Venture Capital: A Catalyst for Innovation and Growth

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This article studies the development of the venture capital (VC) industry in the United States and assesses how VC financing affects firm innovation and growth. The results highlight the essential role of VC financing for U.S. innovation and growth and suggest that VC development in other countries could promote their economic growth. (JEL E13, E22, G24, L26, O16, O31, O40)

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1 INTRODUCTION

Venture capital (VC) is a particular type of private equity that focuses on investing in young companies with high-growth potential. The companies and products and services VC helped develop are ubiquitous in our daily lives: the Apple iPhone, Google Search, Amazon, Facebook and Twitter, Starbucks, Uber, Tesla electric vehicles, Airbnb, Instacart, and the Moderna COVID-19 vaccine. Although these companies operate in drastically different industries and with dramatically different business models, they share one common and crucial footprint in their corporate histories: All of them received major financing and mentorship support from VC investors in the early stages of their development.

This article outlines the history of VC and characterizes some stylized facts about VC's impact on innovation and growth. In particular, this article empirically evaluates the relationship between VC, firm growth, and innovation.

2 THE VC INDUSTRY IN THE UNITED STATES

This section outlines the historical background on the rise of VC firms as limited partnerships and characterizes some stylized facts about the VC industry in the United States.

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2.1 Historical Background: VC Firms as Limited Partnerships

Financing cutting-edge technologies has always been challenging.[1] It is difficult to know whether new ideas are viable, if they will be salable, and how best to bring them to market. Also, it is important to ensure that entrepreneurs' and investors' incentives are aligned. Traditional financial institutions, such as banks and equity/securities markets, are not well suited to engage in this sort of underwriting. Historically, the introduction of new technologies was privately financed by wealthy individuals. Investors were plugged into networks of inventive activity in which they learned about new ideas, vetted them, and drew on the expertise needed to operationalize them. These financiers are similar to today's "angel investors."

The Brush Electric Company provided such a network for inventors and investors in Cleveland around the turn of the twentieth century. The use of electricity rapidly expanded during the Second Industrial Revolution. Individuals linked with the Brush Electric Company network spawned ideas for arc lighting, liquefying air, smelting ores electrically, and electric cars and trolleys, among other things. The shops at Brush were a meeting place for inventors; they could develop and debug new ideas with help from others. Investors connected with the Brush network learned about promising new ideas from the scuttlebutt at the shops. They became partners/owners in the firms that they financed. Interestingly, in the Midwest at the time, prolific inventors (those with more than 15 patents) who were principals in companies were much more likely than other investors to keep their patents or assign them to the companies where they were principals; other investors typically sold their patents to businesses where they had no concern. These practices aligned the incentives of innovators and investors.

World War II and the start of the Cold War ushered in new technologies, such as jets, nuclear weapons, radars, and rockets, along with a splurge of spending by the U.S. Department of Defense. A handful of VC firms were formed to leverage the commercialization of scientific advances. American Research and Development (ARD), founded by General Georges Doriot and others, was one of these. ARD pulled in money from mutual funds, insurance companies, and an initial public stock offering. The founders knew that it was important for venture capitalists to provide advice to the fledging enterprises in which they were investing. In 1956, ARD invested $70,000 in Digital Equipment Corporation (DEC) in exchange for a 70 percent equity stake. ARD's share was worth $38.5 million when DEC went public in 1966, which represented an annual return of 100 percent. While this investment was incredibly successful, the organizational form of ARD did not come to dominate the industry. The compensation structure of ARD made it difficult for the company to retain the VC professionals needed to evaluate startups and provide the guidance necessary for success.

An alternative organizational form came to emblematize the industry: the limited partnership. This form is exemplified by the formation of Davis and Rock in 1961. These partnerships allowed VC professionals to share in the gains from startups along with the entrepreneurs and investors. Limited partnerships served to align venture capitalists' interests with those of entrepreneurs, investors, and key employees. Money was put in only at the beginning of the partnership. The general partners received management fees as a salary plus a share of the capital gains from the investments, say 40 percent, with the limited partners earning 60 percent. The limited partners had no say in the decisions of the general partners. The partnerships were structured for a limited length of time, say seven to ten years. The returns from the partnership were paid out to the investors only when the partnership was dissolved—there were no dividends, interest payments, etc. Therefore, the returns upon dissolution were subject only to capital gains taxation at the investor level. The VC industry also used stock options to reward founders, CEOs, and key employees. Thus, these recipients too were subject to capital gains taxation rather than taxation on labor income. The short time horizon created pressure to ensure a venture's rapid success.

Banks and other financial institutions are not well suited to invest in cutting-edge new ventures. While banks are good at evaluating systematic lending risk, they have limited ability to judge the skill of entrepreneurs or the worth of new technologies and limited expertise to help commercialize them. Additionally, financial institutions have faced roadblocks to investing in ventures. The Glass-Steagall Banking Act of 1993, which was later repealed in 1999, prohibited banks from taking equity positions in industrial firms. The Allstate Insurance Company created a private placements program in the 1960s to undertake VC-type investments; however, it abandoned the program because it could not compensate the VC professionals enough to retain them. The Employee Retirement Income Security Act of 1974 prevented pension funds (and dissuaded other traditional fiduciaries) from investing in high-risk ventures. The act has been reinterpreted since 1979 to allow pension funds to invest in VC-operating companies, which provided a fillip for the VC industry.

2.2 Stylized Facts About the VC Industry

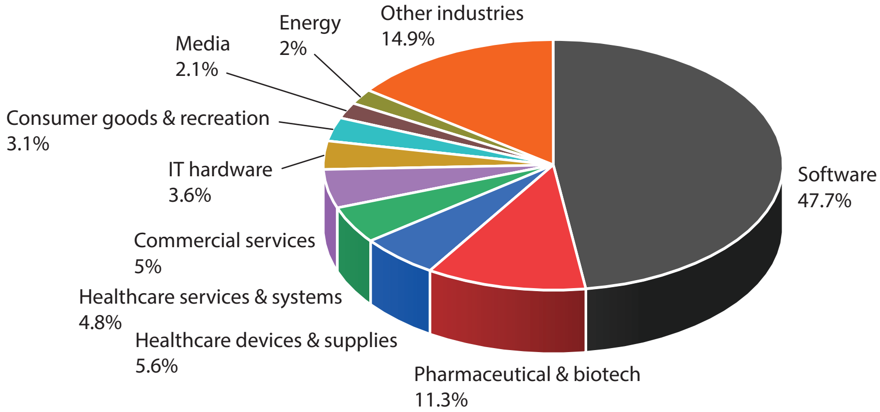
Venture capitalists provide funding to startup companies in exchange for a share of company equity. Apart from money, venture capitalists also provide mentorship services to foster the growth of startups. Since the life span of a VC fund is typically 10 years, venture capitalists are incentivized to target deals where a small amount of investment can generate a large financial return within a short period. Hence, VC investment tends to focus on high-growth companies in the high-tech sector. To illustrate, Figure 1 shows the share of VC investment received by each industry in 2016.[2] Attracting almost one-half of total VC investment, software companies are the top choice of VC investors. Pharmaceutical and biotech companies rank second, accounting for about one-eighth of total VC investment. Together, these two top industries comprise 60 percent of total VC investment. Other major industries receiving VC investment include healthcare devices and supplies (6 percent), healthcare services and systems (5 percent), commercial services (5 percent), IT hardware (4 percent), consumer goods and recreation (3 percent), energy (2 percent), and media (2 percent).[3] As the figure shows, venture capitalists are active investors in virtually all cutting-edge technologies.

There are 898 VC firms in existence in the United States as of 2016.[4] These VC firms are managing 1,562 venture funds with a total amount of assets under management (AUM) of $333 billion. The distribution of VC firms by AUM is shown in Figure 2. Many VC firms are rather small in terms of AUM. One-sixth of VC firms have an AUM of less than $10 million, and the majority of them (92 percent) have an AUM below $1 billion. In fact, only 68 VC firms (8 percent) have an AUM above $1 billion. As revealed by Figure 2, VC is a fairly competitive industry populated with many small players and only a few large ones.

To track the evolution of the VC industry in the United States, Figure 3 plots the time series of VC investment. Numerous prominent VC firms were created in the 1970s, including the renowned industry leader Sequoia Capital, and Kleiner Perkins Caufield & Byers. In the 1980s, VC firms financed a series of successful companies, including Apple, Microsoft, and Cisco in the IT industry; Genentech in the biotech industry; and FedEx in the courier industry. Thanks to the "gold rush" in

Figure 1

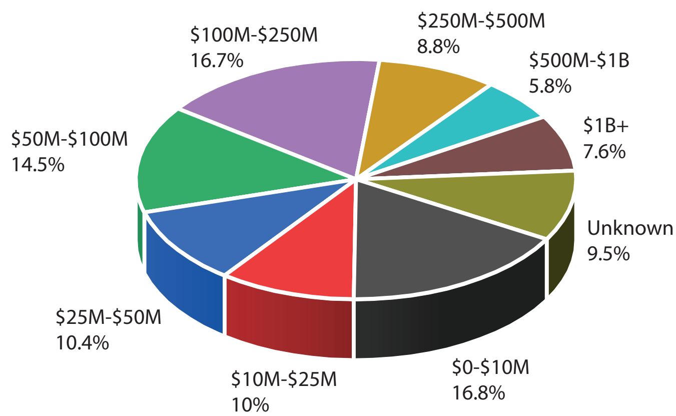
Share of VC Investment Received By Each Industry



SOURCE: NVCA (2016).

Figure 2

Distribution of VC Firms by Assets Under Management

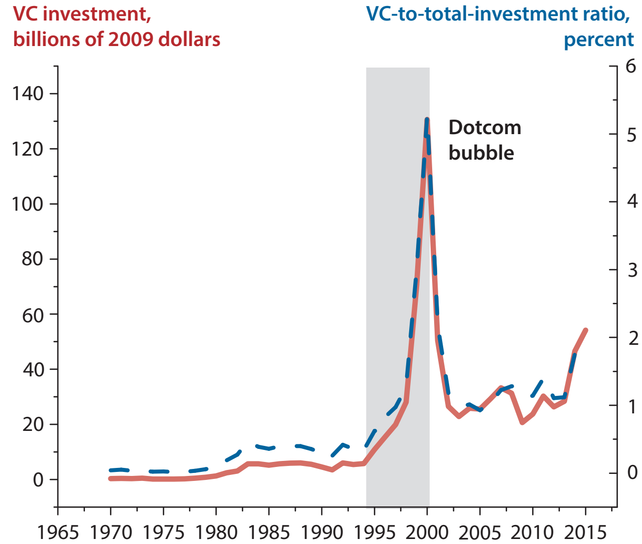


NOTE: M, million; B, billion.

SOURCE: NVCA (2016).

Figure 3

Investment by VC



NOTE: The gray shaded area indicates recession as determined by the National Bureau of Economic Research.

SOURCE: Greenwood, Han, and Sánchez (forthcoming).

the internet sector during the dot.com bubble, the amount of VC investment soared during the 1990s. Many internet-related companies received VC financing during this era, including Amazon, eBay, Netscape, Sun Microsystems, and Yahoo!. The bursting of the dot.com bubble in 2000, however, triggered an unprecedented collapse of VC investment in the early 2000s. Nevertheless, the amount of VC investment in the post-bubble era was still well above its pre-bubble level and has returned to its long-run trend. Despite suffering from a decline during the Great Recession, the VC industry quickly recovered and continued to grow over time.

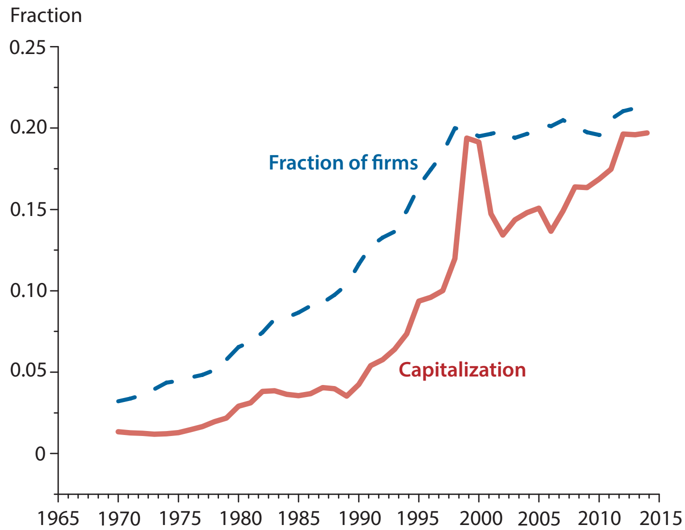
Though the amount of VC investment only accounts for a small share of aggregate U.S. investment, VC-backed companies (i.e., the ones financed by VC before going public) are playing an increasingly critical role in the aggregate economy, as demonstrated in Figures 4, 5, and 6. The fraction of VC-backed companies in all publicly traded firms is shown in Figure 4. The fraction of VC-backed companies in terms of market capitalization surged from 4 percent in 1970 to 20 percent by 2015.

Figure 5 reports the employment and R&D shares of VC-backed companies in all publicly traded firms. As indicated by the booming share of VC-backed companies, such companies are increasingly important for job creation and technological innovation. Analogously, Figure 6 displays the shares of patents and patents adjusted by the quality (proxied by citations) of VC-backed companies. It confirms the increasing importance of VC-backed companies for innovation.

The VC industry has exhibited remarkable resiliency despite the COVID-19 pandemic. The race for a COVID-19 vaccine has been a boon for startups in the pharmaceutical and biotech sector. Social distancing requirements have spurred VC investment in e-commerce, delivery, and work-

Figure 4

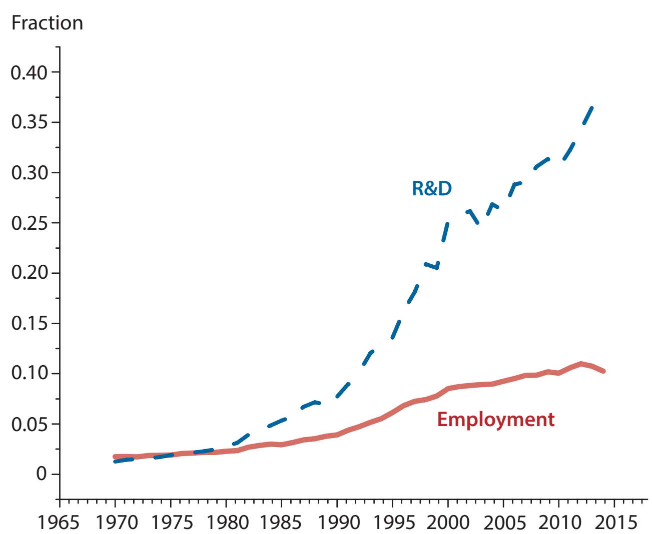
Share of VC-Backed Companies Among Publicly Traded Firms



SOURCE: Greenwood, Han, and Sánchez (forthcoming).

Figure 5

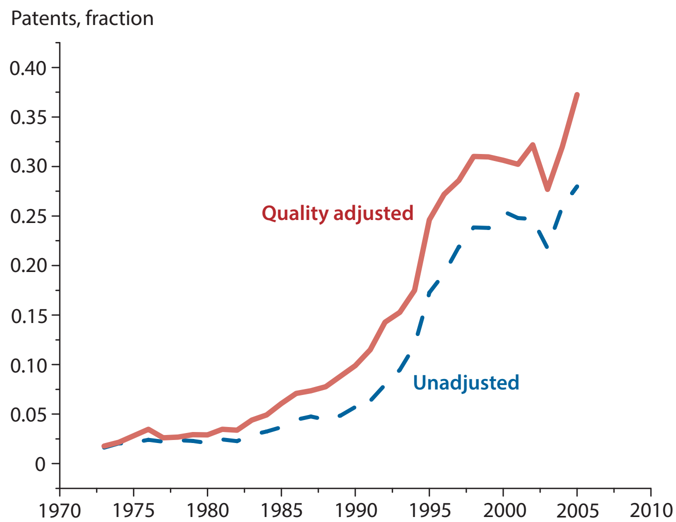
Shares of VC-Backed Public Companies in Employment and R&D Spending Among All Publicly Traded Firms



SOURCE: Greenwood, Han, and Sánchez (forthcoming).

Figure 6

Shares of VC-Backed Public Companies in Innovation Among All Publicly Traded Firms



SOURCE: Greenwood, Han, and Sánchez (forthcoming).

from-home technologies. For instance, DoorDash (a VC-backed online food ordering and delivery company) succeeded in going public in December 2020, raising $3.37 billion from the capital market.

3 THE IMPACT OF VC ON FIRM INNOVATION AND FIRM GROWTH

Building on the descriptive statistics in the last section, some regression evidence is presented in this section to disentangle the relationship between VC, firm growth, and innovation.

3.1 VC and Firm Growth

Regression analysis is now conducted to evaluate the performance of VC-backed and non-VC-backed firms along four dimensions for the years following an initial public offering (IPO) of stock: the R&D-to-sales ratio, growth rate of employment, growth rate of sales, and firm market value (in natural logarithm). The results are presented in Table 1. The regressions are based on U.S. public companies between 1970 and 2014. To compare VC-backed companies with their non-VC-backed counterparts, a VC dummy is entered as an independent variable that takes the value of 1 if the company is funded by VC before its IPO. In all regressions, industry dummies, year dummies, and a year dummy for the IPO are included. In addition, a cross term is added between the VC dummy and the number of years since the firm's IPO.

As shown in the first row of Table 1, VC-backed companies are more R&D intensive and grow faster than their non-VC-backed counterparts. On average the R&D-to-sales ratio of a public VC-backed company is higher than its non-VC-backed counterpart by 5.2 percentage points, and it grows faster—by 4.9 percentage points in terms of employment and 7.0 percentage points in terms of sales. These superior performances translate into higher market values: VC-backed companies

Table 1

VC-Backed vs. Non-VC-Backed Public Companies

	R&D/Sales	Employment growth	Sales growth	ln(Firm value)
VC-backed	0.0521*** (0.0017)	0.0490*** (0.0021)	0.0696*** (0.0027)	0.373*** (0.0141)
VC-backed × years since IPO	–0.000780*** (0.0001)	–0.00304*** (0.0002)	–0.00406*** (0.0002)	–0.0110*** (0.0011)
ln(employment)	–0.0133*** (0.0002)	–0.00567*** (0.0002)	–0.00641*** (0.0003)	0.851*** (0.0017)
Observations	84,116	148,834	149,672	168,549
R^2	0.383	0.084	0.108	0.737

NOTE: All specifications include year dummies, industry dummies (4-digit SIC codes), and a year dummy for the IPO. Standard errors are in parentheses. *** denotes significance at the 1 percent level.

are valued 37.3 percent higher than their non-VC-backed counterparts. The difference in performance, however, gradually dwindles over time, as shown by the negative estimates of the regression coefficients in the second row. As a consequence, the performances of VC- and non-VC-backed public companies tend to converge in the long run, though the speed of convergence is fairly low, as revealed by the magnitudes of the estimates in the second row.

3.2 VC and Innovation

The role of VC in encouraging technological innovation is now gauged at an annual periodicity; specifically, the impact of VC funding on patenting performance is evaluated at the firm level, and the impact of VC on employment and sales growth is assessed at the industry level. The data contains all companies funded by venture capitalists between 1970 and 2015. These VC-funded patentees are identified by matching firm names in VentureXpert and PatentsView.

3.2.1 Firm-Level Regressions. In the firm-level regressions, the primary independent variable is (the natural logarithm of) annual VC funding, while the dependent variable is a measure of patenting performance three years after the firm receives the funding. The primary independent variable may suffer from both measurement error and selection issues.[5] So, an instrumental variable (IV) is used in some of the regressions. The IV is based on the deregulation of pension funds since 1979, as highlighted in Section 2.1. The deregulation of pension funds reduced the fundraising costs of VC and led to increasing VC investment in all industries. In addition, industries that relied more on external finance enjoyed a stronger boost of VC funding.[6] Hence, a cross term between a "deregulation dummy" and a variable reflecting the industry's (i.e., the industry in which the firm operates) dependence on external finance is introduced as an IV. The deregulation dummy takes the value of 1 after 1979. The dependence on external finance is a Rajan-Zingales-type measure (Rajan and Zingales, 1998) that reflects the extent to which outside funds are used in the industry for expendi-

Table 2

VC Funding and Patenting

Panel A: Firm-level regressions, extensive margin analysis

	1{Patent > 0}		1{"Breakthrough patent" > 0}	
	Probit (1)	IV (2)	Probit (3)	IV (4)
ln(firm VC funding)	0.126*** (0.0123)	0.610*** (0.0932)	0.125*** (0.0118)	0.525*** (0.123)
Observations	7,589	7,589	7,589	7,589

Panel B: Firm-level regressions, intensive margin analysis

	ln(Patent)		ln(Patent, quality adjusted)	
	OLS (5)	IV (6)	OLS (7)	IV (8)
ln(firm VC funding)	0.137*** (0.0107)	0.792*** (0.233)	0.182*** (0.0173)	0.748** (0.369)
Observations	5,538	5,538	4,958	4,958
R^2	0.244		0.135	

NOTE: See the main text for a description of the dependent and independent variables. The control variables are the number of patents held by the firm at the beginning of the year, the age of the firm, the total amount of privately and federally funded R&D of the industry in which the firm operates, and a cluster dummy for a firm headquartered in California or Massachusetts. All regressions include year fixed effects and industry fixed effects. Standard errors are in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level.

tures on property, plant and equipment, R&D, advertising, and employee training. In all of the regressions, controls are added for the number of patents held by the firm at the beginning of the year, the age of the firm, and the total amount of privately and federally funded R&D of the industry in which the firm operates. Additionally, both a year dummy and an industry dummy (a 2-digit Standard Industrial Classification [SIC] code) are entered. Last, since both innovation and VC activities are remarkably clustered in California and Massachusetts, a "cluster dummy" for a firm headquartered in California or Massachusetts is included.

The results of the regression analysis are reported in Table 2. Panel A of Table 2 conducts the analysis along the extensive margin, that is, based on whether the firm obtains any patents three years after receiving VC funding. In regressions (1) and (2), the dependent variable is a dummy that takes the value of 1 if the firm files any successful patent applications at the U.S. Patents and Trademark Office within three years following funding. Regressions (3) and (4) focus on "breakthrough" patents, a measure pioneered by Kerr (2010). Breakthrough patents refer to those in the right tail of the citation distribution. Here the dependent variable in regressions (3) and (4) is a dummy variable that takes the value of 1 if the firm files any patents in the top 10 percent of the citation distribution in its cohort (i.e., patents with the same technological class and same application year) within three years following funding. Panel B of Table 2 turns to the intensive margin. In regressions (5) and (6), the dependent variable is (the natural logarithm of) the number of patents filed within three years following funding. The (natural logarithm of the) number of patents is

Table 3

VC Funding and Industry Growth

	Employment growth		Sales growth	
	OLS (1)	IV (2)	OLS (3)	IV (4)
ln(industry VC funding)	0.00338*** (0.000748)	0.00608*** (0.00178)	0.00495*** (0.000958)	0.00898*** (0.00228)
ln(employment)	–0.00646*** (0.00161)	–0.00817*** (0.00189)	–0.00476** (0.00207)	–0.00730*** (0.00243)
Observations	1,909	1,909	1,909	1,909
R^2	0.285		0.334	

NOTE: See the main text for a description of the dependent and independent variables. The control variable is logged employment in each industry, and all regressions include year fixed effects and industry fixed effects. Standard errors are in parentheses. *** denotes significance at the 1 percent level, ** at the 5 percent level.

weighted by citations in regressions (7) and (8).

As shown by the positive estimates for VC funding in Panel A, larger VC funding increases the likelihood of a firm filing a patent. Larger funding also increases the likelihood of a firm coming up with a breakthrough patent, although the impact of VC funding is somewhat smaller in spurring breakthrough patents than ordinary patents. According to the IV estimates in regressions (6) and (8), a 10 percent increase in VC funding will induce in the three years subsequent to that funding a 7.9 percent boost in patenting and 7.5 percent boost in quality-adjusted patenting.

3.2.2 Impact of VC on Industry Growth. Attention is now turned to evaluating the impact of VC funding on growth at the industry level between 1970 and 2011. The main explanatory variable is the (natural logarithm of the) amount of VC funding each industry receives in each year. The dependent variables are the average annual growth rates of employment and sales for the three-year period after an industry receives VC funding.[7] In all the regressions, controls are added for logged employment in each industry, year dummies, and industry dummies (2-digit SIC codes). An IV is applied to address the issues of measurement errors and selection bias in the ordinary-least squares regressions. As detailed earlier, the IV is a cross term between the deregulation dummy and a variable reflecting the industry's dependence on external finance.

As demonstrated in Table 3, increasing VC funding in an industry in a given year is associated with a higher growth rate of employment and sales in the subsequent three years. According to IV regressions (2) and (4), a one-standard-deviation increase in logged industry-level VC funding is associated with increases of 1.3 percentage points and 1.9 percentage points in annual employment and sales growth, respectively, following funding.

4 CONCLUSION

The empirical evidence presented in this article suggests that VC financing is positively associated with firm innovation and growth in the United States. A structural model of VC is developed in Greenwood, Han, and Sánchez (forthcoming). The model is calibrated to fit stylized facts about VC in the United States. Through the lens of this model, the effects of VC and its taxation are examined. One of the crucial questions left unanswered is the role of VC financing in accounting for differences in development across countries. Although more research is needed in this area, the findings in Cole, Greenwood, and Sánchez (2016) and Greenwood, Han, and Sánchez (forthcoming) suggest that differences in the cost of enforcing contracts, the efficiency of financial intermediation in which VC plays a role, and the taxation of successful startups may be behind such cross-country differences. ■

NOTES

1 This section draws *heavily* on Lamoreaux, Levenstein, and Sokoloff (2007) for the period prior to World War II and on Kenney (2011) for the period after.

2 The data source is the *2016 National Venture Capital Association Yearbook* (NVCA, 2016).

3 The category of "other industries" in this figure comprises the following industries: commercial products, commercial transportation, other business products and services, consumer durables, consumer non-durables services (non-financial), transportation, other consumer products and services, utilities, other energy, capital markets/institutions, commercial banks, insurance, other financial services, other healthcare, IT services, other information technology, agriculture, chemicals and gases, construction (non-wood), containers and packaging, forestry, metals, minerals and mining, textiles, and other materials. The data source is NVCA (2016).

4 The number of VC firms in existence is defined as a rolling count of firms that have raised a fund in the last eight years. The data source for all statistics in this paragraph is NVCA (2016).

5 The selection issue refers to the possibility that the positive relationship between VC investment and firm performance may be attributed to the ability of VCs to select promising companies to invest in.

6 This is revealed by the first-stage results of the IV regressions. The first-stage results are not presented due to space limitations.

7 The employment and sales information is based on the NBER-CES Manufacturing Industry Database available at https://www.nber.org/nberces/.

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