5%	9.4%	60.1%	78.1%		52.1%	6.3%	43.9%	51.3%	61.4%		67.7%	3.4%	62.2%	68.6%	72.7%	

Notes and Sources:

[1] Thomson ONE Private Equity data, Jan 1995 to Dec 2010.

[2] OECD real GDP growth from the previous quarter.

[3] Internet users per 100 people obtained from the World Bank's DataBank.