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VENTURE CAPITALISTS' ACCESS TO FINANCE AND ITS IMPACT ON STARTUPS

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ABSTRACT

Although an extensive literature shows that startups are financially constrained and that constraints vary by geography, the source of these constraints is still relatively unknown. We explore intermediary financing constraints, a channel studied in the banking literature, but only indirectly addressed in the venture capital (VC) literature. Our empirical setting is the VC fundraising and startup financing environment around the passage of the Volcker Rule, which restricted banks' ability to invest in venture capital funds as limited partners (LPs). The rule change disproportionately impacted regions of the U.S. historically lacking in VC financing. We find that a one standard deviation increase in VCs' exposure to the loss of banks as LPs led to an 18% decline in fund size and about a 10% decrease in the likelihood of raising a follow-on fund. Startups were not completely cushioned from the additional constraints on their VCs: capital raised fell and pre-money valuations declined. Overall, VC financing constraints manifest as fewer, smaller funds that change investment strategy and experience increases in bargaining power. Last, we show that the rule change increased the likelihood startups move out of impacted states, thus exacerbating the geographic disparity in high-growth entrepreneurship.

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Data on banks investment in VC is available at https://github.com/michaelewens/Banks-In-VC

Access to capital is crucial for firm formation, growth, and survival. Driven by the belief that many entrepreneurial firms are financially constrained and that technology clusters play a central role in economic performance, governments implement policies to foster entrepreneurial and innovative clusters of their own (Lerner, 2012). These policies include direct investments, grants, subsidized loans, education, and support for venture capitalists (VCs) (e.g., Brown and Earle, 2017; Krishnan, Nandy, and Puri, 2015). Effectively targeting these policy solutions demands a full accounting of where financial constraints lie. An extensive literature explores whether changing access to capital (e.g., bank competition, home equity access, or deregulation) helps entrepreneurs. Yet one channel remains relatively under-explored in the entrepreneurial finance literature: local VC financing constraints. Given VC's role in early-stage entrepreneurship, a better understanding of VC financing constraints could provide valuable insight into the agglomeration of the capital that motivates many entrepreneurship policies (e.g. Marshall, 1890; Lerner, 2002; Chatterji, Glaeser, and Kerr, 2014).

There are two primary sources of startup financing constraints in financial markets with intermediaries that could cause positive net present value (NPV) startups to go unfunded. First, information frictions or the intermediaries' market structure could impact startup financing (e.g., Arrow, 1962; Hall and Lerner, 2010). For example, investors may be unable to assess investment quality, or those investors may have high bargaining power relative to the entrepreneur. Second, financial intermediaries themselves may face financing constraints. Evidence for such constraints is well-documented in the banking literature. Among others, Paravisini (2008), Khwaja and Mian (2008) and Gilje (2019), show that banks face frictions in their own external financing markets that impact firm capital access. Similar issues for startups and particularly their investors may exist in venture capital.

We study whether venture capitalists are financially constrained using a policy change that restricted some limited partners' (LPs') access to venture capital funds. After docu-

menting significant investor financing constraints, we ask whether these constraints spillover to local startups. The geographic impact of the policy change also speaks directly to a related issue that motivates economic policy: clustering of both capital and startups in the U.S. VC market. Thus, in our final analysis, we ask whether declines in local VC availability correlate with startup mobility choice.

There are several reasons why venture capitalists could be constrained and why these constraints could be more severe than those found in other settings. First, unlike the banking sector, VCs raise capital in the form of equity from LPs every 3 to 5 years and can rarely use leverage. VCs also lack inter-VC lending or multi-branch markets. Next, a combination of local bias in LP investing (Hochberg and Rauh, 2013) and a market focus on established funds may also lead to constraints for some VCs. Local bias in LP investing can be rationalized using the same argument concerning local VC investing: the local investment preferences of VC funds demand that VCs' capital suppliers have similar local information advantages. An additional reason is that capital raised by VCs – which in aggregate grew three-fold from 2010 to 2019 – flows primarily to large and established VC firms. Over the last six years, less than 20% went to first-time VC funds.[1] Finally, several papers (e.g., Kortum and Lerner, 2000; González-Uribe, 2020) explore the impact of VC investment or fund size on economic outcomes.[2] Their instrumental variable strategies rely on a VC fundraising channel where LPs become less (more) willing to invest in VC funds, implicitly assuming that VCs may be financially constrained.

What might happen to VC fundraising and, ultimately startup financing, in the face of restrictions on LP capital? In a frictionless external finance market, VCs would find substitutes for the lost LPs, and researchers would observe no change in fundraising. Recent experiences suggest this is a sensible prior, as VC and private equity (PE) fundraising have

[1] Pitchbook-NVCA 2020 Q4 report.

[2] Related to the topic, Janeway, Nanda, and Rhodes-Kropf (2021) review the growing literature on the relationship between venture capital booms and startup financing.

experienced significant growth in the last twenty years, while deregulation of the private markets has accelerated (Ewens and Farre-Mensa, 2020). Alternatively, VC fundraising in certain regions or industries may be constrained due to information frictions, LP preferences, or concerns over limited startup investment opportunities (Lerner and Nanda, 2020). Here, a decrease in the set of LPs investing in VC worsens VCs' fundraising ability and startups' access to capital.

We test these hypotheses using a change in U.S. banking regulation from the Volcker Rule. Considered a legal overreach by many, the Volcker Rule (implemented in 2014) prohibits banks and their affiliates from investing in or sponsoring venture capital funds. As shown by Lerner, Schoar, and Wongsunwai (2007) and confirmed using Consolidated Reports of Condition and Income (i.e., Call Reports), banks as LPs are important sources of capital, providing between 4-8% of capital to VC funds in the years before the Volcker Rule passage. Based on administrative data reported by banks, our estimates find that there is a significant variation in states' reliance on banks for the supply of capital prior to the Volcker Rule. Banks in Midwestern states provided as much as 30% of capital to VC funds, while banks provided less than 1% of capital in the VC hub states such as CA. This differential reliance translates into unequal exposure to the Volcker Rule's impact by state. Indeed, the lobbying arm of the venture capital industry, the NVCA, argues for just this view[3]:

> The loss of banking entities as limited partners in VC funds has had a disproportionate impact on cities and regions with emerging entrepreneurial ecosystems – areas outside of Silicon Valley and other traditional technology centers. The more challenging reality of venture fundraising in these areas of the country tends to require investment from a more diverse set of limited partners.

We confirm that the rule change had the intended impact on banks' investments in VC. The fraction of banks that held any VC investments decreased by about 40% from 2013 to 2018

[3] NVCA letter to federal regulators "Proposed Revisions to Prohibitions and Restrictions on Proprietary Trading and Certain Interests in, and Relationships With, Hedge Funds and Private Equity Fund", April 2020.

after the Volcker Rule change.

Our empirical strategy first exploits the fact that the rule change unintentionally impacts regions of the U.S. differently depending on banks' roles as LPs. We first document that VCs in the Midwestern, Southern, and non-coastal states (i.e., non-VC-hub states) had higher bank exposure than other states prior to the Volcker Rule change. Next, differential exposure to the rule change based on bank LP activity will only manifest itself in VCs' fundraising when we incorporate one other well-documented fact: home bias by both limited partners and venture capitalists. Hochberg and Rauh (2013) and subsequent papers using LP supply shocks as instruments (e.g., González-Uribe, 2020) show that some more sophisticated LPs – pension funds – exhibit an abnormal propensity to invest in same-state VC funds. If the rule change was unexpected and the pre-2014 distribution of banks as LPs was not experiencing differential trends across regions, then we can interpret our difference-in-differences coefficient estimates as causal.

Our analysis uses the combination of two datasets for the 2010–2018 sample period. The Call Reports form the basis of our data on banks' exposure to VC funds. Although we cannot directly observe a specific bank's position in a VC fund, these reports include "venture capital revenue" which consists of market value adjustments, gains, and losses on banks' venture capital investments. There are a total of 231 unique banks that have reported venture capital revenue in 42 states from 2001 (the first year Call Reports data are available) to 2013 (the last year before the Volcker Rule change). We aggregate the data at the state level to create the main bank exposure variable. VentureSource (formerly owned by Dow Jones, now CB Insights) and Pitchbook provide data on venture capital fundraising, startup financing, and startup outcomes. The final sample includes 1,617 VC funds and 12,788 startups.

VC funding changes in several ways in states more exposed to the rule change. Two extensive margins exhibit declines: the number of VC funds closed and the probability that a pre-Volcker VC raised a follow-on fund. On the intensive margin we find that total

VC fund raised in the state-year falls, while funds that do successfully close are smaller (a one standard deviation increase in VCs' exposure to the loss of banks as LPs leads to an 18% decline in fund size). These results show that the treated VCs – those headquartered outside the major VC centers – faced financial constraints and that these VCs could not find alternative limited partners after the passage of the Volcker Rule. The declines also speak to a point raised in the last report on the Volcker Rule (Federal Register, 2014):[4]

> To the extent that banking entities may reduce their investments in venture capital funds that are covered funds, the potential funding gap for venture capital funds may also be offset, in whole or in part, by investments from firms that are not banking entities and thus not subject to section 13's restrictions.

Consistent with the comments cited in the report, our results show that VC funds in the impacted states found their "funding gap" only filled "in part".

We next investigate whether VC financing constraints spillover to local high-growth startups. In a world with perfect substitutes, lower capital availability in a state-year can be supplemented with alternatives such as friends and family financing, angels, bank debt, government grants, or other private equity. However, if these capital sources are instead complementary to VC or already exhausted pre-2014, then the decline in VC will be unfilled. We find that startups raise 7% smaller financing rounds and are slightly younger when they raise that capital. Consistent with a change in bargaining power, financed startups have 7% lower pre-money valuations, and VC-backed startups are relatively more likely to have some pre-VC financing (e.g., angel). The changes in valuation mirror the findings in Gompers and Lerner (2000) who show that VC inflows create demand pressure and valuation changes. The collection of results shows that VC financing constraints manifest as worse financing conditions for local startups and change the composition of startups that are financed.

Additional analysis shows that the quantity and quality of startups backed by VCs changed after the Volcker Rule. First, we find that at the state-year level, there is an

[4] See Federal Register, Vol. 79, No. 21 January 31, 2014, Book 2 of 2, Pages 5535–6076.

11% increase in the number of first-time VC financings in the impacted states for each one standard deviation increase in VCs' bank exposure. The increase in the number of startups backed by VCs is confined to relatively less capital-intensive information technology industries. Combined with the results on financing and fund size, these results show VCs switched to less capital-intensive startups and their funds made relatively more investments. We find no change in angel investments, though there is weak evidence that crowdfunding events fell. These results contribute to the literature that examines substitutes for VC (Hellmann, Schure, and Vo, 2013). Additionally, startups financed in states with higher bank exposure are relatively more likely to have successful exits after Volcker. Given that treated states had disproportionately less VC pre-Volcker Rule and thus startups were likely constrained, the only interpretation of this increase in quality is that the demand curve slopes downward as expected.

Our final analysis examines whether the increased VC constraints impact high-growth startups' location choices. The decrease in capital could lead startups to relocate to states that are relatively less exposed to the rule change and have more abundant venture capital supply. Such a shift would exacerbate the existing agglomeration of high-growth startups in the U.S. A simple analysis provides suggestive evidence that startups respond in just this way. Using federal filings for securities exemption (Form Ds) data to track address changes, we follow startups before and after the rule change. Among startups five years or younger that move to California, the probability that they originate from one of the treated states with high bank exposure increases by about 60% after the passage of the Volcker Rule. A difference-in-differences estimation reveals that startups in high exposure states are relatively more likely to move to VC hubs including CA, MA and NY after the rule change. These mobility results show that the rule change had large general equilibrium impacts on the allocation of startups across states.

Our paper contributes to the financial constraints, entrepreneurship, and venture capital

literature. We extend the results on financial intermediary constraints in banking (e.g., Paravisini, 2008; Khwaja and Mian, 2008; Gilje, 2019), showing that despite the differences in the external financing market faced by VCs, these intermediaries face similar issues. Next, Kerr and Nanda (2009) find that bank deregulation and competition matters for high-growth startups, while banks often play a direct role in financing startups (Hellmann, Lindsey, and Puri, 2008). We show that banks' importance for startups also follows their support of startups' funders. Our analysis also provides more evidence for the agglomeration of venture capital and startup mobility (e.g., Chen, Gompers, Kovner, and Lerner, 2010; Guzman, 2019) that guides policymaking (Lanahan and Feldman, 2015). The concentration of VC financing and the home bias of LPs translated into unintended, differential impacts of the Volcker Rule.

Last, we contribute to a literature that uses shocks to LPs or differences in LP commitments to explore causal effects of VC financing. Nanda and Rhodes-Kropf (2013), Bernstein, Lerner, Sorensen, and Strömberg (2017), González-Uribe (2020), Ewens and Farre-Mensa (2020) and Kortum and Lerner (2000) each use this variation as a mechanism to understand the impact of VC on innovation, startup characteristics, knowledge sharing, and founder bargaining power. These papers argue that changes in LP supply or composition will first impact VC fundraising and ultimately, portfolio company outcomes such as the number of financings or their valuations. We take this first assumption head on, confirming the assumption in these identification strategies with our results showing VC constraints.

1 Institutional Background and Data

1.1 Volcker Rule and banks' VC investments

In the aftermath of the 2008 financial crisis, the Dodd-Frank Wall Street Reform and Consumer Protection Act (or the Dodd–Frank Act) was enacted to regulate the financial

industry and prevent future financial crises. As part of the Dodd-Frank Act, the Volcker Rule statute aims to protect bank customers by preventing banks from making certain types of speculative investments that are considered to have contributed to the 2008 financial crisis. The rule specifically prohibits banks and their affiliates from investing in or sponsoring a "hedge fund or a private equity fund" – referred to collectively as "covered funds".

After a long delay, U.S. financial services regulators eventually approved the final Volcker Rule on December 10, 2013.[5] Despite initial expressions of Congressional intent that VC funds should be excluded from covered funds,[6] the final implementation of the rule adopted a broad definition of covered funds. Except for a few exclusions and additions determined by the agencies, the definition includes any issuer that would be an investment company as defined in the Investment Company Act of 1940 but for sections 3(c)(1) or 3(c)(7) of that Act. Because all active VC funds use either the 3(c)(1) or 3(c)(7) exemption to avoid having to register and comply with the the Investment Company Act's requirements (Ewens and Farre-Mensa, 2020), the adopted definition of "covered funds" includes VC funds in its category thus subjecting them to the restriction of the Volcker Rule.

Although prohibited from engaging in VC fund activities by the Volcker Rule, banks and their affiliates have long been making VC investments in the U.S. (Hellmann et al., 2008). Prior to the passage of the Gramm-Leach-Bliley Act in November 1999, banks usually make private investments through two loopholes. First, the Small Business Act of 1958 authorizes banks and bank holding companies to own and operate "Small Business Investment Corporations" (SBICs) as their wholly owned subsidiaries to make equity investments.

[5] The relevant regulators are the Office of the Comptroller of the Currency, the Board of Governors of the Federal Reserve System, the Federal Deposit Insurance Corporation, the U.S. Securities and Exchange Commission, and the U.S. Commodity Futures Trading Commission. See the news release of final rules at: `https://www.sec.gov/news/press-release/2013-258`.

[6] For example, Senator Chris Dodd (D-CT), one of the authors and namesakes of the Dodd-Frank Act states: "...properly conducted venture capital investment will not cause the harms at which the Volcker Rule is directed. In the event that properly conducted venture capital investment is excessively restricted by the provisions of section 619, I would expect the appropriate Federal regulators to exempt it using their authority under section 619(J)."

Second, Section 4(c)(6) of the Bank Holding Company Act of 1956 allows banks to make VC investments at the bank holding company level, including either direct equity investments in portfolio companies, as long as their position does not exceed more than 5% of the outstanding voting equity or indirect investments through limited partnerships. The Gramm-Leach-Bliley Act of 1999 repealed part of the Glass-Steagall Act of 1933, further relaxing constraints on banks' ability to invest in VC.

Prohibiting banks from continuing to invest in VC created an unintended challenge for the VC industry. In contrast to the other asset classes covered by the rule, VC funds typically make illiquid and long-term equity investments into startups and work alongside them to build successful companies. This asset class therefore does not generate the excessive risk typically associated with proprietary trading which the Volcker Rule aims to eliminate.[7] Therefore, many practitioners argue that pooling VC funds with private equity and hedge funds, which bars banks from investing in VC funds, is a legal overreach on the part of financial regulators; it may also go against congressional intent.[8]

1.2 Data

1.2.1 Bank data

We use data collected from banks' Consolidated Reports of Condition and Income (i.e., Call Reports) to identify banks' engagement in VC investments. In 2001, *venture capital revenue* (or VC revenue) was added as a new category of non-interest income on the Schedule RI-Income statement of banks' Call Reports following the change of information collection made by the Federal Financial Institutions Examination Council (FFIEC). Since then, all

[7] VC funds are also different in other dimensions. For instance, they have limited use of leverage compared to buyout funds. The VC industry, with approximately $450 billion under management in 2019 (NVCA, 2020), is also far smaller than other asset classes such as hedge funds.

[8] See e.g. NVCA letter to federal regulators "Re: Proposed Revisions to Prohibitions and Restrictions on Proprietary Trading and Certain Interests in, and Relationships with, Hedge Funds and Private Equity Funds", October 17, 2018.

U.S. banks have been reporting VC revenue on their Call Reports in each quarter.[9] According to the FFIEC, the reported VC revenue mainly includes market value adjustments, interest, dividends, gains, and losses on banks' VC investments, any fee income from VC activities, and the proportionate share of the income or loss from their investments in equity method investees such as VC funds. See Appendix A for a detailed discussion on what constitutes VC revenue for different types of VC events and the data repository for the data used in the paper.

Using banks' VC revenue information, we show in Figure 1 that the number of banks with any VC revenue drops sharply by more than 50% following the implementation of the Volcker Rule.[10] In Figure B.1, we further plot the number and fraction of banks with negative VC revenue and find a temporary and immediate increase after the implementation of the Volcker Rule. This finding suggests that some banks may have chosen to sell their investment positions in VC funds at a loss after the implementation of the Volcker Rule. These results imply that banks' investments through VC funds as LPs is the main channel through which banks engage in VC investment activity. Therefore, the reported VC revenue in Call Reports forms the basis of our information on banks' involvement in VC as LPs across U.S. states over time.[11]

1.2.2 Venture capital data

The commercial data provider VentureSource (formerly owned by Dow Jones, now CB Insights) provides information on venture capital financings, investors, and entrepreneurial

[9] This set of banks include U.S. national banks, state member banks, and insured state nonmember commercial and savings banks.

[10] The number of banks with VC revenue did not drop to 0 after the Volcker Rule because some banks may still use loopholes such as SBICs to invest in VC as discussed in Subsection 1.1.

[11] The reported VC revenue could come from both banks' direct investments in VC-backed startups and also indirect investments through VC funds, where only the second type of VC investments are impacted by the Volcker Rule. Unfortunately, the data do not allow us to separate the two types of VC investments. Under the assumption that banks' investment strategies for the two types of investments do not vary systematically across states, the reported VC revenue is able to reflect the correct sorting of states in terms of their reliance on banks for the supply of capital through VC funds.

firms.[12] A financing event – and thus its investors and startup – is included in the database if at least one of the investors is labeled as a venture capital firm. For our main analyses, we focus on the sample period of 2010–2018 around the implementation of the Volcker Rule in 2014. We start our sample from 2010 to avoid any overlap with the 2008 financial crisis (see relevant discussion below). In the VC fund analysis, we focus on VC funds with vintage year between 2010 and 2018. Because some less-populated U.S. states such as Montana and Wyoming show no VC activity or VC fund raising over the four-year period prior to the implementation of Volcker Rule (2010–2013), we exclude these states from all our analyses. The final VC fund sample includes 1,617 VC funds in 35 states. In our VC-backed startup analysis, we include the first round of VC funding, either a seed or Series A round that occurred between 2010 and 2018. We exclude financings greater than $100 million from our startup sample as they are more likely to involve non-VC-backed startups. Our focus is thus on first, early-stage financings of startups between 2010 and 2018. The final startup sample includes 12,788 entrepreneurial firms. Table 3 presents descriptive statistics for the key variables used in our analyses.

2 Estimation Strategies

2.1 The importance of banks for VCs

Prior to the Volcker Rule, banks were an important source of capital for the VC industry.[13] Using VC revenue reported in Call Reports, we can estimate banks' capital share in overall venture capital raised. For a given year, we first estimate banks' net profits in VC investments (the difference between positive and negative VC revenue) and then back out

[12] The coverage of financing rounds is extremely comprehensive in VentureSource, particularly so during our period of analysis, because Form D filings were available on the SEC website since 2002, making it much easier for data providers to collect comprehensive information.

[13] Banks' involvement in VC is not random, Table B.1 shows that the average bank engaging in VC investments is 40 times larger than an average bank that is not involved in VC investments.

banks' investment position in VCs from their net profits by assuming a fixed annual return of 10%.[14] We then scale this bank investment position by overall venture capital raised in the previous five years to arrive at banks' capital share at a given year over total venture capital raised. The VC industry is highly cyclical (see e.g. Gompers, Kovner, Lerner, and Scharfstein, 2008), so we perform this estimation only when banks' estimated profits are positive.[15] We estimate banks' capital share in total venture capital raised in each year over 2005–2007, a relatively stable period between two economic crises. Last, we average our estimates over these three years to derive a less noisy measure of banks' capital share in total venture capital raised. The estimation, reported in the first and second columns of Table 1, suggests that banks had an annual investment position of about $12 billion in the VC industry, constituting about 8% of all venture capital raised in the U.S. prior to the Volcker Rule. Our estimates are consistent with several other sources. For example, using a large dataset from an earlier period (1991–1998), Lerner et al. (2007) find that banking and finance companies represent the sixth largest investor class in PE and VC funds, accounting for about 4% of all LP investors in VC funds and 8% of all LP investors in both PE and VC funds.[16] Additionally, a Preqin Special Report released prior to the Volcker Rule documents that banks account for about 8% of the total capital invested in private equity, making them the fifth most significant investor type.[17] Overall, these estimates show clearly that banks provided meaningful capital to the VC industry prior to the Volcker Rule and that the Call Reports are an ideal primary source for our analysis.

[14] Our results remain robust if we use a similar annual return between 5% and 20%.

[15] It is possible to back out banks' investment position from investment profits only when the (estimated) profits, either positive or negative, are significantly different from zero. Therefore, our estimation does not rely on the specific sign of the profits.

[16] These estimates are likely underestimates because the data came before the Gramm-Leach-Bliley Act, which further relaxed constraints on banks' ability to invest in VC.

[17] See "Preqin Special Report: Banks as Investors in Private Equity", 2012.

2.2 Construction of the treatment variable

Our goal is to create a variable that approximates the relative exposure of a VC firm or fund to the Volcker Rule change. We use the differences across states in local banks' investing in VCs prior to the Volcker Rule as our proxy.[18] Banks in different regions vary by their size and survival time (see Table B.1). In addition, it takes time to observe banks' VC revenue after they make VC investments. To better capture the stable capital flow from banks to VC funds over time in a given state, we first aggregate the number of bank-years with VC revenue over the period 2001–2013. We then scale this number by the number of VC funds raised over the same period in the state to construct our state-level measure of VC funds' bank exposure prior to the implementation of the Volcker Rule – "Bank Expo". Although the Volcker Rule took time to implement, as shown in Figure 1, there is no evidence that banks or the VC industry anticipated the change nor that they adjusted their allocations in advance of the change. Therefore, the "Bank Expo" variable we construct is plausibly exogenous, and we use it as the main treatment variable in our diff-in-diff analyses throughout the paper. Based on this continuous measure, we also construct two other binary treatment variables for use in some additional tests: "High Expo", a dummy variable indicating whether a state's bank exposure is above the sample median among all states in our sample, and "Top Third", a dummy variable indicating whether a state's exposure is in the top third of the bank exposure distribution relative to the bottom third. Table 2 presents these measures by state.

The bank exposure variable captures the intended variation. First, using the same approach as in Subsection 2.1, we estimate banks' capital share in total VC funds raised for the group of states with high bank exposure and the group of states with low bank exposure. We find that banks' capital share in total VC funds raised is much higher in the high bank

[18] We do not observe the composition of banks' within- vs. out-of-state VC investments. As long as the relative fraction is constant across states, our measure is able to capture variation in local VCs' bank exposure. However, it could be the case that banks in states with low VCs are more likely to invest in out-of-state VC funds due to limited local investment opportunities. In this case, the true bank exposure is lower than our measure, and the true coefficient would be larger than what our estimation suggests.

exposure group than in the low bank exposure group, regardless of the specific parameters we use (Table 1). Second, we correlate the bank exposure variable with state-level attributes, including GDP growth and GDP per capita, and find no correlation, suggesting that states with different bank exposure do not differ significantly in other economic conditions that are not directly related to VCs (Figure B.2).[19]

2.3 Variation in VCs' bank exposure by state

We next examine variation in VCs' bank exposure across the U.S. First, Figure 2 shows that VCs' bank exposure differs significantly across regions: the Midwest and South have higher bank exposure than other regions prior to the Volcker Rule, despite the fact that these regions have a small VC industry presence (Figures B.3 and B.4). Second, states outside traditional VC hubs have much higher bank exposure, while traditional VC hubs such as the top three VC states (CA, MA and NY) all rely little on banks for capital and have very low bank exposure (Table 2). Similarly, non-coastal states typically have higher bank exposure than the coastal states (Figure 3). Last, we find that states with small VC markets relative to their size also have higher bank exposure pre-Volcker Rule (Figure 4). In particular, when we define a state's VC "imbalance" as the ratio of the state's VC market share (measured by the number of VC funds raised in the state over the total number of VC funds raised in the U.S.) over its GDP share, there is a negative correlation (-0.2) between the imbalance measure and the bank exposure variable. This correlation may stem from the fact that the typical VC fund outside a VC hub is too small to attract large institutional investors such as pension funds. Indeed, we find that the median VC fund size in the Midwest and South is only \$29.5 and \$37.0 million, respectively, while those in the other regions are about three

[19] In unreported results, we also correlate the bank exposure variable with more state-level attributes that are commonly used in the literature (e.g., Gompers and Lerner, 1998). These include state capital gain tax rate, per capita state/academic R&D expenditure, and education (percent of adults completing some college or associate's degree), and we find weak or no correlation.

times as large (Figure B.5). Overall, we find that there is significant variation across the U.S. in VCs' bank exposure.

Given the regional differences in banks' involvement in VC and LPs' tendency to invest in local VC funds, we expect that the implementation of the Volcker Rule differentially impacts VCs across U.S. states. Hochberg and Rauh (2013) show that institutional LP investors such as public pension funds exhibit substantial home-state bias in private equity investments and that the home-state bias is greater in venture capital funds than in buyout funds. Like other institutional investors, banks may also exhibit a strong home-state bias in investing in VC funds. Further, Chen et al. (2010) document that both VC firms and VC-backed companies are highly concentrated in geography, and VC investors typically invest locally. We therefore expect that the home bias exhibited by both intermediaries and their own capital suppliers leads to a higher impact of the Volcker Rule for states and regions with higher bank exposure before the rule change.

2.4 Estimation strategy

We exploit the cross-sectional heterogeneity in VCs' bank exposure across states to identify the impact of the Volcker Rule on both VC fundraising and entrepreneurial firm financing. Our estimation strategy is a standard difference-in-differences (or diff-in-diff) regression. Given the timing of the implementation of the Volcker Rule, our analysis compares VC activity between 2010–2013 with that between 2014–2018.[20] We conduct our analyses with different units of analysis including state-year, VC fund, and VC-backed startup level. In these analyses, our regression framework takes similar forms. Using the startup-level analysis

[20] As argued by Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018), it is difficult to point to a single date when the effects of the Volcker Rule became binding. Though the Volcker Rule became effective on April 1, 2014, the final rules to implement it were released on December 10, 2013, which then made clear the prohibition of banks from investing in VC funds. Conducting all our analyses at the year level, we choose 2014 as the beginning of the "Volcker period". This is also consistent with existing literature studying the Volcker Rule (see e.g. Bao, O'Hara, and Zhou, 2018; Bessembinder et al., 2018).

as an example, we conduct the following estimation:

$$Y_{it} = \beta_1 Bank\ Expo_i * Post_t + \beta_2 X_i + \gamma_t + \epsilon_{it} \quad (1)$$

where X_i are entrepreneurial firm characteristics at the time of the investment, including state fixed effects, industry group fixed effects, Series A or Seed round fixed effects, and startup age fixed effects; γ_t are year fixed effects corresponding to the year of investment. The main coefficient of interest (β_1) is the interaction between "Bank Expo" and "Post" (equal to one for 2014 on).

As mentioned earlier, we use the continuous treatment variable "Bank Expo" as our main treatment variable. The continuous variable is able to capture a richer cross-state variation in VCs' bank exposure than the binary treatment variables. For example, Arkansas has bank exposure almost fifty times as high as Alabama, but both would be assigned the same high bank exposure group (see Table 2). On the other hand, Alabama has very similar bank exposure to Virginia, but they would be assigned different bank exposure groups. Though we rely on the continuous variable as our main treatment variable, we also provide robustness checks using the two binary treatment variables "High Expo" and "Top Third" throughout our analyses.

As with any difference-in-differences estimation strategy, our key identifying assumption is parallel trends – that is, the states with low bank exposure provide an appropriate counterfactual for what would have happened to the states with high bank exposure had they not been negatively impacted by the Volcker Rule. While the parallel trends assumption cannot be proven, we aim to validate it in several ways. First, in Figure 5, we plot the coefficient estimates from a dynamic specification of Eq. (1) where each point is an estimate of the interaction of year and the bank exposure variable, relative to year 2013. The bands correspond to with 95% confidence intervals. The patterns in the figure show that there is

no evidence of pre-trends for the number of VC funds raised across states over time, and the timing of the drop in the aggregate of VC fundraising activity is consistent with the implementation of the Volcker Rule. Second, in Figure 6, we show that the number of VC funds in states with high bank exposure evolves similarly to that in states with low bank exposure over the pre-Volcker Rule period (2010–2013). Only after the implementation of the Volcker Rule does the trends diverge. This provides further support for the parallel trends assumption.

Our identification is also predicated on the key assumption that no other change in 2014 impacted VC activity across the states in precisely the same way as we have identified through bank exposure. One such potential channel is the 2008 financial crisis. As mentioned earlier, we start our sample from 2010 in all of our main diff-in-diff analyses to avoid any overlap with the financial crisis period. This approach also follows Ewens, Nanda, and Rhodes-Kropf (2018) who show that the impact of the financial crisis on the VC industry was mostly confined to 2009.[21] Additionally, in all of our main diff-in-diff analyses, we conduct tests over a narrower period between 2011 and 2017, and find similar results.[22] Finally, all specifications include year fixed effects. Thus, alternative explanations must include a reason why states experienced differential impacts in the manner that we document.

3 Venture Capital Financing Constraints

We first document that the implementation of the Volcker Rule negatively impacts VC fundraising activity, suggesting that the funding gap left by the loss of banks as LPs for venture capitalists is not fully filled by other types of LPs; hence some VCs face financing

[21] Ewens et al. (2018) document that while there was a 25% drop in the number of venture deals from 2008 to 2009, deal volume actually increased from 15% from 2009 to 2010.

[22] In Panel A of Table B.2, we focus on just the two-year period of 2013–2014 and still find that the number of VC funds, especially small VC funds, falls post-Volcker Rule in states that are more impacted by the rule change.

constraints. We show these results with both state-year and VC fund level analyses.

3.1 Aggregate of VC fundraising activity

First, we provide descriptive evidence of the impact of the Volcker Rule on VC fundraising activity by calculating the number of newly raised VC funds in the high-exposure and low-exposure states over the 2010–2018 period. In Figure 6 we find that there is a marked difference in the number of newly raised VC funds across the two groups of states in the post-Volcker period, while they evolve similarly prior to the rule change. This result suggests a sharp shift in VC fundraising activity depending on the states' bank exposure prior to the implementation of the Volcker Rule.[23]

We next test for the change in the regression context of Eq. (1) using state-year observations over the 2010–2018 period. Panel A of Table 4 reports the estimation results. Columns (1) - (4) have the natural log of one plus the number of VC funds raised in a given state-year as the dependent variable, while columns (5) - (8) have the natural log of one plus the aggregate amount of venture capital raised in a given state-year as the dependent variable.[24] For each dependent variable, the first column includes state and year fixed effects, the second column adds time-varying, state-year level controls,[25] the third column focuses on a narrower sample period of 2011–2017 around the Volcker Rule passage, and the fourth column replaces the continuous explanatory variable "Bank Expo" with a dummy treatment variable "Top Third", which indicates whether a state's bank exposure is in the top third of the bank exposure distribution (the corresponding regression sample only includes the states

[23] Figure B.6 plots the aggregate of initial VC capital invested in startups by financing year, and shows a similar pattern to Figure 6. Figure B.7 plots the number of newly raised VC funds by U.S. regions, and again shows a similar pattern.

[24] We construct a balanced state-year panel for the regressions. Because the number of VC funds and the total venture capital are zeros for some of the observations, we use the transformation of the natural log of one plus the variables. As the number of VC funds is a count variable, we also conduct robustness checks using Poisson and negative binomial estimations, and find robust results.

[25] Following Gompers and Lerner (1998), we control for lagged state GDP growth and log of state GDP per capita.

in the top and bottom third of the distribution).

The results in Panel A of Table 4 show that there is a significant decrease in the number of VC funds and total venture capital raised after the Volcker Rule in states with higher bank exposure compared to states with lower exposure. In particular, for a one standard deviation increase in bank exposure, there are about 12% fewer VC funds and 8% less total venture capital raised in the state after the implementation of the Volcker Rule.[26] This drop also represents about 0.6 VC funds and $56 million in a state per year. Directly comparing the states in the top third of the bank exposure distribution with those in the bottom third, the coefficients in columns (4) and (8) are not statistically significant, but they are negative and consistent with the results based on the continuous treatment variable. The state-year level regression results show that the implementation of the Volcker Rule has a significant and direct impact on the supply of venture capital.

As discussed earlier, the diff-in-diff framework requires the parallel trends assumption to make causal inferences. Because the assumption is not directly testable, researchers usually inspect the pre-treatment outcome-variable trends of the treated and control groups to determine whether this assumption is empirically violated. We examine pre-treatment trends of the outcome variables using the dynamic version of Eq. (1). Specifically, we replace the single interaction variable with a set of interaction variables between the bank exposure variable and year dummies. To avoid multicollinearity, we omit from the regression the interaction term for 2013 (the last year before the implementation of the Volcker Rule). If the outcome-variable trends diverge prior to the implementation of the Volcker Rule, the

[26] To calculate the percentage change in the outcome variable of interest, e.g., the number of VC funds raised, consider the regression: $Ln(1+Y) = a + bX + u$. For each unit of change in X, the change in Y, ΔY, approximately satisfies $(1+Y+\Delta Y)/(1+Y) = \exp(b)$. Solving the equation yields $\Delta Y/Y = [\exp(b)-1](1+1/Y)$. Thus, for each unit change in X, Y changes by $100 * [\exp(b)-1](1+1/Y)$ percent. Further assume the standard deviation of X is σ, then a one standard deviation change in X corresponds to the changes in Y by $\sigma * 100 * [\exp(b)-1](1+1/Y)$ percent. In our setting, the standard deviation of our treatment variable "Bank Expo" is different across the regression samples due to different units of observation (Table 3), and we use the regression-specific variation whenever reporting magnitudes.

coefficients on the interaction variables for years 2010–2012 will be statistically significant. The results in the first two columns of Panel B in Table 4 show that the coefficients are insignificant for all of 2010–2012 when we use the same dependent variables as those in Panel A. In columns (3) - (5), we further partition the VC funds into three identical groups according to their size in each state and consider the number of VC funds in each group as the outcome variables. We again find that the coefficients are insignificant for all of 2010–2012 in all three columns. Taken together, the results in Panel B of Table 4 corroborate the validity of our diff-in-diff specification.

To further validate our diff-in-diff model, we conduct falsification tests with economic variables that are not directly related to VC fundraising and presumably also less impacted by the Volcker Rule. Estimating a diff-in-diff model as Eq. (1) could produce false positive treatment effects if the treated and control groups have heterogeneous characteristics not included as controls in our regressions. This issue is particularly serious if the heterogeneities are time-varying (Roberts and Whited, 2013). To address this concern, we estimate the diff-in-diff model specified in Eq. (1) using six other economic variables as the dependent variables. These economic variables are in three categories: IPOs of VC-backed companies, patents filed by VC-backed companies, and state GDP. We report the falsification test results in Table 5, which shows that the coefficient on the interaction variable is insignificant throughout the six columns. These findings indicate that the diff-in-diff model does not produce false positive treatment effects in our setting.

3.2 VC fundraising activity at the fund level

Having found a decline in the aggregate of VC fundraising activity in states most exposed to the Volcker Rule, we now explore its impact on the average size of a VC fund raised. Panel A of Table 6 reports the VC fund level regression results estimated from Eq. (1) with the natural log of fund size as the dependent variable. Columns (1) - (3) include all VC funds that

were closed over the 2010–2018 sample period. To control for the cyclicality of overall VC fundraising activity and the cross-sectional heterogeneity in VC firms' ability to raise funds, we include VC fund vintage year fixed effects and VC firm fixed effects in all the columns.[27] In addition, as VC fund size typically increases as a function of the fund sequence within a VC firm, we add VC fund sequence fixed effects in column (2). We further add time-varying, state-year level controls in column (3). The results in the first three columns of Panel A suggest that the average VC fund size falls after the implementation of the Volcker Rule. The economic magnitude is large. For a one standard deviation increase in bank exposure in a state, e.g., moving from New York to Wisconsin (Table 2), the average VC fund size is about 18% smaller conditional on being raised.

In column (4) of Panel A of Table 6, we exclude VC funds based in California from our sample, which account for about 45% of all VC funds. The regression coefficient remains similar, suggesting that our result is not driven by the largest VC market. In column (5), we focus on a shorter sample period: 2011–2017 around the implementation of the Volcker Rule. The result remains significant and similar in terms of economic magnitude, suggesting that our result is also not driven by the years either at the beginning or the end of our sample period. In the last column, we consider VC firms with funds closed both before and after the implementation of the Volcker Rule during our sample period (termed "Active VC"). The coefficient estimate is only slightly smaller than the estimate in column (2) with the same specification, implying that the Volcker Rule not only affected new VCs that did not raise VC funds before the rule, but also the more "experienced" VCs who did raise funds before.

Do VC firms from the pre-Volcker era experience a decline in the likelihood of raising a follow-on fund? In Panel B of Table 6, we estimate changes in VC firms' probabilities of raising a follow-on fund across states in the post-Volcker period conditional on having raised

[27] The VC industry is highly cyclical (see e.g. Gompers et al., 2008), while VC firms' ability to raise big funds varies considerably (Pitchbook-NVCA 2020 Venture Monitor).

a fund over the pre-Volcker period 2010–2013. The dependent variables are indicators of whether a VC firm has raised a new fund up to a certain year over the post-Volcker period. Over different post-Volcker windows, the results in Panel B all suggest that conditional on raising a VC fund over the pre-Volcker period, higher bank exposure leads to a lower probability of raising a follow-on fund over the post-Volcker period. This within-VC firm evidence further suggests that VC firms raise not only smaller, but also fewer funds.

In sum, we document in this section at both the state-year and VC fund level that the implementation of the Volcker Rule negatively impacted VC fundraising activity. As robustness checks, in the Internet Appendix IA1, we use VC funds data from an alternative VC database – the Pitchbook database – to repeat the exercises in this section and find similar results. Overall, these robust findings on VC fundraising activities suggest that no other institutional investors have stepped forward to substitute banks' role following the restrictions on their VC investments as LPs. Given the cross-state variation in VCs' bank exposure, the results indicate that VCs in Midwestern and Southern states and in states outside the traditional VC hubs are financially constrained as funders of local high-growth and innovative startups.

4 Impacts on Startups

Having found evidence that VC funds outside traditional VC hubs are financially constrained, we turn next to understanding the impact on financing local high-growth startups in these areas. The reduced supply of venture capital may be substituted by other sources of early-stage capital such as friends and family financing, angels, bank debt, government grants, or other private equity. In this scenario, we may not see changes in startup financing. However, if these alternative sources of capital are complementary to VC or already exhausted pre-2014, we could observe changes in various aspects of startup financing includ-

ing the amount of capital raised, startup pricing, investor syndication, and the composition of startups funded.

4.1 Capital raised and valuation

Panel A of Table 7 reports the startup-level regression results from estimating Eq. (1) where the dependent variable is the natural log of the investment size in startups' first round of VC financing. The sample in columns (1) - (3) includes all VC-backed startups that have raised their first VC funding between 2010 and 2018 and also have disclosed funding size. We include state and financing year fixed effects in column (1). We add industry group, the specific round (either Seed or Series A), and startup age fixed effects in column (2). We further add time-varying, state-year level controls in column (3). The results in the first three columns of Panel A suggest that there is a significant decrease in the amount of capital invested by VCs in startups' first financings following the implementation of the Volcker Rule. In particular, a one standard deviation increase in bank exposure leads to a smaller average amount of capital invested of about 7% (column (2)). This difference represents a \$0.4 million dollar fall in the average amount of capital invested in the first round of funding.

In the remaining columns of Panel A, we consider a few robustness tests for the main specification. In column (4), we exclude startups headquartered in CA from our sample. The coefficient estimate increases slightly in magnitude, suggesting that our result is not driven by startups located in CA. In column (5), we focus on a shorter sample period of 2011–2017 around the implementation of the Volcker Rule. The coefficient in column (5) is almost identical to the one in column (2) with the same specification. This suggests our result is not driven by events either at the beginning of our sample period, such as the 2008 financial crisis, or at the end of our sample period. In the last column of Panel A, we use the dummy treatment variable "Top Third" to compare the average amount of capital invested in startups that are located in the states in the top third of the bank exposure

distribution with those in the bottom third. The estimate remains negative with a large economic magnitude.[28]

Startup valuation is an important metric of the interaction between the supply of and demand for venture capital (Gompers and Lerner, 2000). Changes in valuation can reveal changes in the bargaining power of VCs and entrepreneurs. Panel B of Table 7 reports the estimation results of Eq. (1) for startups' pre-money valuation at the time of their first VC funding.[29] The specifications in all columns mirror those in Panel A of Table 7 except that the dependent variable has been replaced with the natural log of startup pre-money valuation. The sample consists of 5,903 VC-backed startups with reported valuations that have raised their first VC funding between 2010 and 2018 in the VentureSource database.[30] The results in the first three columns of Panel B suggest that there is a significant decrease in the pricing of startups post implementation of the Volcker Rule. In particular, for a one standard deviation increase in bank exposure in the home state, the average price of startups in their first funding is about 7% smaller (see column (2)). This difference represents a $1.1 million fall in the pricing of startups in their first round of funding. As in Panel A, we also consider robustness tests for the main specification, and the results, reported in the remaining columns of Panel B, all remain similar.

A comparison of the economic magnitudes estimated from Panels A and B of Table 7 suggests that the pricing of startups and the capital invested actually fell at a similar rate of around 7% for each one standard deviation increase in bank exposure, despite the fact

[28] In Figure B.6 and Panel B of Table B.2, we also examine the changes in the aggregate of capital invested in all initial VC financings and consistently find that the total initial capital invested in startups located in high exposure states were lower relative to those located in low exposure states post-Volcker Rule.

[29] The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round, expressed in millions of 2019 dollars. The pre-money valuation is the perceived NPV of the company before the capital injection, and hence it more accurately measures financing conditions faced by startups than post-money valuation.

[30] Valuation revelation is non-random (Ewens and Farre-Mensa, 2020) so the results use a positively selected set of startups. For these tests, we believe this attenuates our ability to find impacts because relatively higher valuation are most likely to be reported.

that the sample size in the two regressions differs dramatically. Since the fraction of equity shares sold to VC investors is equal to the amount of new capital invested divided by the sum of pre-money valuation and the amount of new capital invested, a similar rate of drop in pre-money valuation and new capital invested indicates that the fraction of equity shares sold to investors should not change. The estimation results in Panel C of Table 7 confirm this prediction.[31]

Taken together, the results in Table 7 show that startups inherit their VC investors' financial constraints: startups raise less money and face worse financing conditions after the Volcker Rule.

4.2 Financing round syndication

Having shown a decline in the amount of capital invested in startups' first VC funding, we also want to understand whether this is driven by having fewer VC investors investing or less capital invested by participating investors. To answer this question, we estimate Eq. (1) using the natural log of syndication size – the number of investors in the financing – in startups' initial VC financing round as the dependent variable. Syndication is common among VC investments, e.g., there are on average almost 3 VC investors in the first round of VC financing in our sample (Table 3).[32] Panel A of Table 8 reports the estimation results. The specifications in all columns also mirror those in Table 7. Across these specifications, we find that the number of VC investors that co-invest in a startup's first financing falls in states with higher bank exposure post rule change. These results provide direct evidence that the implementation of the Volcker Rule reduced the set of VC investors available to

[31] Since post-money valuation is the sum of pre-money valuation and the amount of new capital invested, a similar rate of drop in pre-money valuation and new capital invested indicates that post-money valuation should also fall by about 7%, which is indeed what the estimation in Panel A of Table B.3 suggests.

[32] Syndication is believed to bring a number of benefits to investors such as leading to better selection of investments, and it has been studied extensively in the literature (see e.g. Lerner, 1994; Nanda and Rhodes-Kropf, 2019).

startups to raise capital in regions more exposed to the impact of the rule change.[33] These findings are also consistent with our earlier results in Tables 4 and 6 that fewer VC funds in those regions are raised after the Volcker Rule.

4.3 Pre-VC financing

Last, we examine the changes in the characteristics of startups receiving their first VC funding around the Volcker Rule. A decrease in the supply of venture capital could lead VCs to invest in startups at earlier stages because they would require less capital. At the same time, startups at earlier stages are riskier, so if the set of startups demanding venture capital is unchanged, then VCs may choose to invest in startups with proven track records. Since startups typically lack products and revenue at the time of their first VC financing, an important track record benchmark is whether a startup has received funding from early-stage investors such as angels or accelerators (see e.g. Kerr, Lerner, and Schoar, 2014; Hochberg and Fehder, 2015; González-Uribe and Leatherbee, 2018). To assess the changes in the characteristics of startups funded by VCs, we estimate Eq. (1) using a dummy variable indicating whether a startup has received pre-VC financing (e.g., angel financing, grants or crowdfunding) as the dependent variable. The results, reported in Panel B of Table 8, show that VCs are more likely to invest in startups that have received pre-VC funding after the Volcker Rule in the states more exposed to the rule change. The economic magnitude is also large; for example, the result in column (6) shows that VCs in states with the highest bank exposure are about 5% more likely to invest in startups that have received pre-VC funding relative to states with the lowest bank exposure. Overall, the results in Panel B suggest that following the implementation of the Volcker Rule, VCs choose to invest in startups that have better track records and appear to be less risky, thus indicating a shift in VCs' investment

[33] In Panel B of Table B.3, we also find that conditional on financing, the average amount of capital invested per investor also falls after the implementation of the Volcker Rule.

strategies.

In Table B.4, we examine changes in more characteristics of VC-funded startups including whether a startup has a serial entrepreneur in its founding team as well as the startup's age at its first VC funding (Gompers, Kovner, Lerner, and Scharfstein, 2010). In Panel A of Table B.4, though the coefficients are largely statistically insignificant, they all remain positive and are consistent with the results in Panel B of Table 8. In Panel B of Table B.4, we find some evidence that VCs invest in slightly younger startups post-Volcker Rule in more affected states. Together with Table 8, these results suggest that VCs have shifted their investment strategies towards startups that are slightly younger, have better track records, and likely demand less capital. These new strategies may leave some riskier and more financially constrained startups, especially those located outside the traditional VC hubs, unable to receive the funding that is necessary to support their innovation and growth post-Volcker Rule.

In sum, the results in this section document that startups outside traditional VC hubs have been negatively impacted in their financing conditions and that the composition of startups funded by VCs has also changed after the implementation of the Volcker Rule. In combination with our earlier results on VC fundraising, the results demonstrate that startups absorb some of their VC investors' financing constraints. In turn, there are likely profitable investments and riskier startups unfunded in affected regions.[34]

[34] In the Internet Appendix IA2, as a robustness check, we repeat all our analyses so far using an instrumental variable approach as in Ewens and Farre-Mensa (2020). We find similar results that a shock on LPs' supply of capital impacts VC fundraising and startup financing.

5 Volume of Startup Financing and Mobility

5.1 Volume of startup financing

Previous sections show that both the aggregate of new venture capital raised and the average initial VC deal size fell after the Volcker Rule, but these results do not speak directly to the number of startups funded by VCs. First, the supply and demand for capital are measured according to different event times: the former is measured at the fund closing year, while the latter is at the startup financing year. VC funds closed in a given year are not fully responsible for the funding of startups that occur in the same year. VC funds typically spend their first few years investing in new startups, and startups funded after the Volcker Rule may have received their funding from funds closed before the Volcker Rule. Second, the change in the number of startups funded also depends on the relative magnitude of decline in the aggregate of venture capital raised and average financing deal size. Lastly, as our earlier results have already documented, VCs shift their investment strategies after the implementation of the Volcker Rule. In particular, they may become more likely to invest in less capital-intensive industries such as information technology (IT).

In Table 9, we investigate the changes in the number of startups funded by VCs in response to the Volcker Rule. The result in the first column shows that at the state-year level, there is an 11% increase in the number of first-time VC financings for each one standard deviation increase in VCs' bank exposure. In the second and third columns, we break up the sample by sector and examine the changes in the number of first-time VC financings in the IT sectors and in all other sectors. We find that the increase in the number of startups funded after the Volcker Rule is confined to IT industries that are relatively less capital-intensive.[35] The results in the first three columns suggest that VCs switched to less capital-intensive

[35] IT sectors are less capital-intensive in VC investing. For example, among the first VC financings, the capital raised by startups in the IT sectors only accounts for about 65% of that raised by startups in healthcare.

startups and their funds made relatively more investments. In the remaining columns of Table 9, we examine the impact of the Volcker Rule on alternative early-stage investments. We find no change in angel investments, though there is some evidence that crowdfunding events fell. Overall, the results show that the Volcker Rule has not impacted other types of early-stage financings directly; there is also no evidence that the impact of the rule on VC financings has spilled over to other early-stage financings.

In additional analysis, we examine the change in the quality of startups funded around the Volcker Rule. It is challenging to measure startup quality in the VC setting because the outcome is typically realized several years after the initial funding, and it is not always observable. These challenges are particularly acute in our setting because the post-Volcker period is still relatively short. Nevertheless, we conduct the analysis using a sample of VC funds that are raised in a narrower 2013–2016 window around the implementation of the Volcker Rule and examine their performance.[36] The estimation results are reported in Table 10. In the first three columns, we measure VC fund performance by the rate of successful exit through either an IPO or acquisition in 3 years post financing among the fund's portfolio companies. The results suggest that the quality of startups financed by VC funds raised after the Volcker Rule increases in states with higher bank exposure. In columns (4)-(6), we measure VC fund performance using a 4-year post-financing window and find similar results. In the last three columns, we measure VC fund performance by the multiples in average exit valuations over total capital invested and again find robust results.[37] Taken together, the findings in Table 10 suggest that startups financed in states with higher bank exposure are relatively more likely to have successful exits after the Volcker Rule change. Given that the treated states had disproportionately less VC pre-Volcker Rule and thus startups were

[36] We stop at 2016 because it is the last year that we can track funds' performance up to 4 years as of 2020.

[37] As robustness checks, we also conduct similar analyses using the binary treatment variable. The results in Table B.5 suggest our results are robust relative to the choice of specific treatment variable.

likely more constrained, the best interpretation of this increase in quality is that VCs are moving up the quality ladder and potentially leaving some positive NPV startups unfunded post-Volcker Rule.

5.2 Startup mobility

Although technology clusters such as Silicon Valley have played a central role in innovation and both regional and national economic activity (see e.g., Kerr and Robert-Nicoud, 2020), debates continue about the role of risk capital's availability in formation, growth and persistence of such clusters. Under the scenario where risk capital supply matters, damage to the financing environment of startups in states outside the traditional VC hubs could lead startups to move away from these states to VC clusters. This movement would only exacerbate geographic clustering. We have thus far documented real, negative consequences to the supply of VC for local startups post-Volcker. Our final analysis explores whether the increased financing constraints faced by startups in non-VC-hub states impacts high-growth startups' relocation to VC hubs.

We first ask whether startups in treated states with more exposure to the increased financing constraints are more likely to move to the persistently largest VC cluster in the US – California (also see Guzman, 2019). To do so, we construct a sample of startup mobility using address information on Form D filings (exemption from registration requests used by VC-backed startups). The Form D data provides detailed information on the startup's principal place of business, industry and incorporation year among those that have raised or seek to raise private capital. We exclude sectors where VC is less active: Agriculture, Banking & Financial Services, Energy, Real Estate, Restaurants and Travel from our analysis. A startup moves to CA if it files two consecutive Form Ds with the first showing a non-CA headquarter state and the second showing CA as the headquarter state.[38] Figure 7 provides descriptive

[38] Therefore, our sample of startups is conditional on having raised or seeking to raise at least two rounds

evidence that mobility responds to worse financing conditions. It shows the fraction of young firms moving from high-exposure (treated) states to CA each year among all similar firms moving to CA. Among all startups within 5 years old that move to California, the probability that they originate from one of the treated states increases by about 60% after the implementation of the Volcker Rule.[39] The results in Figure 7 show that the decrease in capital availability correlates with startups' relocation to states that were relatively less exposed to the rule change.

We next study startups' migration to VC hubs using a diff-in-diff analysis at the startup-year level. We construct a sample that includes both startup movers and non-movers to allow for a study of changes in startups' likelihood to move to VC hubs around the Volcker Rule. Specifically, we include all startups that are at most five years old in 2014 when the Volcker Rule passes (i.e., those incorporated during 2009–2013) and track them over the period of 2010–2018. The results, reported in the first two columns of Panel A of Table 11, show that the treated startups are more likely to move their headquarters to California, a state with the most abundant venture capital supply and with little exposure to the Volcker Rule (i.e., "High Expo X Post" is positive and significant).[40] The results are unchanged when we consider startup migration to VC hubs defined as the top three VC states including CA, MA and NY (columns (3)-(4)).[41] Lastly, as a placebo test, columns (5)-(6) consider startup migration to any other state. Reassuringly, treated startups have a similar likelihood to move across states compared to startups in the control group around the Volcker Rule.

of financings, i.e. filing two Form Ds.

[39] As a robustness check, we also examine a sample of startups that move to California within five years of filing their first Form D, and see a similar pattern.

[40] The main outcome variable for startups' migration is binary and a rare event. Therefore, to focus on the direction rather than magnitude of any effects our main specification uses the dummy treatment variable. The results are robust to the continuous treatment variable.

[41] Various VC metrics such as capital under management, capital commitments and total VC investments all consistently show that CA, MA and NY are the top three VC states. For example, in 2013, the year before the passage of the Volcker Rule, capital under management in the top three states are $94,076.6, $32,636.6, and $19,480.4 million, while the fourth state CT has $5,818.1 million (NVCA, 2014).

Taken together, startups in high exposure states are more likely to move to VC hubs after a negative shock on the supply of local venture capital.

In Panel B of Table 11, we examine the trend of startups' migration to VC hubs by estimating the dynamic version of Eq. (1). First, the results in columns (1) - (4) show that there is no pre-trend for startups' migration to CA, or VC hubs prior to the Volcker Rule. Second, the dynamic estimates only become gradually stronger after the Volcker Rule, suggesting that startups in the treated states have a delayed response to the implementation of the Volcker Rule. This is consistent with the idea that it takes time for startups to relocate to another state. In columns (5) - (6), similar as before, we examine startups' migration to any other state, and unsurprisingly find that the coefficients are insignificant for all years. Taken together, the results in Panel B of Table 11 corroborate the validity of our diff-in-diff specification and show that startups respond to the worsen financing environment by migrating to VC hubs after the implementation of the Volcker Rule.

As a robustness check, we conduct another diff-in-diff analysis for startups' migration to VC hubs using address information collected in the VentureSource database. The data are updated quarterly, therefore we conduct our analysis at the startup-quarter level. We focus on a set of startups that raised their first VC financing over the 2011–2013 pre-Volcker Rule period and track them over a window of quarters from 2013 to 2018 around the implementation of the Volcker Rule. The results, reported in Table 12, show that the treated startups are more likely to move their headquarters to VC hubs (columns (1)-(4)),[42] even though they have a similar likelihood to move across states compared to startups in the control group (columns (5)-(6)). Therefore, consistent with the results in Table 11, we find that startups in high exposure states are relatively more likely to move to VC hubs after the rule change.

In sum, these mobility results show that the Volcker Rule had meaningful general equi-

[42] In Figure B.8, we plot the coefficients from a similar dynamic specification and find no pre-trend for startup migration to VC hubs pre-Volcker Rule.

librium impacts on the allocation of startups across states. More generally, our results provide suggestive evidence that the supply of venture capital is an important driving force for entrepreneurship and innovation clustering among some other forces such as knowledge spillover or labor market pooling (see e.g. Marshall, 1890; Kerr and Robert-Nicoud, 2020).

5.3 SBIC venture funds

In previous sections, we document that the Volcker Rule reduces banks' VC investment, leading to fewer VC funds and less total venture capital raised in states with higher bank exposure. As discussed, banks may partially avoid these regulations by operating a SBIC venture fund for startup investing. In other words, banks can substitute their investments in VC funds by investing in SBIC funds to continue to provide capital for startups. In this scenario, startups located in these states may not inherit the financial constraints of their VC funders and thus may not be negatively impacted by the Volcker Rule. As a robustness check, we use a dataset on SBIC venture funds obtained from a FOIA request to the SBA, and directly examine the impact of the Volcker Rule on aggregate of SBIC venture fundraising activity.

Table 13 presents the estimation results from a diff-in-diff analysis at the state-year level. In the first two columns, we look at the changes in the overall SBIC funds that are raised before and after the Volcker Rule. We find no evidence that states more affected by the rule change behave differently from those less affected. In the last two columns, we specifically focus on the sample of bank-owned SBIC funds. Here we find some weak evidence that banks increased their operation of SBIC funds after the Volcker Rule. However, this increase started from a very low level. For example, there were only 11 bank-owned SBIC funds raised in 8 U.S. states over the four years (2010–2013) pre-Volcker Rule. Overall, we find no conclusive evidence that banks substituted VC funds with SBIC funds to continue providing capital for startups.

6 Conclusions

We investigate venture capital firm financing constraints and their impact on local startups. Following the implementation of the Volcker Rule in early 2014, banks were prohibited from investing in VC funds as limited partners. Their participation was predominantly in VC funds outside the VC hubs of California, Massachusetts and New York. Thus, this rule change disproportionately impacted regions where policymakers had worked hard to fill in funding gaps for both VCs and startups. The rule change led to fewer and smaller VC funds, while startups in the impacted states raised less money at worse valuations. The results show that VCs in the treated states are financially constrained and that startups can not completely cushion themselves. These negative impacts were predicted by several institutions during the finalizing of the Volcker Rule and motivated a strong lobbying effort by the VC industry. In late 2020, the SEC and Treasury scaled back these restrictions. With some time (ignoring the confounding Covid crisis), we may be able to disentangle whether this return to normal regulation will positively impact the effected states.

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7 Figures and Tables

Figure 1: Number and fraction of banks with VC revenue by reporting year

Notes: This figure plots the number and fraction of banks with VC revenue by reporting year from 2001 to 2018. The data come from banks' Call Reports. The vertical line represents the year 2013, the last year before the implementation of the Volcker Rule.

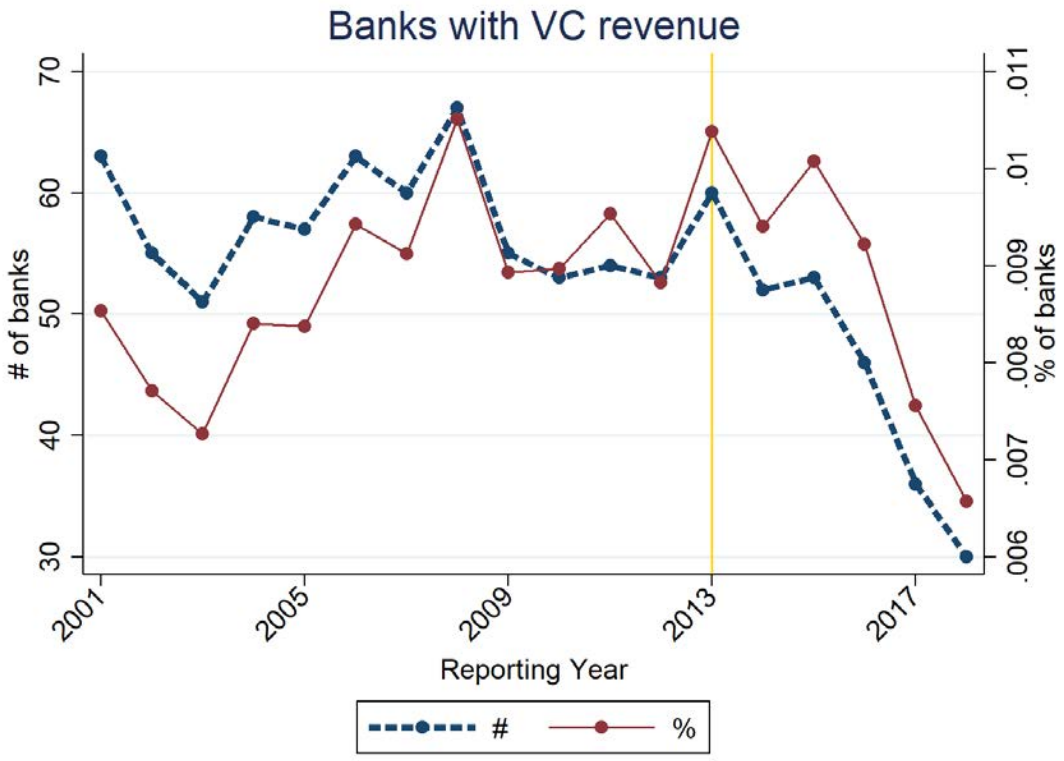

Figure 2: Bank exposure by U.S. region

Notes: This figure plots the average bank exposure by U.S. region. Bank exposure is computed at the state level as the number of bank-years with VC revenue over the 2001–2013 period scaled by the number of VC funds raised in the state during the same period.

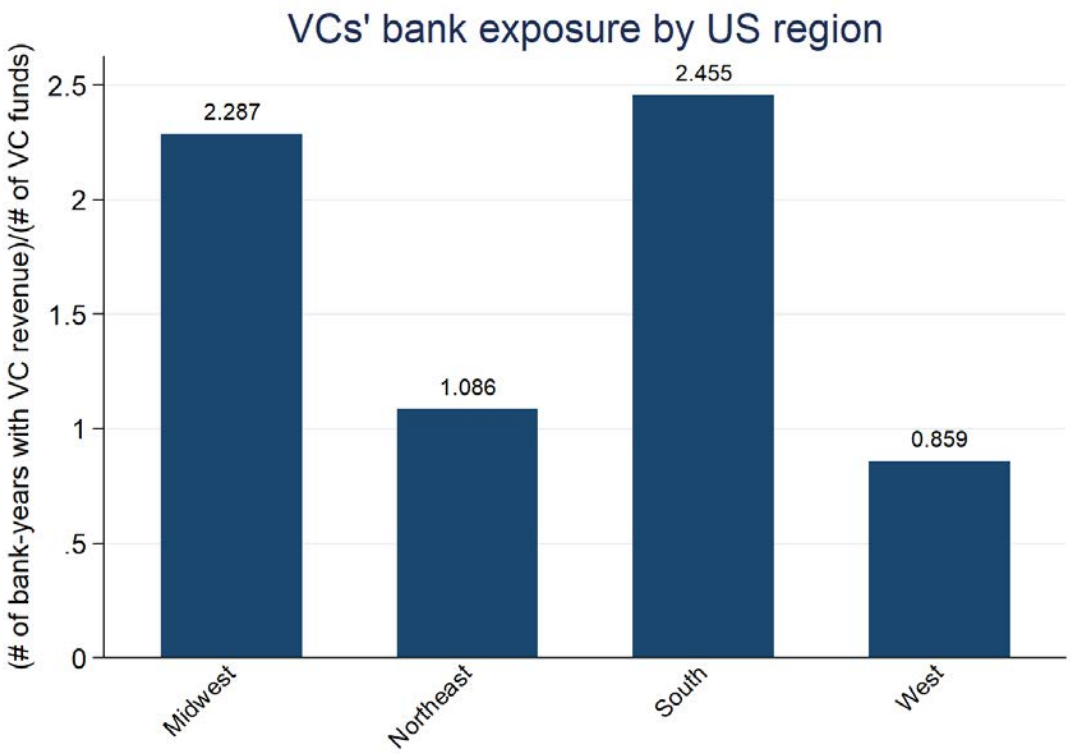

Figure 3: Bank exposure by U.S. state

Notes: This map shades each state and the District of Columbia according to our measure of bank exposure. States that do not have any VC funds raised over the 2010–2013 period are white.

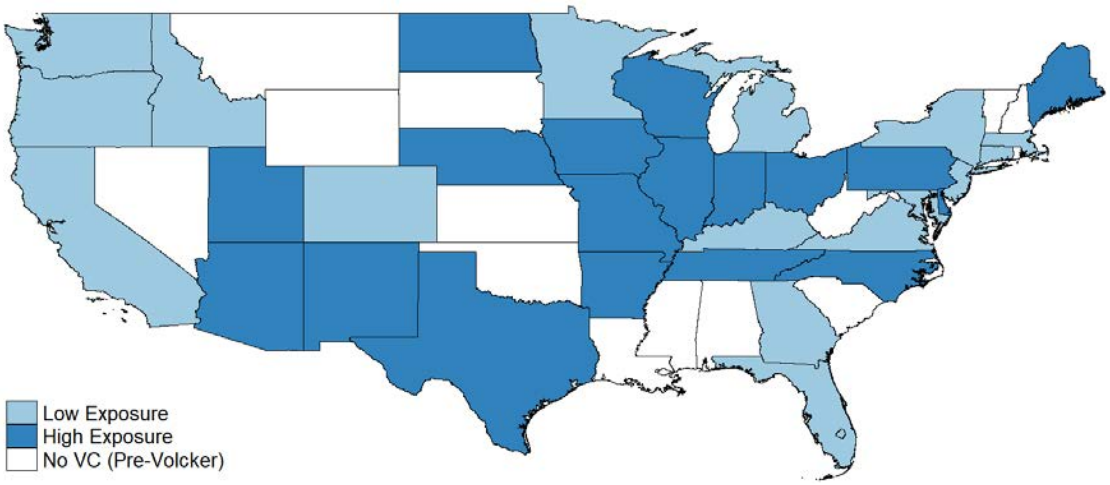

Figure 4: Bank exposure and VC imbalance

Notes: This figure presents the scatter plots of the bank exposure variable against state-level VC imbalance. VC imbalance is defined as the average ratio of a given state's VC market share (measured by the number of VC funds raised) over its GDP share, i.e. $(VC_{state}/VC_{US})/(GDP_{state}/GDP_{US})$ over the 2010–2013 period pre-Volcker Rule. The correlation between bank exposure and VC imbalance is −0.20.

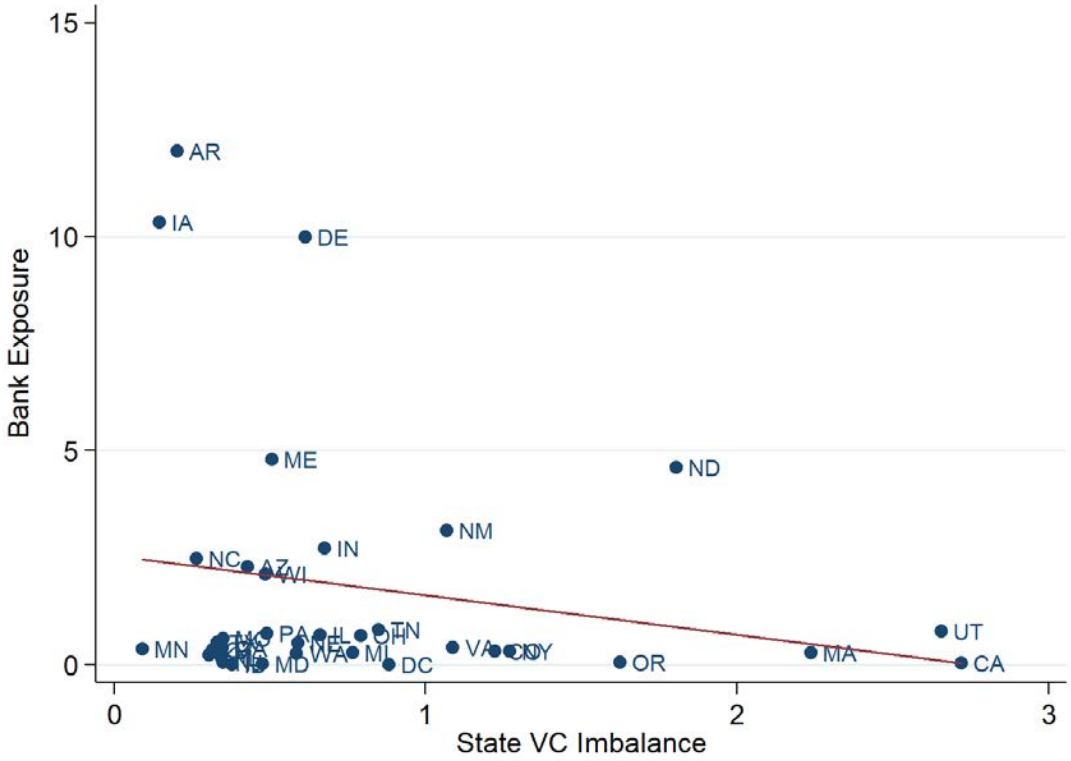

Figure 5: Difference-in-difference estimates for number of VC funds raised

Notes: This figure plots the coefficients for the interaction terms of each VC fund closing year and the bank exposure variable estimated from a dynamic version of Eq. (1) where the dependent variable is the natural log of one plus the number of VC funds raised. The 2013 interaction term is the excluded category, reported as zero in the figure. The vertical red lines represent the 95% confidence interval for the coefficient estimates with standard errors clustered by state.

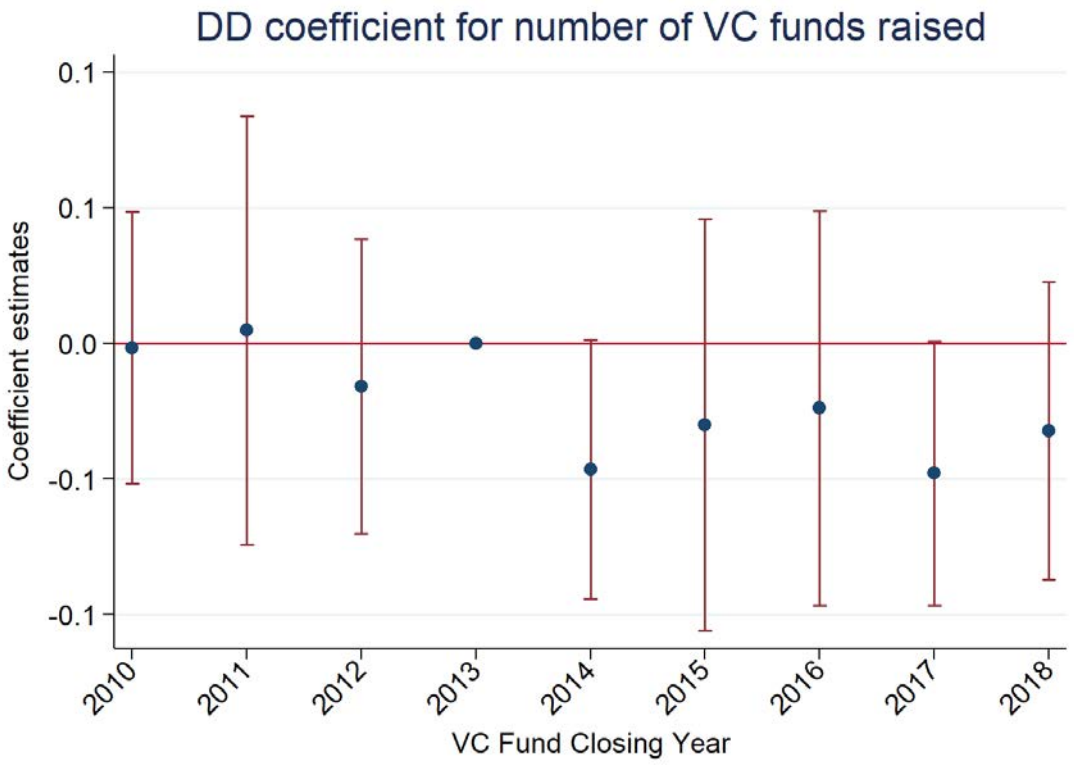

Figure 6: Number of VC funds by vintage year and bank exposure

Notes: This figure plots the number of VC funds raised by vintage year for the group of high and low bank exposure states, respectively. The sample includes all VC funds raised between 2010 and 2018 in the VentureSource database. A state is classified as a high exposure state if its bank exposure is above the median exposure of all states in our sample. The vertical line represents the year 2013, the last year before the implementation of the Volcker Rule.

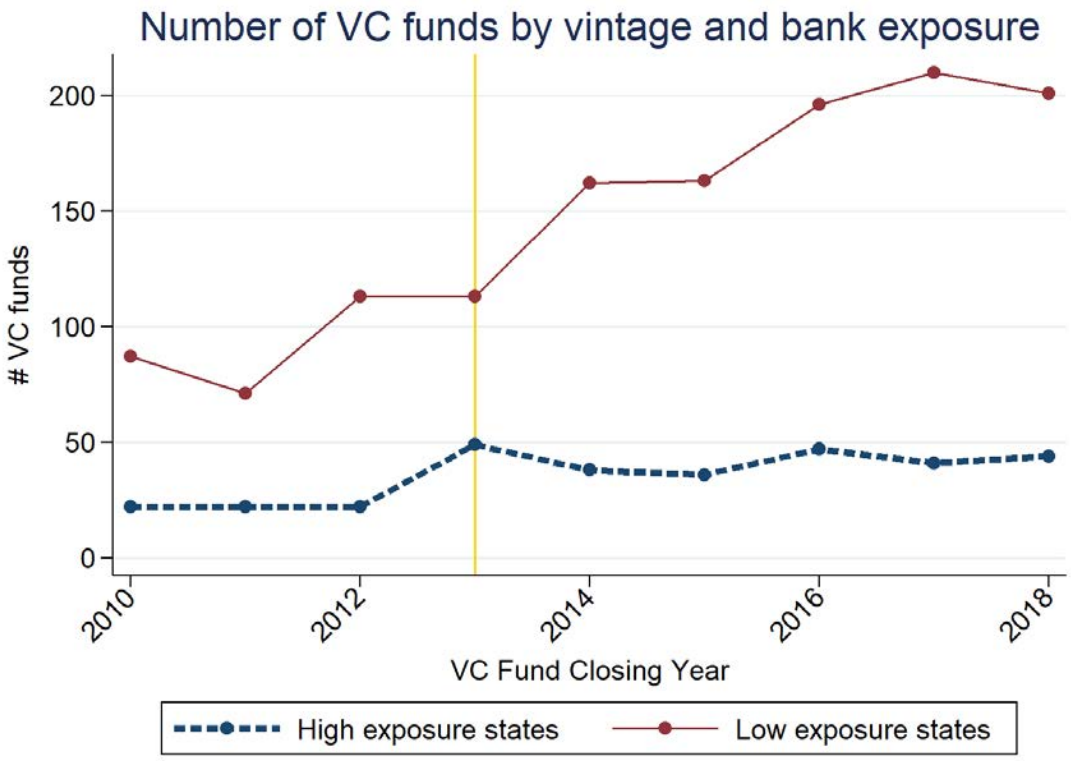

Figure 7: Startup migration from high-exposure states to California

Notes: This figure plots the fraction of young firms moving from high-exposure (treated) states to CA each year among all similar firms moving to CA. The sample is derived from Form D filings. A startup's relocation across states is measured using its two consecutive Form D filings that show different headquarter states, and the filing date of the second Form D is defined as the moving time (i.e. "moving in" time). The blue dashed line is plotted using the sample of movers that migrated within five years old as indicated in their Form D filing; the red solid line is plotted using the sample of movers that migrated within five years of filing their first Form D.

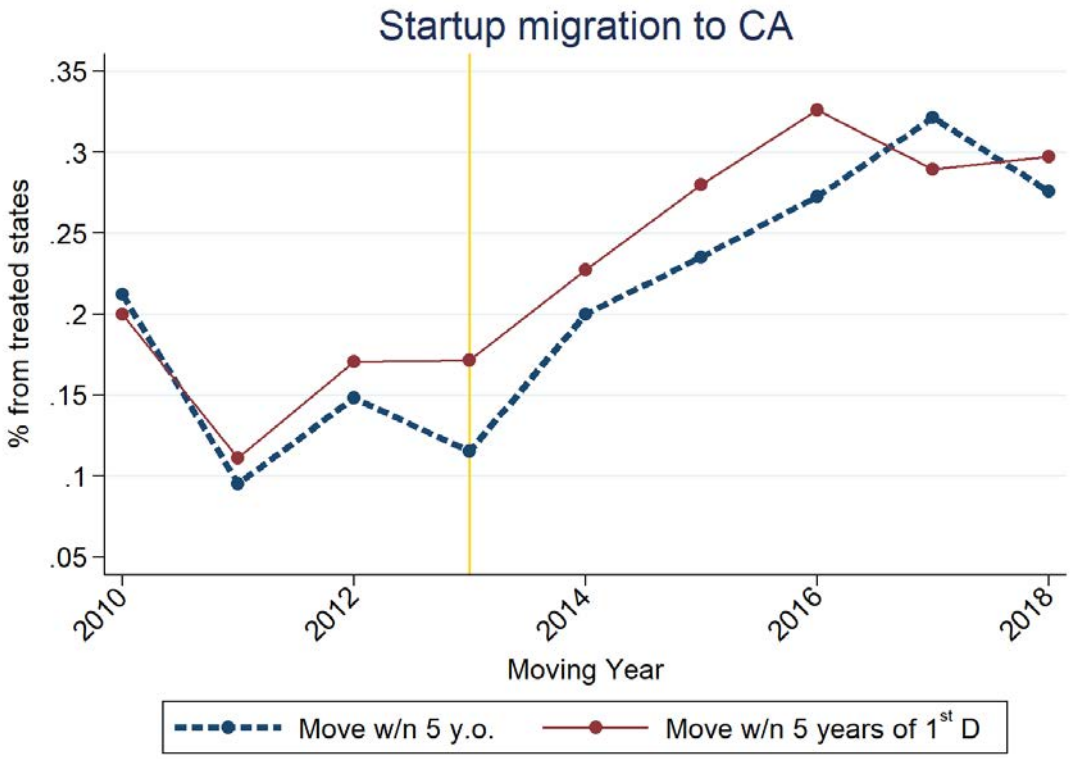

Table 1: Estimation of banks' capital share in total VC funds raised

Notes: This table reports the estimation of banks' investment position in VC and their capital share over total VC funds raised for different groups of U.S. states using data from the 2005–2007 period. For a given group of U.S. states, we estimate the aggregate of banks' net profits from their VC investments using VC revenue reported in Call Reports. We then back out banks' investment position in a given year by assuming a fixed annual return of 10%. We then scale this estimated banks' investment position by the aggregate of venture capital raised over a fixed window in the past to derive banks' capital share in total venture capital raised in a given year. Last, we average banks' investment position and their capital share over the 2005–2007 period. The results on banks' capital share in the last three columns are derived from scaling banks' investment position by the aggregate of venture capital raised in the past 5, 7 and 10 years, respectively.

	Bank Capital (Billions)	Share of Bank Capital (Over VC raised in past 5 years)	Share of Bank Capital (Over VC raised in past 7 years)	Share of Bank Capital (Over VC raised in past 10 years)
U.S.	11.8	8.1	3.8	2.8
High Exposure States	10.0	52.4	26.1	19.1
Low Exposure States	1.8	1.4	0.6	0.5
Midwest	3.1	25.1	13.5	9.9
South	5.7	36.6	15.3	11.5
Northeast	2.9	6.2	2.8	2.1
West	0.1	0.2	0.1	0.1

Table 2: Bank exposure by state

Notes: This table reports our treatment variables on VCs' bank exposure by state and the aggregate of VC fundraising around the implementation of the Volcker Rule. The pre-Volcker period is over 2010–2013 and the post-Volcker period is over 2014–2018. Total VC capital is expressed in billions of 2019 dollars. States that do not have any VC funds raised over the 2010–2013 period are excluded.

	Bank Exposure	High Exposure	Top Third	# VC funds (pre)	# VC funds (post)	Total VC Capital (pre)	Total VC Capital (post)
AR (S)	12.000	1	1	1	1	0.000	0.000
IA (MW)	10.333	1	1	1	0	0.002	0.000
DE (S)	10.000	1	1	1	2	0.114	0.033
ME (NE)	4.800	1	1	1	1	0.011	0.010
ND (MW)	4.600	1	1	3	3	0.051	0.051
NM (W)	3.143	1	1	3	0	0.046	0.000
IN (MW)	2.714	1	1	7	4	0.218	0.192
NC (S)	2.486	1	1	5	22	0.296	1.146
AZ (W)	2.286	1	1	4	5	0.078	0.131
WI (MW)	2.111	1	1	5	9	0.205	0.311
TN (S)	0.815	1	1	8	9	0.608	1.877
UT (W)	0.774	1	N/A	12	12	0.658	0.577
PA (NE)	0.727	1	N/A	11	20	1.275	1.820
IL (MW)	0.688	1	N/A	17	42	2.444	7.514
OH (MW)	0.672	1	N/A	15	31	0.249	1.280
MO (MW)	0.611	1	N/A	4	11	0.390	0.769
TX (S)	0.514	1	N/A	15	33	0.615	1.010
NE (MW)	0.500	1	N/A	2	1	0.023	0.032
VA (S)	0.396	0	N/A	16	11	0.802	1.144
GA (S)	0.389	0	N/A	6	12	0.260	0.666
MN (MW)	0.364	0	N/A	1	4	0.167	0.022
CT (NE)	0.346	0	N/A	3	7	1.102	0.400
NY (NE)	0.318	0	N/A	58	157	7.975	26.349
CO (W)	0.313	0	0	12	20	0.965	2.086
MI (MW)	0.280	0	0	11	12	0.311	0.655
MA (NE)	0.279	0	0	35	86	8.802	17.261
WA (W)	0.267	0	0	9	30	0.802	3.227
KY (S)	0.222	0	0	2	1	0.036	0.000
FL (S)	0.160	0	0	8	15	0.181	0.564
OR (W)	0.050	0	0	10	14	0.037	0.209
NJ (NE)	0.048	0	0	5	8	2.380	0.844
CA (W)	0.040	0	0	198	540	35.760	70.314
MD (S)	0.024	0	0	6	10	4.176	7.339
ID (W)	0.000	0	0	1	0	0.001	0.000
DC (S)	0.000	0	0	3	5	0.737	0.921

Table 3: Summary statistics

Notes: Panel A presents summary statistics of the variables relevant to the state-year level analysis. Panel B presents summary statistics of the variables relevant to the VC fund level analysis. Panel C presents summary statistics of the variables relevant to the VC-backed startup level analysis.

Panel A: At the state-year level

	N	Mean	Std. Dev.	5-%ile	25-%ile	50-%ile	75-%ile	95-%ile
# VC Funds	315	5.197	15.161	0.000	0.000	1.000	4.000	21.000
# Small Funds	315	2.454	7.524	0.000	0.000	1.000	2.000	11.000
# Medium Funds	315	1.413	4.264	0.000	0.000	0.000	1.000	6.000
# Large Funds	315	1.330	3.744	0.000	0.000	0.000	1.000	7.000
Total VC Capital (B)	315	0.700	2.231	0.000	0.000	0.045	0.279	3.633
Bank Exposure	315	1.808	3.021	0.000	0.267	0.500	2.286	10.333

Panel B: At the VC fund level

	N	Mean	Std. Dev.	5-%ile	25-%ile	50-%ile	75-%ile	95-%ile
VC Fund Size (B)	1617	0.136	0.328	0.000	0.005	0.035	0.134	0.559
VC Fund Sequence	1617	7.407	17.640	1.000	1.000	2.000	5.000	38.000
Located in CA	1617	0.453	0.498	0.000	0.000	0.000	1.000	1.000
Bank Exposure	1617	0.372	0.856	0.040	0.040	0.160	0.318	0.815

Panel C: At the startup level

	N	Mean	Std. Dev.	5-%ile	25-%ile	50-%ile	75-%ile	95-%ile
Capital Raised	11048	5.256	9.090	0.111	1.080	2.273	5.393	20.362
Pre-money Valuation (M)	5903	15.320	30.164	1.807	4.710	7.989	14.881	46.283
Post-money Valuation (M)	5903	21.487	36.739	2.816	6.694	11.414	22.476	65.186
Equity Sold	5903	0.289	0.153	0.083	0.190	0.267	0.354	0.590
Syndication Size	12788	2.718	2.112	1.000	1.000	2.000	4.000	7.000
Has Serial Entrepreneur	12788	0.165	0.371	0.000	0.000	0.000	0.000	1.000
Has Pre-VC	12788	0.244	0.429	0.000	0.000	0.000	0.000	1.000
Series A Round	12788	0.661	0.473	0.000	0.000	1.000	1.000	1.000
Age at Financing	12788	1.885	1.780	0.000	1.000	1.000	3.000	5.000
Located in CA	12788	0.462	0.499	0.000	0.000	0.000	1.000	1.000
Information Technology	12788	0.333	0.471	0.000	0.000	0.000	1.000	1.000
Bank Exposure	12788	0.349	0.948	0.040	0.040	0.160	0.318	0.774

Table 4: Changes in the aggregate of VC fundraising activity

Notes: This table presents diff-in-diff analyses examining the impact of the Volcker Rule on the aggregate of VC fundraising activity at the state-year level. Panel A reports the OLS regression results of estimating Eq. (1). The sample period is over 2010–2018 for all columns except columns (3) and (7) in which it is over 2011–2017. In columns (4) and (8), only states in the top and bottom third of the bank exposure distribution are included. The dependent variables are the natural log of one plus the number of VC funds raised in columns (1)-(4), and the natural log of one plus the aggregate amount of venture capital raised in columns (5)-(8). "Bank Expo" is a continuous treatment variable measuring VCs' reliance on banks for capital prior to the Volcker Rule. We also use a binary treatment variable "Top Third" in columns (4) and (8). "Post" is set to be 1 if the observation is after 2014, and 0 otherwise. All regressions include state fixed effects and fund closing year fixed effects. Panel B reports the estimation results of a dynamic version of Eq. (1) in which the lone interaction variable in Eq. (1) is replaced with a set of interaction variables between the bank exposure variable and year dummies; the interaction variable for 2013 is omitted to avoid multi-collinearity. The dependent variables are the same as in Panel A in the first two columns and are the natural log of one plus the count of VC funds in three identical groups that are defined by partitioning VC funds in each state according to their size in columns (3)-(5). ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by state.

Panel A: Number of VC funds and total VC capital raised

	ln(# VC Funds)				ln(Total VC Capital)			
	(1) All	(2) All	(3) 11-17	(4)	(5) All	(6) All	(7) 11-17	(8)
Bank Expo × Post	−0.033***	−0.032**	−0.033***		−0.011**	−0.011*	−0.010**	
	(0.012)	(0.013)	(0.012)		(0.005)	(0.005)	(0.005)	
Top Third × Post				−0.250				−0.074
				(0.163)				(0.052)
State GDP growth		0.005				−0.003		
		(0.012)				(0.006)		
Log of GDP p.c.		0.189				0.987		
		(1.014)				(0.704)		
Constant	1.080***	−0.982	1.102***	0.992***	0.279***	−10.438	0.285***	0.286***
	(0.012)	(11.019)	(0.012)	(0.043)	(0.005)	(7.644)	(0.005)	(0.014)
Observations	315	315	245	207	315	315	245	207
Adj. R^2	0.783	0.781	0.791	0.796	0.820	0.822	0.829	0.866
State FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y

Panel B: Dynamic estimation

	ln(# VC Funds)	ln(Total VC Capital)	ln(# VC Funds)		
	(1) All	(2) All	(3) small	(4) medium	(5) large
Bank Expo × Year= 2010	−0.001	0.006	0.005	0.012	0.002
	(0.023)	(0.008)	(0.025)	(0.023)	(0.017)
Bank Expo × Year= 2011	0.005	0.005	0.008	0.006	0.027
	(0.037)	(0.009)	(0.025)	(0.022)	(0.026)
Bank Expo × Year= 2012	−0.016	−0.001	0.016	−0.011	−0.007
	(0.025)	(0.007)	(0.030)	(0.021)	(0.017)
Bank Expo × Year= 2014	−0.046**	0.000	−0.038	−0.012	−0.000
	(0.022)	(0.006)	(0.023)	(0.021)	(0.016)
Bank Expo × Year= 2015	−0.030	−0.013	−0.008	−0.016	−0.020
	(0.035)	(0.009)	(0.034)	(0.022)	(0.018)
Bank Expo × Year= 2016	−0.024	−0.015*	−0.011	−0.003	−0.024
	(0.034)	(0.008)	(0.027)	(0.030)	(0.021)
Bank Expo × Year= 2017	−0.048**	−0.007	−0.032	−0.032	0.004
	(0.023)	(0.008)	(0.025)	(0.022)	(0.011)
Bank Expo × Year= 2018	−0.032	−0.008	−0.037	−0.001	−0.006
	(0.025)	(0.008)	(0.024)	(0.034)	(0.018)
Observations	315	315	315	315	315
Adj. R^2	0.778	0.816	0.685	0.683	0.717
State FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y

Table 5: Falsification tests with measures less impacted by the Volcker Rule

Notes: This table reports the falsification tests of our diff-in-diff model specified in Eq. (1) at the state-year level using measures of economic activities that are not directly related to VCs and presumably also less impacted by the Volcker Rule. The sample period is over 2010–2018 for all columns. The dependent variables are the natural log of one plus the average market valuation of VC-backed IPOs in column (1), the natural log of one plus the total market valuation of VC-backed IPOs in column (2), the natural log of one plus the number of VC-backed IPOs in column (3), the natural log of one plus the total number of patents filed by VC-backed companies in column (4), state GDP growth in column (5), and the natural log of state GDP per capita in column (6). "Bank Expo" is a continuous treatment variable measuring VCs' reliance on banks for capital prior to the Volcker Rule. "Post" is set to be 1 if the observation is after 2014, and 0 otherwise. All regressions include state fixed effects and year fixed effects. ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by state.

	IPO			Patents	GDP	
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(Avg. MktVal of VC-backed IPO)	ln(Total MktVal of VC-backed IPO)	ln(# of VC-backed IPO)	ln(# of Patents by VC-backed Companies)	State GDP Growth	Log of GDP p.c.
Bank Expo × Post	−0.001	−0.009	−0.008	−0.003	−0.137	−0.002
	(0.037)	(0.039)	(0.007)	(0.016)	(0.125)	(0.002)
Constant	2.407***	2.736***	0.538***	3.631***	2.161***	10.880***
	(0.037)	(0.039)	(0.007)	(0.017)	(0.125)	(0.002)
Observations	315	315	315	315	315	315
Adj. R^2	0.495	0.585	0.789	0.963	0.154	0.991
State FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y

Table 6: Changes in VC fundraising at the fund level

Notes: This table examines the impact of the Volcker Rule on VC fundraising activity at the VC fund level. Panel A reports the diff-in-diff estimation results of Eq. (1) where the dependent variable is the natural log of VC fund size. The sample period is over 2010–2018 for all columns except column (5) in which it is over 2011–2017. In column (4), VC funds based in California are excluded from the sample. In column (6), only VC firms that have raised at least one VC fund both before and after the Volcker Rule are included. "Bank Expo" is a continuous treatment variable measuring VCs' reliance on banks for capital prior to the Volcker Rule. "Post" is set to be 1 if the fund is raised after 2014, and 0 otherwise. "VC Firm FE" are VC firm fixed effects, "Vintage Year FE" indicate dummies for fund closing year, and "Fund Seq FE" are within-VC-firm fund sequence fixed effects. Panel B reports OLS estimation results of a single-difference regression at the VC firm level. The sample includes VC firms that have raised at least one VC fund over the pre-Volcker period (2010–2013). The dependent variables are dummy variables indicating whether a VC firm has raised a follow-on fund by a certain year between 2014 and 2018 over the post-Volcker period. "Year of Pre-Volcker Fund FE" indicate dummies for the last year the VC firm raised a fund over the pre-Volcker period 2010–2013. ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by VC firm in Panel A and by state in Panel B.

Panel A: VC fund size

	ln(VC Fund Size)					
	(1)	(2)	(3)	(4)	(5)	(6)
	All	All	All	w/o CA	11-17	Active VC
Bank Expo × Post	−0.198*	−0.216**	−0.241***	−0.262***	−0.237**	−0.204*
	(0.107)	(0.107)	(0.084)	(0.093)	(0.101)	(0.115)
State GDP growth			−0.047**			
			(0.023)			
Log of GDP p.c.			1.487			
			(2.469)			
Constant	−3.747***	−3.340***	−19.559	−3.607***	−3.400***	−3.037***
	(0.024)	(0.026)	(27.112)	(0.038)	(0.026)	(0.022)
Observations	1,617	1,617	1,617	884	1,265	740
Adj. R^2	0.833	0.783	0.783	0.789	0.795	0.775
VC Firm FE	Y	Y	Y	Y	Y	Y
Vintage Year FE	Y	Y	Y	Y	Y	Y
Fund Seq FE	N	Y	Y	Y	Y	Y

Panel B: Probability of raising a new fund after the Volcker Rule

	Raising Fund after the Volcker Rule				
	(1)	(2)	(3)	(4)	(5)
	(By 2014)	(By 2015)	(By 2016)	(By 2017)	(By 2018)
Bank Expo	−0.027***	−0.035	−0.045*	−0.038	−0.044
	(0.009)	(0.022)	(0.025)	(0.026)	(0.026)
Observations	395	395	395	395	395
Adj. R^2	0.032	0.020	0.036	0.047	0.049
Year of Pre-Volcker Fund FE	Y	Y	Y	Y	Y
Mean of Dep. Var.	0.137	0.284	0.392	0.478	0.519

Table 7: Impacts on startup financing size and pre-money valuation

Notes: This table presents diff-in-diff analyses examining the impact of the Volcker Rule on startup financing at the startup level. Specifically, each panel reports the OLS regression results of estimating Eq. (1) with a different dependent variable: the natural log of capital raised in the startup's first VC funding in Panel A, the natural log of pre-money valuation in Panel B, and the fraction of equities sold to VC investors in Panel C. The sample period is over 2010–2018 for all columns except column (5) in which the sample period is over 2011–2017. In column (4), startups headquartered in California are excluded from the sample. In column (6), only startups headquartered in states in the top and bottom third of the bank exposure distribution are included. "Bank Expo" is a continuous treatment variable measuring VCs' reliance on banks for capital prior to the Volcker Rule. The binary treatment variable "Top Third" is used in column (6). "Post" is set to be 1 if the startup raised its first VC financing after 2014, and 0 otherwise. "State FE", "Financing Year FE", "Industry FE", "Series A or Seed FE", and "Startup Age FE" indicate dummies for a startup's headquarter state, year receiving their first VC financing, industry group, a Series A or Seed round in its first VC financing, and age at its first VC financing, respectively. ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by startup headquarter state.

Panel A: First venture capital raised

	ln(Capital Raised)					
	(1)	(2)	(3)	(4)	(5)	(6)
	All	All	All	w/o CA	11-17	
Bank Expo × Post	−0.074***	−0.071***	−0.086***	−0.090***	−0.074***	
	(0.025)	(0.023)	(0.022)	(0.024)	(0.021)	
Top Third × Post						−0.178
						(0.141)
State GDP growth			0.020**			
			(0.009)			
Log of GDP p.c.			−1.781**			
			(0.792)			
Constant	0.769***	0.768***	20.293**	0.649***	0.728***	0.871***
	(0.005)	(0.005)	(8.694)	(0.009)	(0.004)	(0.006)
Observations	11,048	11,048	11,048	6,056	8,999	7,685
Adj. R^2	0.079	0.275	0.276	0.290	0.279	0.255
State FE	Y	Y	Y	Y	Y	Y
Financing Year FE	Y	Y	Y	Y	Y	Y
Industry FE	N	Y	Y	Y	Y	Y
Series A or Seed FE	N	Y	Y	Y	Y	Y
Startup Age FE	N	Y	Y	Y	Y	Y

Panel B: Pre-money valuation

	ln(Pre-money Valuation)					
	(1)	(2)	(3)	(4) w/o	(5)	(6)
	All	All	All	CA	11-17	
Bank Expo × Post	−0.056	−0.076**	−0.106***	−0.109***	−0.081**	
	(0.043)	(0.030)	(0.029)	(0.027)	(0.032)	
Top Third × Post						−0.244***
						(0.082)
State GDP growth			−0.003			
			(0.006)			
Log of GDP p.c.			−1.611**			
			(0.643)			
Constant	2.155***	2.159***	19.876***	2.052***	2.161***	2.213***
	(0.008)	(0.005)	(7.065)	(0.009)	(0.006)	(0.002)
Observations	5,903	5,903	5,903	3,031	4,955	4,239
Adj. R^2	0.064	0.202	0.203	0.202	0.189	0.196

Panel C: Fraction of equity sold

	Equity Sold					
	(1)	(2)	(3)	(4) w/o	(5)	(6)
	All	All	All	CA	11-17	
Bank Expo × Post	−0.004	−0.003	−0.003	−0.002	−0.002	
	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)	
Top Third × Post						−0.001
						(0.031)
State GDP growth			0.002*			
			(0.001)			
Log of GDP p.c.			−0.086			
			(0.109)			
Constant	0.289***	0.289***	1.230	0.297***	0.285***	0.292***
	(0.001)	(0.001)	(1.194)	(0.002)	(0.001)	(0.001)
Observations	5,903	5,903	5,903	3,031	4,955	4,239
Adj. R^2	0.043	0.166	0.166	0.171	0.158	0.183
State FE	Y	Y	Y	Y	Y	Y
Financing Year FE	Y	Y	Y	Y	Y	Y
Industry FE	N	Y	Y	Y	Y	Y
Series A or Seed FE	N	Y	Y	Y	Y	Y
Startup Age FE	N	Y	Y	Y	Y	Y

Table 8: Impacts on additional startup-level outcomes

Notes: Using the same specifications as Table 7, this table presents diff-in-diff analyses examining the impact of the Volcker Rule on additional startup-level outcomes. Specifically, this table reports the OLS regression results of estimating Eq. (1) with the following dependent variables: the log of the number of investors (syndication size) in Panel A and a dummy variable indicating whether the startup has received financing from other non-VC investors (e.g., angels or crowdfunding) before its first VC funding in Panel B.

Panel A: Syndication size

	ln(Syndication Size)					
	(1)	(2)	(3)	(4)	(5)	(6)
	All	All	All	w/o CA	11-17	
Bank Expo × Post	−0.026**	−0.025**	−0.028**	−0.028**	−0.019*	
	(0.011)	(0.011)	(0.011)	(0.011)	(0.010)	
Top Third × Post						−0.081
						(0.075)
State GDP growth			0.004			
			(0.004)			
Log of GDP p.c.			−0.329			
			(0.226)			
Constant	0.756***	0.756***	4.366*	0.707***	0.756***	0.770***
	(0.003)	(0.003)	(2.476)	(0.005)	(0.002)	(0.003)
Observations	12,788	12,788	12,788	6,881	10,390	8,922
Adj. R^2	0.041	0.054	0.054	0.064	0.058	0.044

Panel B: Startups' pre-VC financing

	Has Pre-VC Financing					
	(1)	(2)	(3)	(4)	(5)	(6)
	All	All	All	w/o CA	11-17	
Bank Expo × Post	0.009***	0.012***	0.011**	0.015***	0.006*	
	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	
Top Third × Post						0.048*
						(0.026)
State GDP growth			−0.001			
			(0.002)			
Log of GDP p.c.			−0.088			
			(0.188)			
Constant	0.241***	0.241***	1.216	0.261***	0.233***	0.236***
	(0.001)	(0.001)	(2.067)	(0.002)	(0.001)	(0.001)
Observations	12,788	12,788	12,788	6,881	10,390	8,922
Adj. R^2	0.040	0.123	0.123	0.131	0.110	0.127
State FE	Y	Y	Y	Y	Y	Y
Financing Year FE	Y	Y	Y	Y	Y	Y
Industry FE	N	Y	Y	Y	Y	Y
Series A or Seed FE	N	Y	Y	Y	Y	Y
Startup Age FE	N	Y	Y	Y	Y	Y

Table 9: Volume of VC and non-VC investments

Notes: This table presents diff-in-diff analyses examining the impact of the Volcker Rule on the number of investments made by different types of early-stage investors at the state-year level. Specifically, it reports OLS regression results of estimating Eq. (1) over the 2010–2018 period with the following dependent variables: the natural log of one plus the number of startups receiving their first VC financing in column (1), the natural log of one plus the number of startups in the IT sectors receiving their first VC financing in column (2), the natural log of one plus the number of startups in the non-IT sectors receiving their first VC financing in column (3), the natural log of one plus the number of all non-VC financing events (the sum of angel, crowdfunding, ICO, and seed events) in column (4), the natural log of one plus the number of angel financing events in column (5), and the natural log of one plus the number of crowdfunding events in column (6). "Bank Expo" is a continuous treatment variable measuring VCs' reliance on banks for capital prior to the Volcker Rule. "Post" is set to be 1 if the observation is after 2014, and 0 otherwise. All regressions include state fixed effects and year fixed effects. ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by state.

	VC			Non-VC		
	(1)	(2)	(3)	(4)	(5)	(6)
	ln(# initial VC)	ln(# initial VC in IT)	ln(# initial VC in others)	ln(# Non-VC Events)	ln(# Angel Events)	ln(# CF Events)
Bank Expo × Post	0.034**	0.038**	0.006	0.017	−0.000	−0.051***
	(0.016)	(0.016)	(0.016)	(0.038)	(0.040)	(0.016)
State GDP growth	−0.007	0.010	−0.014	0.010	0.015	−0.009
	(0.013)	(0.011)	(0.015)	(0.016)	(0.017)	(0.014)
Log of GDP p.c.	−0.914	−0.893	−0.429	−1.492	−1.587	1.862
	(0.866)	(1.204)	(0.704)	(1.052)	(1.040)	(1.547)
Constant	12.445	11.201	6.912	18.216	18.980	−19.959
	(9.408)	(13.077)	(7.655)	(11.410)	(11.274)	(16.794)
Observations	315	315	315	315	315	315
Adj. R^2	0.936	0.898	0.921	0.838	0.812	0.533
State FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y

Table 10: VC fund performance around the Volcker Rule

Notes: This table presents diff-in-diff analyses investigating VC fund performance using the sample of VC funds raised over 2013–2016 around the Volcker Rule. Specifically, the table reports OLS regression results of estimating Eq. (1) at the VC fund level. VC fund performance is measured by the rate of successful exit through either an IPO or acquisition in 3 years post financing in columns (1)-(3), in 4 years post financing in columns (4)-(6), multiples in average exit valuation over total capital invested in column (7), and the natural log of multiples in average exit valuation over total capital invested in columns (8)-(9). "Bank Expo" is a continuous treatment variable measuring VCs' reliance on banks for capital prior to the Volcker Rule. "Post" is set to be 1 if the VC fund is closed after 2014, and 0 otherwise. "VC Firm FE" are VC firm fixed effects, "Vintage Year FE" indicate dummies for fund closing year, and "Fund Seq FE" are within-VC-firm fund sequence fixed effects. "Late Stage Financing" measures the fraction of the fund's deals that are late-stage. ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by VC firm.

	% of IPO/Acq in 3 years			% of IPO/Acq in 4 years			Multiples in Valuation over Invested		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All	All	All	All	All	All	raw	log	log
Bank Expo × Post	0.174	0.337**	0.227	0.414*	0.575**	0.505*	15.998*	3.888**	4.562***
	(0.149)	(0.156)	(0.213)	(0.208)	(0.274)	(0.288)	(7.438)	(0.990)	(0.844)
Late Stage Financing			0.200			0.176			−1.165***
			(0.137)			(0.180)			(0.276)
State GDP growth			0.000			−0.030			
			(0.054)			(0.074)			
Log of GDP p.c.			−2.804			−6.058			
			(2.858)			(4.093)			
Constant	0.218***	0.143***	30.894	0.221***	0.147**	66.750	0.828	0.608***	1.387***
	(0.030)	(0.033)	(31.325)	(0.042)	(0.058)	(44.871)	(1.375)	(0.094)	(0.280)
Observations	205	205	205	205	205	205	82	72	72
Adj. R^2	0.628	0.493	0.481	0.518	0.288	0.346	0.866	0.974	0.968
VC Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vintage Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fund Seq FE	N	Y	Y	N	Y	Y	N	N	N
Mean of Dep. Var.	0.253	0.253	0.253	0.305	0.305	0.305	3.785	0.978	0.978
S.D. of Bank Expo	0.249	0.249	0.249	0.249	0.249	0.249	0.199	0.131	0.131

Table 11: Startup migration conditional on raising private capital

Notes: This table presents diff-in-diff analyses examining the impact of the Volcker Rule on startups' migration to VC hubs at the startup-year level. The sample is derived from Form D filings, and includes startups that have raised (or seek to raise) private capital identified by a filing of Form D. We focus on startups that are at most five years old in 2014 when the treatment starts, i.e. those incorporated during 2009–2013, and track them over the period of 2010–2018. In columns (2), (4) and (6), only startups that have ever moved to another state are included. Panel A reports the OLS regression results of estimating Eq. (1). The dependent variables are: a dummy variable indicating whether the startup has moved its headquarter to CA in columns (1)-(2), a dummy variable indicating whether the startup has moved its headquarter to one of the VC hubs including CA, MA and NY in columns (3)-(4), and a dummy variable indicating whether the startup has moved its headquarter to another state in columns (5)-(6). "High Expo" is a dummy treatment variable indicating whether the startup is headquartered in a state with high bank exposure prior to the Volcker Rule. "Post" is set to be 1 if the observation is after 2014, and 0 otherwise. "Year FE", "Industry FE", "Incorporation State FE", and "Incorporation Year FE" indicate dummies for the tracking year, a startup's industry group, incorporation state, and incorporation year, respectively. Panel B reports the estimation results of a dynamic version of Eq. (1) in which the lone interaction variable in Eq. (1) is replaced with a set of interaction variables between the high bank exposure variable and year dummies; the interaction variable for 2013 is omitted to avoid multi-collinearity. The dependent variables mirror those in Panel A. ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by startup.

Panel A: Startup migration based on Form D filings

	Moved to CA		Moved to VC hubs		Moved to Another State (Placebo)	
	(1) All	(2) cond. on moving	(3) All	(4) cond. on moving	(5) All	(6) cond. on moving
High Expo × Post	0.004***	0.053**	0.005**	0.065**	0.005	0.043
	(0.001)	(0.021)	(0.002)	(0.028)	(0.003)	(0.035)
High Expo	−0.001	−0.017	−0.000	−0.016	−0.002	−0.025
	(0.001)	(0.014)	(0.001)	(0.020)	(0.002)	(0.026)
Constant	0.003***	0.047***	0.006***	0.098***	0.015***	0.232***
	(0.000)	(0.005)	(0.001)	(0.006)	(0.001)	(0.006)
Observations	34,900	2,303	34,900	2,303	34,900	2,303
Adj. R^2	0.000	0.003	0.001	0.002	0.002	-0.009
Year FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
Incorporation State FE	Y	Y	Y	Y	Y	Y
Incorporation Year FE	Y	Y	Y	Y	Y	Y
Mean of Dep. Var.	0.003	0.051	0.007	0.103	0.015	0.233

Panel B: Dynamic estimation

	Moved to CA		Moved to VC hubs		Moved to Another State (Placebo)	
	(1) All	(2) cond. on moving	(3) All	(4) cond. on moving	(5) All	(6) cond. on moving
High Expo × Year= 2010	0.004	0.100	0.003	0.064	−0.001	−0.038
	(0.003)	(0.065)	(0.003)	(0.073)	(0.005)	(0.099)
High Expo × Year= 2011	0.000	0.000	0.001	0.025	−0.000	−0.011
	(0.002)	(0.027)	(0.003)	(0.050)	(0.005)	(0.084)
High Expo × Year= 2012	0.000	0.008	0.003	0.056	0.002	0.053
	(0.002)	(0.032)	(0.003)	(0.053)	(0.005)	(0.086)
High Expo × Year= 2014	0.004*	0.069*	0.005	0.089	0.005	0.067
	(0.003)	(0.042)	(0.003)	(0.055)	(0.005)	(0.081)
High Expo × Year= 2015	0.002	0.031	0.002	0.036	−0.001	−0.035
	(0.003)	(0.037)	(0.004)	(0.052)	(0.005)	(0.074)
High Expo × Year= 2016	0.008**	0.099**	0.010**	0.128**	0.006	0.052
	(0.004)	(0.046)	(0.005)	(0.059)	(0.006)	(0.082)
High Expo × Year= 2017	0.005	0.064	0.009*	0.119**	0.011	0.120
	(0.004)	(0.042)	(0.005)	(0.060)	(0.008)	(0.092)
High Expo × Year= 2018	0.006	0.070	0.009	0.113*	0.010	0.091
	(0.005)	(0.051)	(0.006)	(0.066)	(0.010)	(0.097)
Observations	34,900	2,303	34,900	2,303	34,900	2,303
Adj. R^2	0.000	0.003	0.001	0.001	0.002	-0.010
Year FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
Incorporation State FE	Y	Y	Y	Y	Y	Y
Incorporation Year FE	Y	Y	Y	Y	Y	Y

Table 12: Startup migration conditional on VC financing

Notes: This table presents diff-in-diff analyses investigating VC-backed startups' migration across states at the startup-quarter level. A startup's relocation across states is tracked using address information quarterly updated by the VentureSource database. The sample includes startups that raised their first VC financing over the 2011–2013 period. The startups are tracked over the quarters of 2013Q2–2018Q4 for all columns. In columns (2), (4) and (6), only startups that have ever moved to another state are included. The dependent variables are: a dummy variable indicating whether the startup has moved its headquarter to CA in columns (1)-(2), a dummy variable indicating whether the startup has moved its headquarter to one of the VC hubs including CA, MA and NY in columns (3)-(4), and a dummy variable indicating whether the startup has moved its headquarter to another state in columns (5)-(6). "High Expo" is a dummy treatment variable indicating whether the startup is headquartered in a state with high bank exposure prior to the Volcker Rule. "Post" is set to be 1 if the observation is after 2014, and 0 otherwise. "Quarter FE", "Financing Year FE" and "Industry FE" indicate dummies for the tracking quarter, year receiving the first VC financing, and a startup's industry group, respectively. ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by startup.

	Moved to CA		Moved to VC hubs		Moved to Another State (Placebo)	
	(1) All	(2) cond. on moving	(3) All	(4) cond. on moving	(5) All	(6) cond. on moving
High Expo × Post	0.001***	0.013***	0.001***	0.024***	−0.001	−0.015
	(0.000)	(0.005)	(0.000)	(0.006)	(0.001)	(0.017)
High Expo	−0.001***	−0.012***	−0.001***	−0.027***	0.001	0.010
	(0.000)	(0.004)	(0.000)	(0.005)	(0.001)	(0.015)
Constant	0.001***	0.012***	0.001***	0.023***	0.002***	0.047***
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Observations	159,152	8,182	159,152	8,182	159,152	8,182
Adj. R^2	0.000	0.006	0.000	0.011	0.001	0.025
Quarter FE	Y	Y	Y	Y	Y	Y
Financing Year FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
Mean of Dep. Var.	0.001	0.012	0.001	0.022	0.002	0.046

Table 13: Aggregate of SBIC venture fundraising activities

Notes: This table presents diff-in-diff analyses examining the impact of the Volcker Rule on the aggregate of SBIC venture fundraising activity at the state-year level over the 2010–2018 period. Specifically, it reports the OLS regression results of estimating Eq. (1) with the following dependent variables: the natural log of one plus the number of SBIC venture funds raised in column (1), a dummy variable indicating whether there is a SBIC venture fund raised in column (2), the natural log of one plus the number of bank-affiliated SBIC venture funds raised in column (3), and a dummy variable indicating whether there is a bank-affiliated SBIC venture fund raised in column (4). The data come from a FOIA request to the SBA and include all VC funds that participate in the SBIC program. "Bank Expo" is a continuous treatment variable measuring VCs' reliance on banks for capital prior to the Volcker Rule. "Post" is set to be 1 if a SBIC venture fund is raised after 2014, and 0 otherwise. All regressions include state fixed effects and fund closing year fixed effects. ***, **, and * correspond to statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors in parentheses are clustered by state.

	(1) ln(# SBIC)	(2) Raised SBIC?	(3) ln(# Bank-owned SBIC)	(4) Raised Bank-owned SBIC?
Bank Expo × Post	0.017	0.012	0.005*	0.006*
	(0.014)	(0.017)	(0.003)	(0.004)
Constant	0.371***	0.379***	0.030***	0.041***
	(0.014)	(0.017)	(0.003)	(0.004)
Observations	315	315	315	315
Adj. R^2	0.471	0.277	0.115	0.135
State FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y

A Appendix: Venture Capital Revenue

According to the FFIEC instructions on filing Call Reports, bank investments in VC funds with non-controlling stakes should adopt the equity method of accounting. Under this method, the carrying value of a bank's investment in a VC fund is originally recorded at cost but is adjusted periodically to record as income the bank's proportionate share of the fund's earnings or losses and decreased by the amount of cash dividends or similar distributions received from the fund.

Capturing earnings or losses from their VC investments, venture capital revenue is reported by banks on their Call Reports as part of non-interest income since 2001. To better understand the sources of this income, consider an example in which a bank invests as an LP into VC fund X. They invest \$I and receives 20% of the fund (i.e. they are 20% of total committed capital), and the bank's equity position in the fund is 20% of all proceeds up to \$I/0.2, and 80%*20% of all distributions after \$I is paid back (i.e., 20% carry). The fund has a 2% annual fee on committed capital, i.e., \$I*0.02 is paid by the bank every year. For the bank's VC investments in fund X, we can then analyze whether there will be venture capital revenue booked for different types of events.

1. *Capital commitment:* After the bank makes capital commitments to VC fund X and signs the commitment agreement, the bank has a legal liability to pay \$I to the fund over the next 10 years. However, if this commitment does not come with an initial cash transfer, then there will be no accounting entries on the bank's accounting books, and no venture capital revenue booked. On the other hand, if it does come with a cash transfer (as initial investment), it is equivalent to a capital call (analyzed below). Under the equity method of accounting, the bank will record this initial investment in its long-term equity investment account, but will not book any venture capital revenue.
2. *Management fee:* After VC fund X starts operating, the bank pays the fund \$I*0.02

each year for the cost of managing the fund. Paid out of the original capital commitment $I, the management fee is considered part of the investment cost and will not have venture capital revenue effect. Therefore, it will not be booked as venture capital revenue.

3. *Capital calls (Drawdown):* Suppose fund X makes a capital call of $Z. After receiving a notice of the capital call from the fund, the bank will transfer the cash of $Z to the fund within a given time. Then the bank will increase the carrying value of its VC investments by $Z in its long-term equity investment account. In this case, the bank will not book any venture capital revenue. Note that the sum of all calls will be $(I - 0.02*10*I) (i.e., invested capital).
4. *VC marks up or down the investment:* Suppose at the end of each quarter, VC fund X marks up or down the bank's investment from $Z to $Z+m, where m can be positive or negative. According to the U.S. Financial Accounting Standards Board (FASB) accounting standards (see Topic 946, the AICPA Audit and Accounting Guide, Investment Companies), VC funds are treated as investment companies for accounting purposes and thus will use the fair value method of accounting. Under this method, when the VC fund marks up or down the investment, the VC fund will record the change on its own accounting books either as income or losses. Because the bank uses the equity method of accounting, it will accordingly record the adjustments $m as venture capital revenue.
5. *Capital distribution:* Suppose VC fund X sells its investments (e.g. after a portfolio company exit) at a price $Z+m+n (the bank's proportionate share), and the bank receives a capital distribution (cash) in that amount. In this case, the bank will reduce the carrying value of its VC investments from $Z+m to 0 in its long-term equity investment account. At the same time, the bank will book the extra $n (it can be either positive or negative) as venture capital revenue. Note that after the capital

distribution, the bank's position in VC fund X is no longer active.

6. *The bank (either partially or fully) sells it position in the fund:* Suppose the bank has a position left in the VC fund at time t with original book value of 4*$Z and current carrying value of $Y, and then the bank sells that position in the VC fund for $V. In this case, after the bank sells its position, the bank reduces the carrying value of its VC investments from $Y to 0 and records the difference between $Y and $V, i.e. $(V-Y) as venture capital revenue in its income statement in the period of sale. Note that the venture capital revenue recorded is the difference between the price sold and the current fair value of the bank's VC investment, not the book value. Under the equity method of accounting, the bank adjusts the value of its VC investments over time according to capital calls, capital distribution, and changes in the fair value of VC funds' investments.

In summary, under the equity method of accounting, a bank investing in VC funds will report venture capital revenue when the VC fund reports earnings or losses, e.g. in the case of writing up or down the fund value or making capital distributions. This is also consistent with the FFIEC's direct instruction on how venture capital revenue should be reported in Call Reports (see instructions for item 5.e of Schedule RI – Income Statement of Call Reports):

> Report as venture capital revenue market value adjustments, interest, dividends, gains, and losses (including impairment losses) on venture capital investments (loans and securities). Include any fee income from venture capital activities that is not reported in one of the preceding items of Schedule RI, Income Statement.
>
> Also include the bank's proportionate share of the income or loss before extraordinary items and other adjustments from its investments in equity method investees that are principally engaged in venture capital activities. Equity method investees include unconsolidated subsidiaries; associated companies; and corporate joint ventures, unincorporated joint ventures, general partnerships, and limited partnerships over which the bank exercises significant influence.

Finally, capturing the earnings/losses from VC investments but not the amount of capital allocated to the asset class, venture capital revenue is more representative of banks' VC investment position only when observed in a relatively long window. First, VCs' investments in startups are illiquid, the VC fund's earnings or losses may not be adjusted frequently. Therefore, banks may not report any venture capital revenue in a short period of time. Second, the venture capital revenue reported could exhibit strong cyclic patterns based on the VC fund's investment life. A VC fund is more likely to have large gains towards the second half of its life during which there will be more startups having exits (either through IPO or acquisition). For these reasons, we construct our measure of VCs' bank exposure using venture capital revenue over a relatively long window, 2001–2013, to more precisely capture banks' involvement in VC.

B Appendix: Additional Figures and Tables

Figure B.1: Number and fraction of banks with negative VC revenue by year

Notes: This figure plots the number and fraction of banks with negative VC revenue by reporting year from 2001 to 2018. The data come from banks' Call Reports. The vertical line represents the year 2013, the last year before the implementation of the Volcker Rule. We determine that a bank has negative VC revenue in a reporting year if it reports negative revenue in any of the 4 quarters in that year.

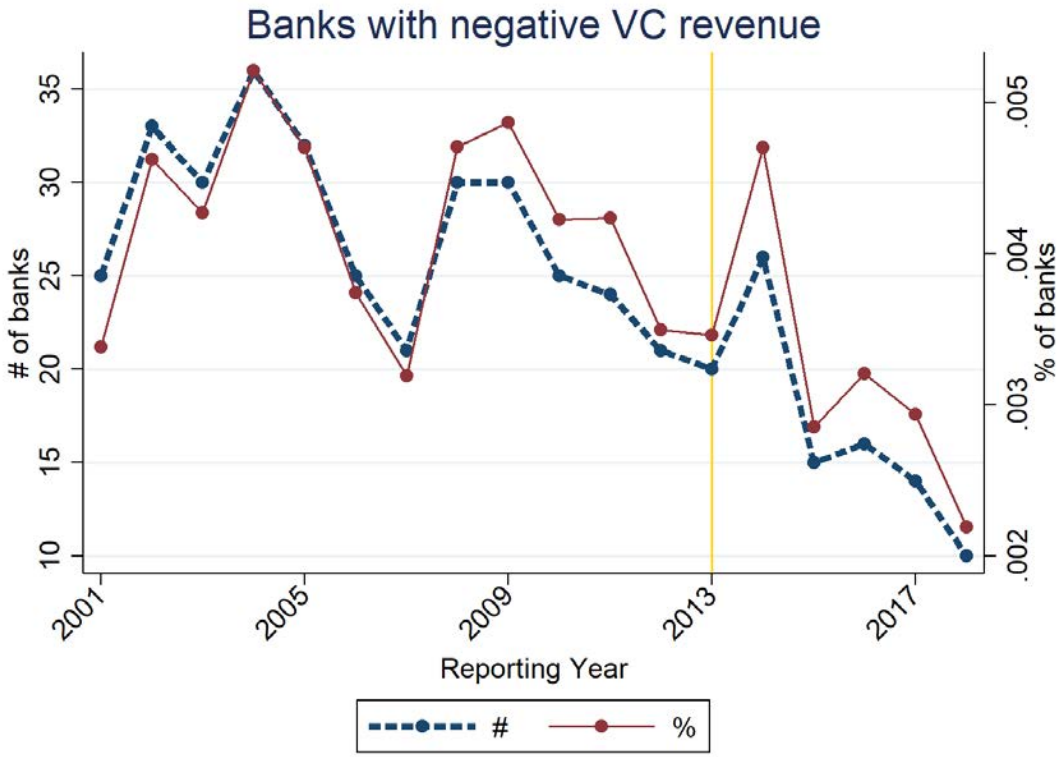

Figure B.2: Bank exposure and state-level attributes

Notes: This figure presents the scatter plots of the bank exposure variable against state attributes: GDP growth and log GDP per capita. The state attributes are averaged over the pre-Volcker period 2010–2013 to reduce the influence of outliers, while time-varying analogues of these measures are included as state-year level controls in our regressions.

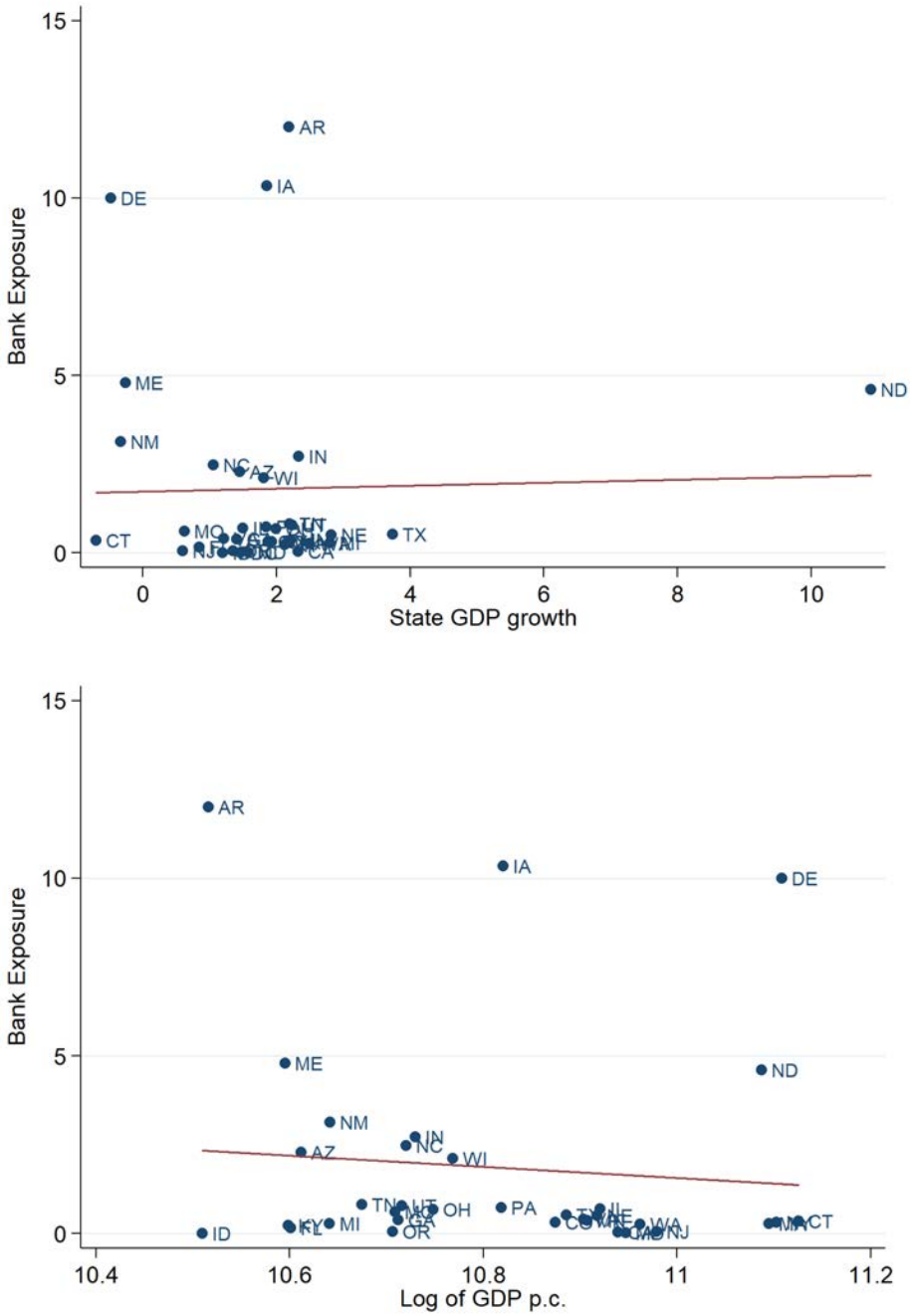

Figure B.3: VC fundraising by U.S. region

Notes: This figure plots VC fundraising activity by U.S. region based on VC funds closed over the 2001–2013 period. VC fundraising activity is measured by the number of VC funds and total venture capital raised. The data come from the VentureSource database.

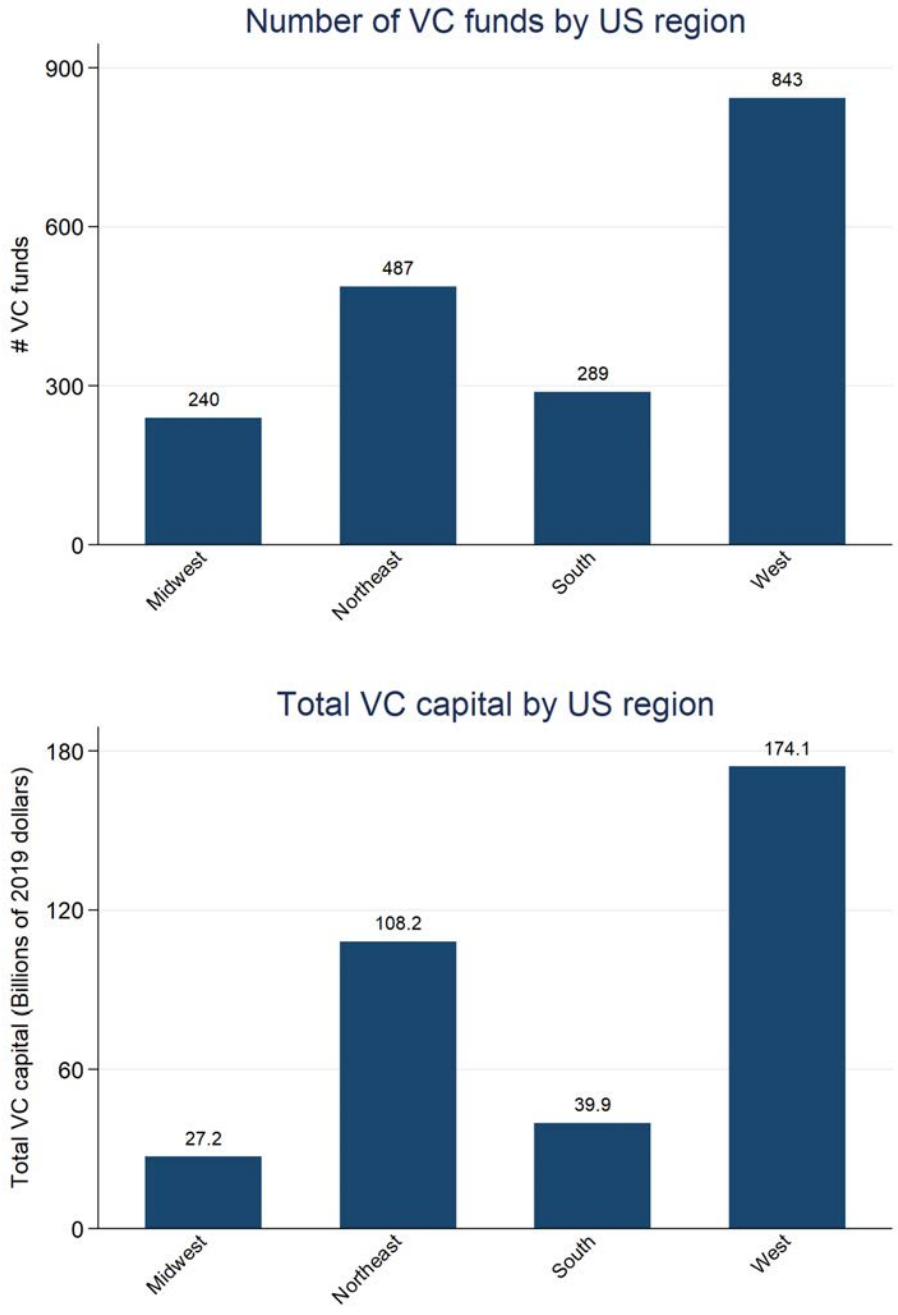

Figure B.4: VC activity by U.S. states

Notes: This map shades each state and the District of Columbia according to the number of VC funds closed over the 2001–2013 period. States that do not have any VC funds raised over the 2010–2013 period are white. The data come from the VentureSource database.

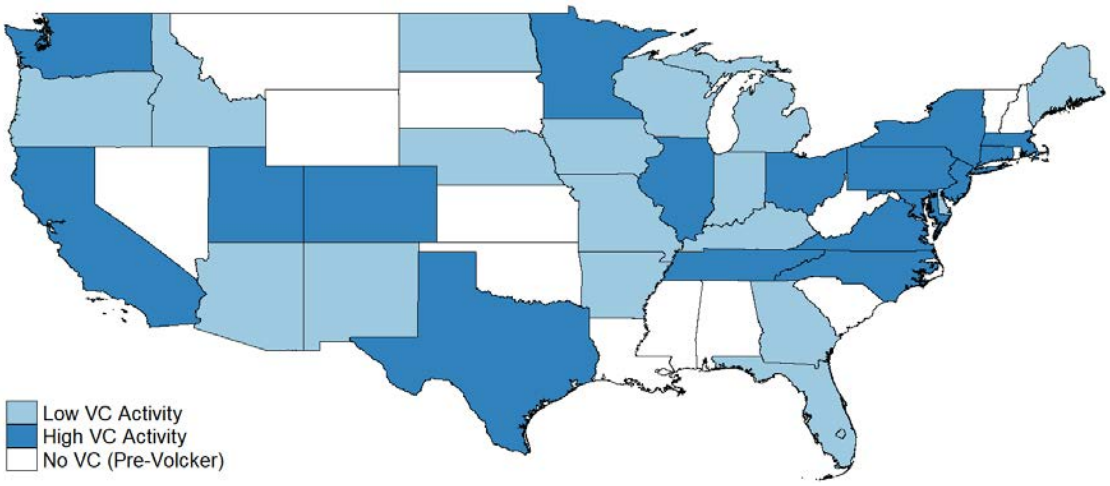

Figure B.5: Median of VC fund size by U.S. region

Notes: This figure plots the median size of VC funds closed over the 2001–2013 period by U.S. region. The fund size is expressed in millions of 2019 dollars. The data come from the VentureSource database.

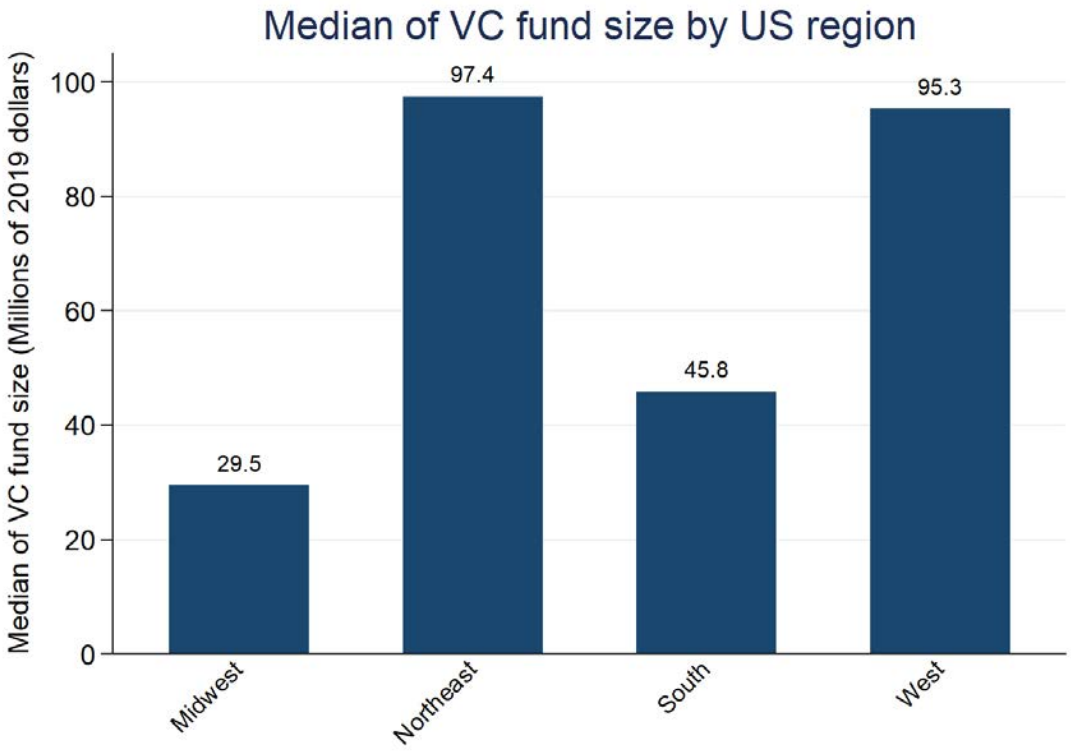

Figure B.6: Aggregate of initial capital invested by year and bank exposure

Notes: This figure plots the aggregate of initial VC capital invested in startups by financing year over the 2010–2018 period for the group of high and low exposure states, respectively. The sample includes all initial VC financings that occurred between 2010 and 2018 in the VentureSource database. A state is classified as a high exposure state if its bank exposure is above the median exposure of all states in our sample. The vertical line represents the year 2013, the last year before the implementation of the Volcker Rule.

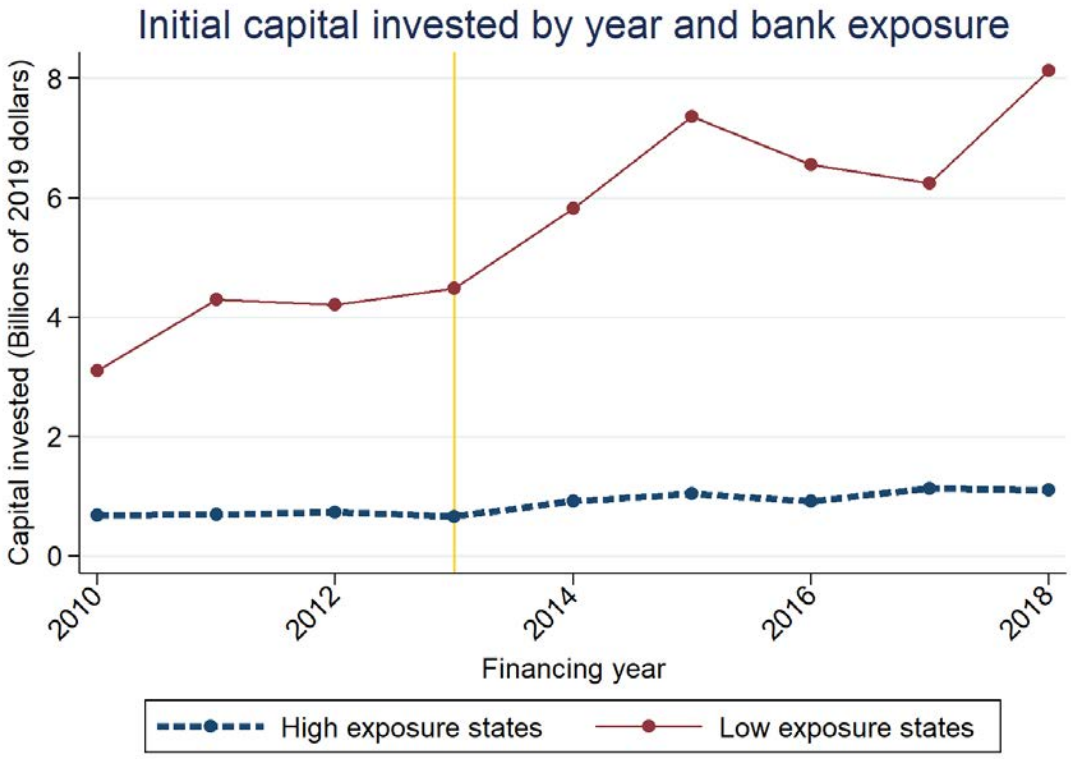

Figure B.7: Number of VC funds by vintage year and U.S. region

Notes: This figure plots the number of VC funds raised by vintage year over the 2010–2018 period for the group of Midwestern and Southern states and the group of Northeastern and Western states, respectively. The sample includes all VC funds raised between 2010 and 2018 in the VentureSource database. The vertical line represents the year 2013, the last year before the implementation of the Volcker Rule.

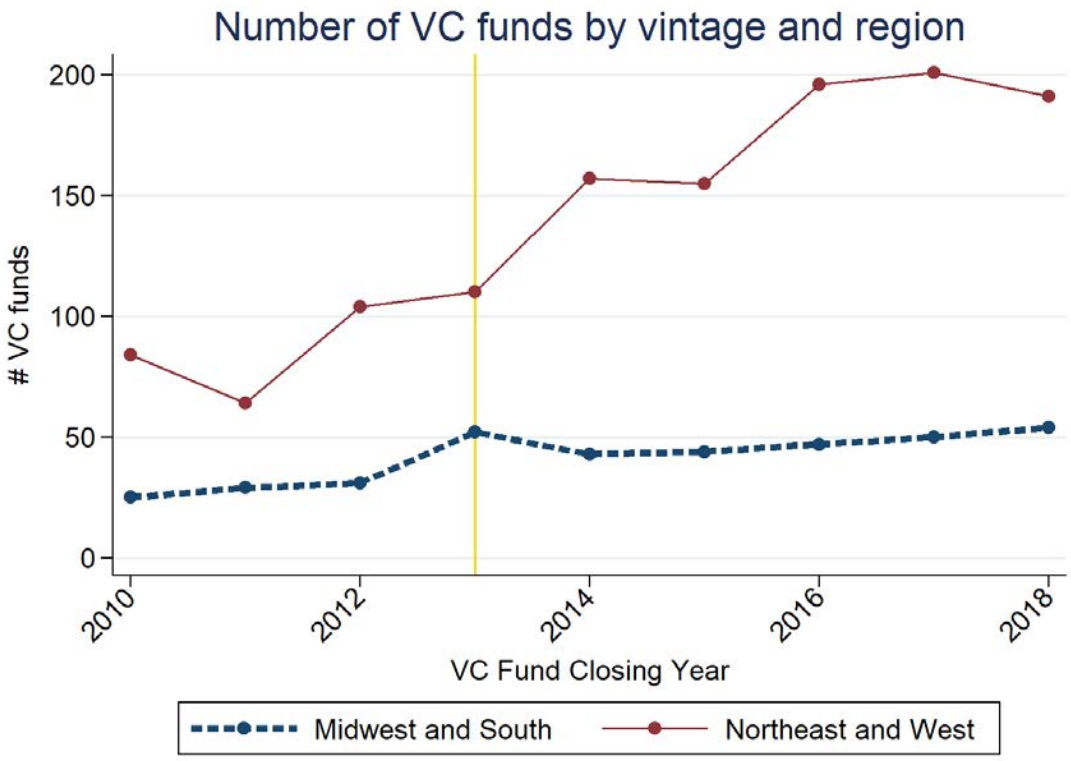

Figure B.8: Difference-in-difference estimates for startup migration

Notes: This figure plots the coefficients for the interaction terms of each quarter and the bank exposure variable estimated from a dynamic version of Eq. (1) where the dependent variable is a dummy variable indicating whether the startup has moved its headquarter to one of the VC hubs including CA, MA and NY in a given quarter. The sample is derived from the VentureSource database over the period 2013Q2–2015Q4. The 2013Q4 interaction term is the excluded category, reported as zero in the figure. The vertical red lines represent the 95% confidence interval for the coefficient estimates with standard errors clustered by startup.

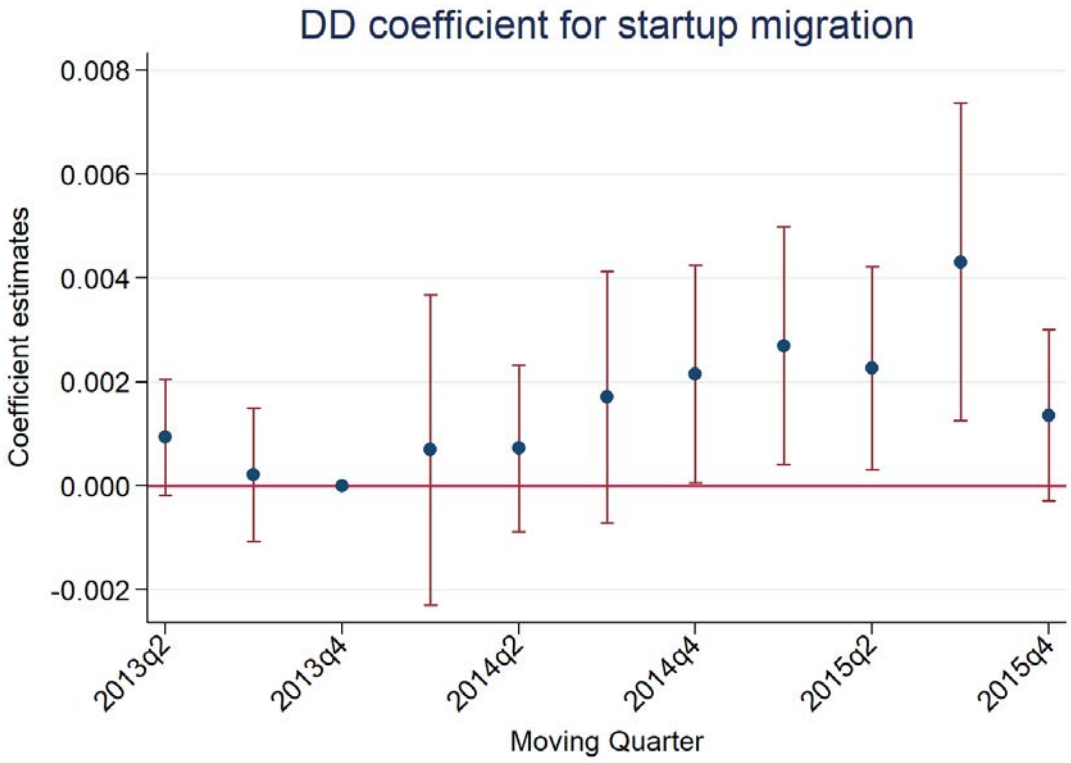

Table B.1: Summary statistics for banks

Notes: The table presents summary statistics of bank characteristics for the sample of banks with and without VC revenue reported over the 2001–2013 period. The data come from banks' Call Reports.

Panel A: The sample of banks with VC revenue								
	N	Mean	Std. Dev.	5-%ile	25-%ile	50-%ile	75-%ile	95-%ile
Total Assets (B)	191	37.349	166.552	0.054	0.180	0.606	4.369	167.114
No Foreign Office	191	0.828	0.356	0.000	1.000	1.000	1.000	1.000
High Exposure States	191	0.639	0.482	0.000	0.000	1.000	1.000	1.000
Low Exposure States	191	0.361	0.482	0.000	0.000	0.000	1.000	1.000
Total Gain from VC (B)	191	0.053	0.336	0.000	0.000	0.000	0.001	0.125
Total Loss from VC (B)	191	0.038	0.258	0.000	0.000	0.000	0.001	0.071
# Year with VC	191	3.921	3.821	1.000	1.000	2.000	6.000	13.000
Panel B: The sample of banks without VC revenue								
	N	Mean	Std. Dev.	5-%ile	25-%ile	50-%ile	75-%ile	95-%ile
Total Assets (B)	8767	0.880	6.545	0.028	0.081	0.164	0.375	1.896
No Foreign Office	8767	0.987	0.107	1.000	1.000	1.000	1.000	1.000
High Exposure States	8767	0.568	0.495	0.000	0.000	1.000	1.000	1.000
Low Exposure States	8767	0.432	0.495	0.000	0.000	0.000	1.000	1.000

Table B.2: Changes in the aggregate of VC activity

Notes: Using the same specifications as Panel A of Table 4, this table presents diff-in-diff analyses examining the impact of the Volcker Rule on the aggregate of VC activity at the state-year level. Specifically, using the same dependent variables as Panel B of Table 4, Panel A of this table reports the OLS regression results of estimating Eq. (1) with the aggregate of VC fundraising activity as the dependent variables over the two-year period of 2013–2014 around the implementation of the Volcker Rule. Panel B reports the OLS regression results of estimating Eq. (1) with the natural log of one plus the aggregate amount of capital invested in startups' initial VC financings as the dependent variable.

Panel A: VC fundraising over narrow window (2013-2014)

	ln(# VC Funds)	ln(Total VC Capital)	ln(# VC Funds)		
	(1) All	(2) All	(3) small	(4) medium	(5) large
Bank Expo × Post	−0.056***	0.005	−0.053**	−0.019	0.009
	(0.020)	(0.008)	(0.020)	(0.026)	(0.016)
State GDP growth	0.011	0.001	−0.009	−0.005	0.021
	(0.015)	(0.004)	(0.011)	(0.010)	(0.013)
Log of GDP p.c.	−7.018	2.591	−6.388	−2.685	1.002
	(4.705)	(1.961)	(5.583)	(5.208)	(3.921)
Constant	77.356	−27.878	70.141	29.661	−10.425
	(51.086)	(21.294)	(60.620)	(56.549)	(42.570)
Observations	70	70	70	70	70
Adj. R^2	0.846	0.866	0.740	0.686	0.671

Panel B: Total capital invested in initial VC fundings

	ln(Capital Invested in Initial Funding)			
	(1) All	(2) All	(3) 11-17	(4)
Bank Expo × Post	−0.007**	−0.007**	−0.006***	
	(0.003)	(0.003)	(0.002)	
Top Third × Post				−0.074**
				(0.034)
State GDP growth		−0.000		
		(0.002)		
Log of GDP p.c.		0.340		
		(0.278)		
Constant	0.127***	−3.570	0.127***	0.143***
	(0.003)	(3.023)	(0.002)	(0.009)
Observations	315	315	245	207
Adj. R^2	0.947	0.948	0.962	0.958
State FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y

Table B.3: Impacts on post-money valuation and capital raised per VC investor

Notes: Using the same specifications as Table 7, this table presents diff-in-diff analyses examining the impact of the Volcker Rule on startup post-money valuation and the average amount of capital raised per investor in their first VC financing. Specifically, this table reports the OLS regression results of estimating Eq. (1) with the following dependent variables: the natural log of post-money valuation for the startup's first VC funding in Panel A and the natural log of capital raised per investor in the startup's first VC funding in Panel B.

Panel A: Post-money valuation

	ln(Post-money Valuation)					
	(1)	(2)	(3)	(4) w/o	(5)	(6)
	All	All	All	CA	11-17	
Bank Expo × Post	−0.058	−0.076**	−0.106***	−0.108***	−0.080**	
	(0.045)	(0.028)	(0.027)	(0.024)	(0.031)	
Top Third × Post						−0.219**
						(0.083)
State GDP growth			0.001			
			(0.006)			
Log of GDP p.c.			−1.819***			
			(0.642)			
Constant	2.531***	2.534***	22.527***	2.439***	2.529***	2.596***
	(0.008)	(0.005)	(7.054)	(0.008)	(0.006)	(0.002)
Observations	5,903	5,903	5,903	3,031	4,955	4,239
Adj. R^2	0.061	0.249	0.249	0.258	0.239	0.239

Panel B: Capital raised per VC investor

	ln(Capital Raised per Investor)					
	(1)	(2)	(3)	(4) w/o	(5)	(6)
	All	All	All	CA	11-17	
Bank Expo × Post	−0.037*	−0.036**	−0.049**	−0.051**	−0.050**	
	(0.020)	(0.018)	(0.018)	(0.021)	(0.020)	
Top Third × Post						−0.062
						(0.086)
State GDP growth			0.017			
			(0.011)			
Log of GDP p.c.			−1.536**			
			(0.746)			
Constant	−0.055***	−0.056***	16.782**	−0.123***	−0.092***	0.034***
	(0.004)	(0.004)	(8.188)	(0.008)	(0.004)	(0.004)
Observations	11,048	11,048	11,048	6,056	8,999	7,685
Adj. R^2	0.048	0.254	0.254	0.269	0.252	0.241
State FE	Y	Y	Y	Y	Y	Y
Financing Year FE	Y	Y	Y	Y	Y	Y
Industry FE	N	Y	Y	Y	Y	Y
Series A or Seed FE	N	Y	Y	Y	Y	Y
Startup Age FE	N	Y	Y	Y	Y	Y

Table B.4: Impacts on having serial entrepreneurs and age at first financing

Notes: Using the same specifications as Table 7, this table presents diff-in-diff analyses examining the impact of the Volcker Rule on the changes in the characteristics of startups funded in initial VC financings. Specifically, this table reports the OLS regression results of estimating Eq. (1) with the following dependent variables: a dummy variable indicating whether the founding team of the startup has a serial entrepreneur in Panel A and the natural log of a startup's age at its first VC funding in Panel B.

Panel A: Having a serial entrepreneur

	Has Serial Entrepreneur					
	(1)	(2)	(3)	(4) w/o	(5)	(6)
	All	All	All	CA	11-17	
Bank Expo × Post	0.008	0.006	0.004	0.003	0.005	
	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	
Top Third × Post						0.048
						(0.035)
State GDP growth			0.002			
			(0.002)			
Log of GDP p.c.			−0.264***			
			(0.096)			
Constant	0.164***	0.164***	3.064***	0.144***	0.164***	0.177***
	(0.001)	(0.001)	(1.055)	(0.002)	(0.001)	(0.001)
Observations	12,788	12,788	12,788	6,881	10,390	8,922
Adj. R^2	0.009	0.028	0.028	0.032	0.028	0.026

Panel B: Startup age at first financing

	ln(Startup Age)					
	(1)	(2)	(3)	(4) w/o	(5)	(6)
	All	All	All	CA	11-17	
Bank Expo × Post	−0.012*	−0.012**	−0.012*	−0.010	−0.012*	
	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)	
Top Third × Post						−0.027
						(0.045)
State GDP growth			0.000			
			(0.003)			
Log of GDP p.c.			0.045			
			(0.223)			
Constant	0.924***	0.924***	0.431	0.981***	0.918***	0.903***
	(0.001)	(0.001)	(2.452)	(0.002)	(0.001)	(0.002)
Observations	12,786	12,786	12,786	6,881	10,388	8,920
Adj. R^2	0.039	0.171	0.171	0.161	0.166	0.171
State FE	Y	Y	Y	Y	Y	Y
Financing Year FE	Y	Y	Y	Y	Y	Y
Industry FE	N	Y	Y	Y	Y	Y
Series A or Seed FE	N	Y	Y	Y	Y	Y
Startup Age FE	N	N	N	N	N	N

Table B.5: VC fund performance around the Volcker Rule with dummy treatment variable

Notes: Using the same specifications and dependent variables as Table 10, this table presents diff-in-diff analyses investigating VC fund performance around the Volcker Rule using the binary treatment variable "High Expo" instead of the continuous treatment variable.

	% of IPO/Acq in 3 years			% of IPO/Acq in 4 years			Multiples in Valuation over Invested		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All	All	All	All	All	All	raw	log	log
High Expo × Post	0.108	0.172	0.197	0.186**	0.240	0.432**	2.901	1.565	1.531
	(0.066)	(0.117)	(0.119)	(0.090)	(0.159)	(0.157)	(2.298)	(1.800)	(1.842)
Late Stage Financing			0.195			0.166			−0.195
			(0.127)			(0.164)			(0.509)
State GDP growth			−0.014			−0.063			
			(0.054)			(0.073)			
Log of GDP p.c.			−2.872			−6.198			
			(2.838)			(4.024)			
Constant	0.236***	0.185***	31.697	0.275***	0.228***	68.412	3.912***	0.869***	1.013**
	(0.011)	(0.020)	(31.138)	(0.015)	(0.027)	(44.138)	(0.591)	(0.323)	(0.492)
Observations	205	205	205	205	205	205	82	72	72
Adj. R^2	0.628	0.487	0.488	0.509	0.264	0.374	-0.104	0.078	0.062
VC Firm FE	Y	Y	Y	Y	Y	Y	N	N	N
Vintage Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fund Seq FE	N	Y	Y	N	Y	Y	N	N	N
State FE	N	N	N	N	N	N	Y	Y	Y
Mean of Dep. Var.	0.253	0.253	0.253	0.305	0.305	0.305	4.222	1.065	1.065
S.D. of High Expo	0.413	0.413	0.413	0.413	0.413	0.413	0.392	0.393	0.393