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Global air network and cross-border venture capital mobility

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ABSTRACT

Using 23-year panel data of cross-border venture capital investment and global air network expansion as a natural experiment, this paper investigates the effect of air travel on cross-border capital mobility. We find international airlines have a significant facilitating effect on venture capital mobility. Based on the difference-in-differences estimate, for our research period one additional flight per day leads to an increase in VC investment between the city pair by 0.14 deals on average per year (1.08 times the mean value). The heterogeneous analysis indicates that, with more air connections, emerging industries and firms in earlier developmental stages receive more investment, and non-syndication investment increases more than syndication investment. In addition, we find the effect significantly increases with geographical distance: city pairs that are far away from each other experience a larger increase in VC flow after flight connections exist. Lastly, the evidence suggests that most of this increase in capital flows happens in wealthier cities. Connections between poor cities show little effect on VC flow. The paper presents evidence on the role of the global air network in reducing information transmission cost and raising the expectation for future growth potential. All results are shown to be robust using alternative VC investment measures and the regression discontinuity method.

1. Introduction

The expansion of global air networks that connects cities in different countries contributes to the convenience of cross-border travel in our age of globalization. Today as never before it is far cheaper and faster for humans to travel back and forth between distant places. Over the past two decades, international air traffic volume has grown rapidly. Fig. 1 illustrates the dynamics of the count and passenger traffic volume of international flights from 1995 to 2017. During the 23 years, the annual count of international flights increased rapidly from 2.70 million to 8.17 million (increasing by 203%). Meanwhile, more and more international travelers have benefited from the global air network, as total passenger traffic volume reached 1.2 billion in 2017, about 4.2 times the amount in 1995. The direct consequence of the explosion in air travel is that the whole world is effectively connected in a global network, greatly facilitating the speed of travel and of information transmission, broadening cities' boundaries of agglomeration economies and promoting urban vibrancy.

Venture capital (VC) firms are specialized financial intermediaries that invest in and provide value-added service to high risk innovative start-ups, thus play an essential role in promoting urban vibrancy and economic evolution (Black & Gilson, 1998; Devigne, Vanacker, Manigart, & Paeleman, 2013; Gompers & Lerner, 2004; Sapienza, Manigart, & Vermeir, 1996). During the last two decades, there has been a significant increase in both deals and amount of cross-border VC investments (Aizenman & Kendall, 2012; Wuebker, Kräussl, & Schulze, 2015). Fig. 2 presents that cross-border VC investments are booming, with annual deals exceeding 14,000 in 2017. The annual growth rate between 1995 and 2017 in cross-border VC investment is greater than 25%. In addition, the count of city-pairs with VC flows reached 4000 in 2017, indicating that more and more city-pairs are establishing a cross-border VC investment relationship. VC flows are fluid among different countries and provide international assistance with the development of local start-ups.

In this paper, we examine whether the global air network can facilitate cross-border venture capital movements. Intuitionly, with the rapid development of the international flight network, geographically remote firms have improved access to information from capitals seeking investment opportunities in other cities and in other countries within the global air network. For further analysis, we merge the Crunchbase VC

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investment Database with the Traffic by Flight Stage (TFS) dataset published by the International Civil Aviation Organization (ICAO). Taking advantage of the 23-year city-pair level panel dataset, we construct a high-dimensional fixed-effects model (staggered DID) to explore the causal effect of flight connections on international VC investment at the city-pair level. To further alleviate the endogeneity concern, we implement a regression discontinuity (RD) design at a distance of 6000 miles following Campante and Yanagizawa-Drott (2017)'s recent work.

The remainder of the paper is organized as follows. Section 2 review the related literature. Section 3 describes the data, demonstrate the theoretical framework, and outlines the empirical approach. The main results and heterogeneity analyses appear in Section 4, and Section 5 concludes.

2. Literature review

2.1. The economic effects of air travels

A growing literature empirically estimates the effects of air links on local economic growth, including employment, trade, economic activities, and so on. Brueckner (2003) firstly examined the effect of US domestic air travel on employment, finding that airline passenger enplanements promote employment in service industries rather than in manufacturing. Blonigen and Cristea (2015) employed an instrumental variables estimation to determine the causal effect of airline traffic on income and employment. Cattaneo, Malighetti, and Percoco (2018) carried out a difference-in-differences (DID) analysis on Italian de-hubbing shock, showing that air traffic reduction lead to contraction in employment in the export-oriented sector but had no effect on heavy industry. Yilmazkuday and Yilmazkuday (2017) specified the trade cost reduction effect caused by direct flights based on a variety of instrumental variables. Alderighi and Gaggero (2014) examined the effect on Italy of international flights within the European Union (EU) using the generalized method of moments (GMM) method, demonstating that direct flights promote exports from Italian manufacturing firms to the EU. Brugnoli, Dal Bianco, Martini, and Scotti (2018) extended the analysis to DID on de-hubbing shock, further revealing a stronger effect in high tech- and medium-tech manufacturing sectors. In addition, Bel and Fageda (2008) showed that direct international flights attract large firms to locate their headquarters in EU cities. Catalini, Fons-Rosen, and Gaule (2016) demonstrated that passenger enplanement facilitates scientific collaboration based on exogenous shock to airline fares. Campante and Yanagizawa-Drott (2017) studied the impact of international long-distance flights on the global spatial allocation of economic activity. This paper adds to the literature from a new empirical perspective by estimating the effects of international flight on a particular but important capital — venture capital mobility. It provides evidence for the investment channel by which air links facilitate economic growth and innovation.

2.2. The determinants of cross-border VC investments

Another literature that is closely related to our study is on the determinants of cross-border VC investments. Previous studies have investigated the relationship between VC investment likelihood and various factors. Sorenson and Stuart (2001) firstly investigated the determinates of the geographical reach of VC firms, finding that investor firm attributes, investee firm attributes and the investment syndication network are highly corelated with VC investment likelihood. Specifically, geographic distance has a negative impact on the likelihood of VC investment. As was shown by Wu and Barnes (2008), the establishment of special economic zones played a dominant role in attracting cross-border investments. Li et al. (2014) found the negative impact of cultural distance and institutional distance on the likelihood of cross-border VC investment. In addition, Tykvová and Schertler (2011) showed that local tie intensity is positively associated with syndicated cross-border deals but has no effect on stand-alone deals, and the proximity within syndication network increases total cross-border inflows. Similarly, Jääskeläinen and Maula (2014) also proved that proximity within a syndication network is beneficial to cross-border transactions. Kim and Han (2014) indicated that international migrants flows has been shown to facilitate cross-border investments, which further contribute to the vitality of the economy creating job opportunities. In this paper, we investigate the effects of international long-distance flights opening and shed light on the heterogeneous effects from a variety of perspectives, such as industry, investment size, syndication and so on.

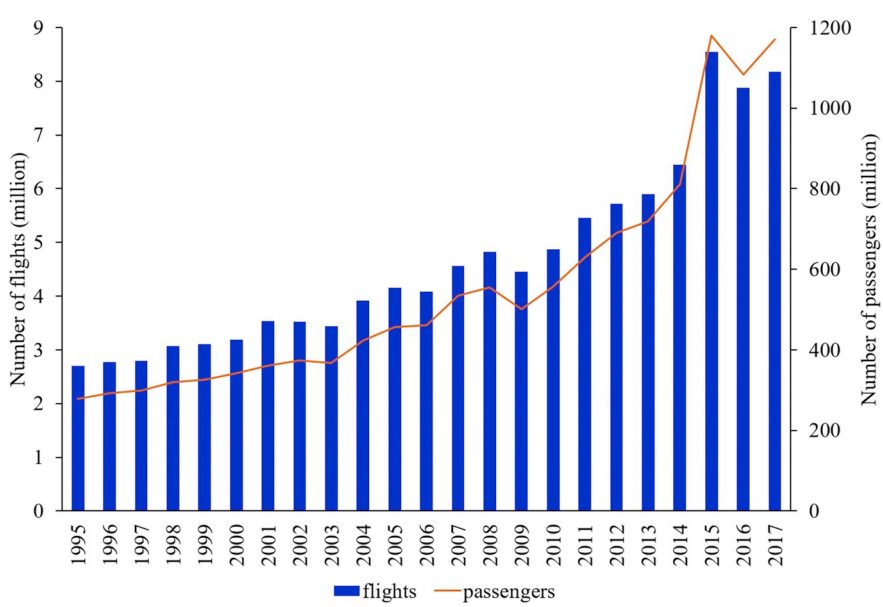

Fig. 1. International flights and passengersNotes: (1) The data are obtained from ICAO's Traffic by Flight Stage dataset. (2) The blue bar shows the annual total count of international flights from 1995 to 2017, and the orange line in the plot presents the dynamics of passenger traffic volume for the same period. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

3. Data and method

3.1. Data description

Venture Capital: Cross-border VC investment data are collected from the Crunchbase Database (www.crunchbase.cn). The database reports detailed information for each investment event, including investment date, total amount of investment, names and non-standardized location of both venture capital firms and investee companies, industry type of investee companies, and the developmental stage of investee companies. Through data cleaning and processing, we finally access 44,130 VC investment events happened across 2273 country pairs and 11,958 city pairs, and 23.5% happened within city pairs that can be connected by non-stop direct flights.

International flights: To construct the global air network, we collect the city-pair annual traffic of cross-border air services from the Traffic by Flight Stage (TFS) dataset published by the International Civil Aviation Organization (ICAO). The TFS dataset, classified by international flight stage, shows each flight's departure city name and destination city name, as well as aircraft type used, number of flights operated, and total traffic volume carried, including passengers, freight, and mail. Our empirical study, finally, contains 1233 cities with international airports across 217 countries throughout the world.

Fig. 3 illustrates the spatial distribution of VC investment and international flights in 1995 and 2017, respectively. On the map, larger size indicate more international flight connections, and the red color means more VC investment deals. The figures display two primary patterns. First, there is a large increase in both international flights and cross-border VC investments from 1995 to 2017, especially in developing regions. For example, neither India nor China received much cross-border VC flow in 1995, while both become the top ten countries preferred by VC firms in 2017. Second, it is clear that a positive relationship exists between international flights and VC in-flows, as the size of red points tend to be larger on the map.

3.2. Theoretical framework

In comparison with general economic activities, there are two unique features of VC investment. Firstly, as the investment targets are usually start-ups that lack public information, VC firms bear additional transportation costs in order to reduce information asymmetries (Portes & Rey, 2005; Wright & Robbie, 1998). Secondly, VC investments are regarded as cities' growth engine, and emerging cities are also preferred by VC firms (Samila & Sorenson, 2011; Chen et al., 2013). Inspired by these features, we construct theoretical framework with two mechanisms by which global air network contributes to cross-border VC mobility.

The first mechanism is information cost reduction. In general, Tjandradewi and Marcotullio (2009) suggested that free flows of information are critical to successful city-to-city collaborations. In the context of VC investment, cross-border VC investment is more likely to be hindered by information asymmetries due to geographical distance, cultural differences and institutional differences (Wright, Filatotchev, Hoskisson, & Peng, 2005; Zaheer, 1995). So, cross-border VC firms bear additional transportation costs in order to reduce information asymmetries (Portes & Rey, 2005; Wright & Robbie, 1998). In addition, information asymmetries have also been shown to negatively corelated to the eventual performance of VC investments (Cumming & Dai, 2010; Cumming & Johan, 2008). Nevertheless, the expansion of global air network could largely facilitate face-to-face communication among city-pairs, thus reduce the information cost and increase the cooperation likelihood between VCs and start-ups in different countries.

The second mechanism is growth expectation. As for VC investment, the city's economic growing potential could be considered as essential factors when VCs decide to invest. For example, more than 50% of VC firms in the United States are concentrated and invest actively in San Francisco, Boston and New York (Chen et al., 2013). However, being connected to global air network could substantially raise cities' economic growing potential, which further push up VCs' growth expectation for start-ups and increase the investment likelihood. As was shown by Zheng and Kahn (2013), transportation network played an important role in regional integration and futher push up growth expectation. In addition, Gibbons and Wu (2017) studied the effect of airports on local economic performance, demonstrating growth expectation by better access to domestic markets.

3.3. Empirical approach

The main objective of our empirical study is to investigate the causal effect of air links on cross-border VC investment flows. In this regard, we

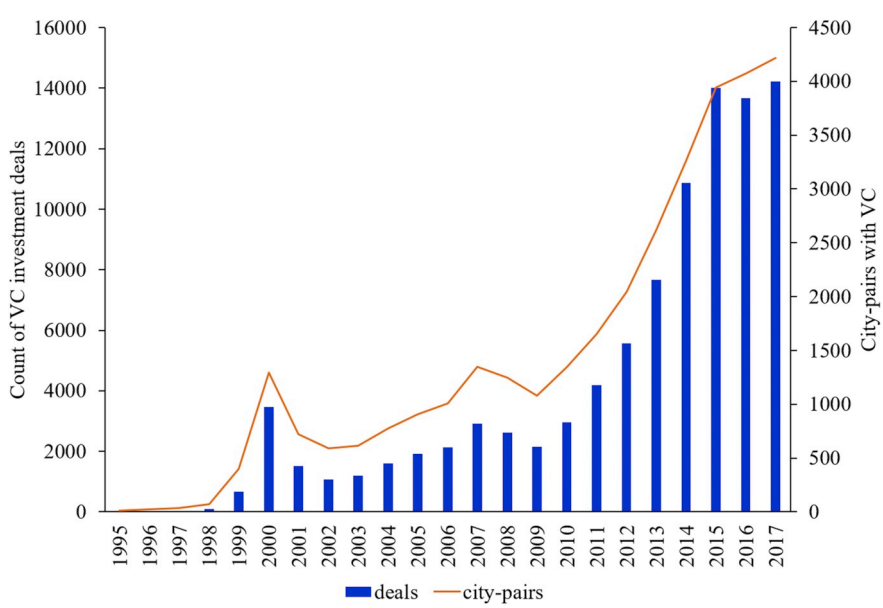

Fig. 2. Cross-border VC investmentNotes: (1) The data are obtained from Crunchbase database (www.crunchbase.cn). (2) The blue bar presents the annual count of VC investment deals from 1995 to 2017, and the orange line in the figure demonstrates the count of city pairs with VC flow for the same period. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

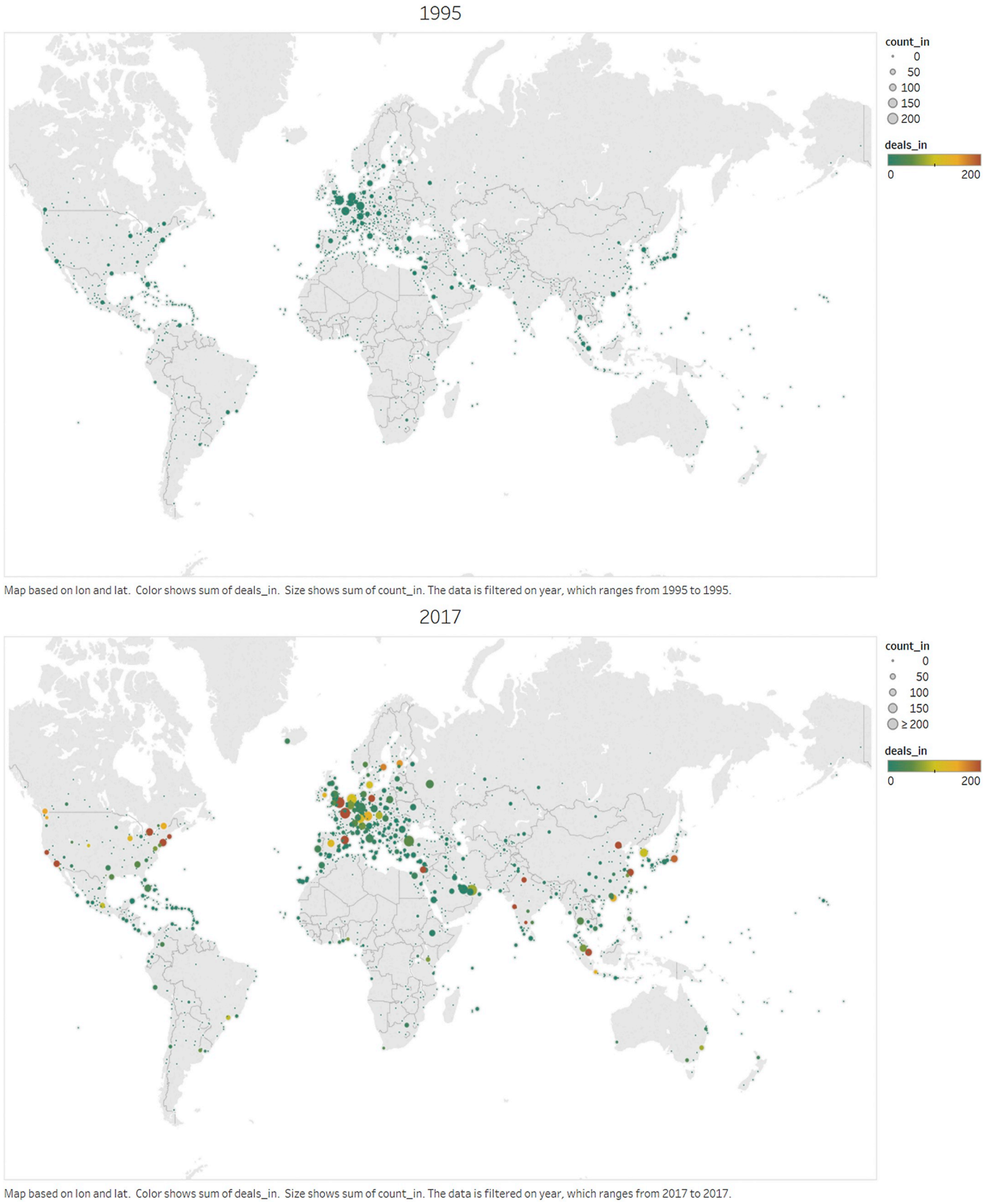

Fig. 3. World map of VC investment and international flightsNotes: (1) The data are obtained from Crunchbase database (www.crunchbase.cn) and ICAO's Traffic by Flight Stage dataset. (2) The size of each point indicates the total count of international flights connecting to the city. (3) The color of the point represents the total count of VC investment deals flowing to the city. Specifically, green means smaller VC flow, while red means larger VC flow. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

construct a staggered DID regression on city-pair level panel data. The model specification is as follows:

$$y_{ijt} = \alpha + \beta \cdot flight_{ijt} + \rho_{ij} + \tau_{kl} \cdot t + \varepsilon_{ijt} \quad (1)$$

where the dependent variable y_{ijt} is the measure of VC flows from city i to city j in year t. We employ three quantity measures: total number of VC investment events, total number of firms invested in by VC firms, and the total value of VC. The main explanatory variable is $flight_{ijt}$, which measures the number of direct non-stop international flights from city i to city j in year t. ρ_{ij} is city-pair fixed effects, which captures all city-pair level time-invariant characteristics such as geographical features. In addition, given that different county pairs may have their own growth potential, we control the country pair-specific time trend $\tau_{kl} \cdot t$. ε_{ijt} is the error term. To deal with potential serial correlation, we cluster standard errors at the city pair level.

We expect that coefficient β would reflect a positive relationship between air links and VC flows. The coefficient indicates that one more flight per year would lead to β more VC investment events. Table 1 summarizes the descriptive statistics for the variables in equation (1).

The commencing of international flights requires negotiation between two countries, and such diplomatic affairs are handled by the central government. City-pair level VC investment activities have a minimal impact on the top-down decision on global air network expansion. So, the reverse causality problem does not pose a substantial threat to our identification. However, the estimates from equation (1) would suffer from omitted variable bias. There might exist some common factors that simultaneously influence the opening of international flight and VC investment, such as local economic fundamentals, cultural similarities, institutional background and so on. For example, if two countries establish closer diplomatic and economic partnerships, both the number of flights between the two countries and VC flows will tend to significantly increase. More importantly, statistical methods and standards differ greatly from country to country throughout the world. It is nearly impossible to obtain a consistent measure of worldwide cities' socioeconomic attributes. Following Campante and Yanagizawa-Drott (2017), we implement a regression discontinuity design on geographical distance to address the endogeneity problem. As mentioned in the background section, regulatory and technological constraints give rise to a discontinuity in connectedness between cities at a distance of 6000 miles, which provides a good opportunity to identify the causal effect. The original RD design is as follows:

$$\Delta y_{ij,2017-1995} = \alpha + \beta \cdot over6K_{ij} + f(distance_{ij}) + X_{ij,1994} + \varepsilon_{ij} \quad (2)$$

where the dependent variable $\Delta y_{ij,2017-1995}$ is the long difference in VC flow measures between 1995 and 2017. Similarly, the total number of VC investment events, the total number of firms invested in by VC, and the total value of VC are used as the measure of VC flows. The dummy $over6K_{ij}$ indicates the distance discontinuity, which is equal to 1 if the distance is larger than 6000 miles. And $f(distance_{ij})$ is the polynomial function of distance. We also include a vector of economic variables for year 1994 to control for the economic fundamentals that may affect a city's VC flows, including GDP per capita of departure country and destination country. As for econometric techniques, we follow the instruction from Calonico, Cattaneo, Farrell, and Titiunik (2019) on clustered standard error calculation, polynomial order choice, and optimal bandwidth selection.

4. Empirical results

4.1. Effects on air links

We first show the evidence that flights directly increase the international connections between cities. Column (1) of Table 2 reports the estimates from regressing the number of passengers (in log) on the number of flights connecting the city pair. We see a significantly positive estimate indicating the increase in the number of passengers as more direct international flights commence. Specifically, one more flight per day (365 flights per year) will lead to an increase in travelers by air between two cities by 2.2%, implying the facilitation effect of flights opening on cross-border connections. Columns (2) and (3) show the RD estimates of equation (2) with the increases in number of flights and

Table 2
Effects on air links.

Dep. var.	DID Regression	RD Regressions	
	log (*passengers*)	Δ*flights*	Δlog (*passengers*)
	(1)	(2)	(3)
flights	0.00605***		
	(0.000269)		
Distance > 6000 Miles		−56.02*	−0.964*
		(32.30)	(0.550)
Controls	YES	YES	YES
Polynomial order		3	3
Observations	428,160	36,999	36,999
Adj. R^2	0.747		

Notes: (1) This table reports the effect of international flights on passenger traffic volume. (2) The dependent variable of the DID regression, ln(*passengers*) is the logarithm of annual passengers between city pairs. The dependent variables of the RD regressions, Δ*flights* and Δln(*passengers*) are the difference in the annual international flight count between 1995 and 2017, and the difference in the logarithm of passenger volume between 1995 and 2017, respectively. (3) The main explanatory variable of the DID regression, *flights,* is the total number of international flights. The main explanatory variable of the RD regression is the dummy indicating whether the geographical distance is larger than 6000 miles. (4) Controls for the DID regression include city pairs fixed effect and country pairs × year fixed effect. Controls for the RD regression include the logarithm of GDP per capita of the departure country in 1994 and the logarithm of GDP per capita of the destination country in 1994. (5) City pairs clustered robust standard errors are reported in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Table 1
Variable description.

Variable	Definition	Obs.	Mean	Std. Dev.	Min	Max
deals	The total number of VC investment deals per year	428,160	0.13	1.54	0	200
firms	The total number of VC invested firms per year	428,160	0.12	1.20	0	119
value	The total amount of VC flow (million dollars) per year	428,160	1.03	33.08	0	11000
flights	The total number of international flights per year	428,160	100.00	338.96	0	10981
passengers	The total number of passengers per year	428,160	15954.41	59740.95	0	2083642
distance	The geographical distance between cities (miles)	428,160	3515.99	2330.91	1000	12337
Δdeals	The difference in *events* between 1995 and 2017	36,999	0.26	2.46	−1.00	163.00
Δfirms	The difference in *firms* between 1995 and 2017	36,999	0.23	1.98	−1.00	104.00
Δln_value	The difference in the logarithm of *value* between 1995 and 2017	36,999	0.13	0.64	0.00	8.05
Δflights	The difference in *flights* between 1995 and 2017	36,999	266.34	337.41	−5222	8057.00
Δln_passengers	The difference in the logarithm of *passengers* between 1995 and 2017	36,999	6.69	5.54	−13.86	14.22
from_gdp_per	The GDP per capital of the departure country in 1994	36,999	15552.34	16456.66	124.60	74763.88
to_gdp_per	The GDP per capital of the destination country in 1994	36,999	14907.41	15939.84	124.60	74763.88

passengers (in log) as explained variables, respectively.[1] Similar to Campante and Yanagizawa-Drott (2017), we find a significant pattern where city pairs just over 6000 miles apart are less likely to be connected, and thus have fewer travel passengers as compared with those separated by slightly less than 6000 miles.

4.2. Main results

The central estimation results of this study are presented in Table 3. The DID estimates are presented in columns (1) to (3) where the significantly positive estimates of *flights* with different VC flow measures indicate that international flights substantially increase cross-border VC mobility. The economic magnitude of the effect is also significant. Specifically, the estimate in column (1) means one more flight per day (365 flights per year) will lead to an increase in VC investment between two cities by 0.14 deals per year (0.000374*365). Given that the mean of city-pair annual international flights in 2017 was 207.07, the global air network contributes to an average 0.08 increase in deals in VC flows between each city-pair, which translates into 1759 deals in total and accounts for 9.97% of the global cross-border investment. Then, the estimates in Columns (2) and (3) show robust patterns with two alternative VC flow measures, indicating that one more flight per day will significantly increase the annual VC flows in terms of newly-invested firms count and investment amount by 0.12 and 4.63% respectively. Combined, more VC investment occurs, and more firms receive investment as a result of improvements to the global air network. What's more, these cross-border VC mobility would further lead to urban vibrancy enhancement in terms of more firm births, more job opportunities and payroll increase. According to Samila and Sorenson (2011), the elasticities of VC investment with respect to firm births, employment and income are 0.0301, 0.0178 and 0.0535 respectively. So, the economic implications of one more flight per day is 0.14% increase in firm births, 0.08% increase in employment, and 0.25% increase in total income.

The RD estimates are reported in columns (4) to (6).[2] All coefficients are significantly negative, indicating that less VC investment occurs between city pairs just over 6000 miles apart as compared with those separated by slightly less than 6000 miles. What's more, we find a much larger local average treatment effect around the threshold. For instance, the 6000-mile distance discontinuity gives rise to a sharp decrease in the number of international flights by 56.02 (column (2) in Table 2) and a decrease in the count of annual VC investment deals by 0.79. Combined, one more daily flight between 6000-mile city pairs will increase VC investment by 5.15 deals, nearly 40 times that of DID estimate. Two primary reasons may contribute to the huge gap observed when using these two methods. First, the underestimation of the effects in panel data regressions could be introduced by some omitted variables that have simultaneously opposite effects on international flight connections and VC investment. For example, some cities are not conducive to the commencement of international flights due to geographical complexities (e.g., mountains, extreme weather conditions), but loose regulations and taxes abatements in these areas could be beneficial to the development of some start-ups. Second, and more importantly, the effect of flights on VC investment probably varies with geographic distance. By intuition, remote cities will benefit more from new flights as there might be alternative transportation for cities that are proximate to one another (e.g., train, ship). Meanwhile, initially there are fewer flights connecting city pairs that are further apart (see Fig. 2), so the diminishing marginal effect could also contribute to the difference. As will be seen in the following heterogeneity analysis, city pairs that are further apart will benefit more from improvements in flight connections.

4.3. Heterogeneous effects

4.3.1. Industry type

Venture capital plays an essential role in promoting the development of high-tech industries and industry improvements. To investigate the heterogeneous effects of global air network connections on VC flows among firms in different industries, we classify the investee firms into emerging industry and nonemerging industry based on the industry label (see details in Appendix.1). For instance, *Artificial Intelligence* and *Biotechnology* among other 47 industries are classified as emerging industry, while *Restaurants* and *Food Delivery* as nonemerging industry. Panel A of Table 4 presents the DID estimation for the effects of international flights on VC flows to both emerging industries and nonemerging industries, respectively. We find that the VC investment flow in both industry types significantly increase when air travel connections between city-pairs increase, and interestingly the effect is much larger for emerging industries than for nonemerging industries. Take the number of VC events as an example: one more flight per day will increase VC investment in emerging industries by 0.10 (365*0.000271), which is nearly triple the effect seen for nonemerging industries. RD estimation in Panel B of Table 4 also shows a similar pattern which confirms the larger effect on firms in emerging industries. These findings also make sense from the view that emerging industries are more likely to suffer from information asymmetries. Since international flights reduce transportation cost and improve access to information, emerging industries, especially high-tech industries, benefit more from the global network.

4.3.2. Development stage

Next, we examine the heterogeneity of global air network's impact on firms at different stages of development. The Crunchbase Database classifies VC investment rounds into Seed round, Series-A round, Series-B round, and Series-C and later round, representing the maturity of firms in ascending order. We define firms at the Seed round and Series-A round as early stage (we call them young firms), and those in Series-B round, Series-C and Later round as matured firms. From the regression results in Panel A of Table 5, we find interesting results that young firms tend to receive more VC investment in terms of quantity (columns (1) to (4)) but experience less increase in investment value (columns (5) to (6)) through global air network than do matured firms. Specifically, one more flight per day gives rise to increase in VC events into young firms and mature firms by 0.08 and 0.06 respectively. However, the total value of VC investment into matured firms increases by 0.04% compared to 0.02% for young firms with one more flight per day. The RD estimates in Panel B show similar patterns. The findings are reasonable as firms in an early stage of development face difficulties both in releasing information to investors and accessing information about investors, such as financial budget constraints and lack of market reputation. As a result, transportation improvement caused by the commencement of international flights will accelerate information transmission and facilitate the financing activity of young firms. Another possible explanation is that the new flight connections raise VC investors' expectation for the future growth potential of the city where those young firms locate. Young firms have not established their own reputation yet and the investors also do not have enough information of them, so the investors might rely more on their judgement of the city's economic potential when they decide to invest in those young firms. But considering the relatively lower investment value on young (and always small) firms, matured firms

[1] The results are robust with a first-order polynomial for f ($Distance_{ij}$), as well as with a second-order polynomial.

[2] To check the robustness of our main result, we carry out analysis in first, second and third order polynomial functions following Campante and Yanagizawa-Drott (2017)'s instruction. The effects of discontinuity remains significantly negative on flights, passenger traffic volumne and VC mobility. For example, the 6000 miles discontinuity lead to a sharp dropdown of flights by 50.81, 56.44 and 56.02 in the specification of first, second and third order polynomial.Tables are available upon request. We do not report the first order and second order results in detail to avoid redundancy.

Table 3
Venture capital investment.

Dep. var.	DID Regressions			RD Regressions		
	deals	*firms*	ln (*value*)	Δ*deals*	Δ*firms*	Δln (*value*)
	(1)	(2)	(3)	(4)	(5)	(6)
flights	0.000374***	0.000333***	0.000127***			
	(0.0000524)	(0.0000431)	(0.0000112)			
Distance > 6000 Miles				−0.790**	−0.689**	−0.235*
				(0.388)	(0.337)	(0.127)
Controls	YES	YES	YES	YES	YES	YES
Polynomial order				3	3	3
Observations	428,160	428,160	428,160	36,999	36,999	36,999
Adj. R^2	0.328	0.335	0.285			

Notes: (1) This table reports the effect of international flights on VC investment. (2) The dependent variables of the DID regressions, *events*, *firms* and ln(value) are the total number of VC investment events, the total number of firms invested in by VC, and the total value of VC (in log), respectively. The Δ*events*, Δ*firms* and Δln(value) of the RD regressions are the difference in the total number of VC investment events, the total number of firms invested in by VC, and the total value of VC (in log) between 1995 and 2017, respectively. (3) The main explanatory variable of the DID regressions, *flights*, is the total number of international flights. The main explanatory variable of the RD regression is the dummy indicating whether the geographical distance is larger than 6000 miles. (4) Controls for the DID regression include city pairs fixed effect and country pairs × year fixed effect. Controls for the RD regression include the logarithm of GDP per capita of the departure country in 1994 and the logarithm of GDP per capita of the destination country in 1994. (5) City pairs clustered robust standard errors are reported in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Table 4
Heterogeneous effects by industry type.

PANEL A: DID Regressions						
Dep. var.	*deals*		*firms*		ln (*value*)	
Industry type	*Emerging*	*Non-emerging*	*Emerging*	*Non-emerging*	*Emerging*	*Non-emerging*
	(1)	(2)	(3)	(4)	(5)	(6)
flights	0.000271***	0.000103***	0.000237***	0.0000955***	0.0000990***	0.0000621***
	(0.0000391)	(0.0000144)	(0.0000318)	(0.0000122)	(0.00000926)	(0.00000730)
Controls	YES	YES	YES	YES	YES	YES
Observations	428,160	428,160	428,160	428,160	428,160	428,160
Adj. R^2	0.308	0.270	0.316	0.270	0.267	0.154
PANEL B: RD Regressions						
Dep. var.	Δ*deals*		Δ*firms*		Δln (*value*)	
Industry type	*Emerging*	*Non-emerging*	*Emerging*	*Non-emerging*	*Emerging*	*Non-emerging*
	(7)	(8)	(9)	(10)	(11)	(12)
Distance > 6000 Miles	−0.601**	−0.159	−0.525**	−0.156	−0.249**	−0.0741
	(0.282)	(0.125)	(0.244)	(0.113)	(0.114)	(0.0786)
Controls	YES	YES	YES	YES	YES	YES
Polynomial order	3	3	3	3	3	3
Observations	36,999	36,999	36,999	36,999	36,999	36,999

Notes: Detail information of the specification is the same as Table 3.

receive more VC investement value with more air links between city-pairs.

4.3.3. Syndication

Many studies have focused on syndication in VC investments, which occurs when several VC firms invest in the same investee company together. According to Sorenson and Stuart (2001), the syndication network will broaden the geographical range of VC firms' investments, especially syndication with local VC firms taking advantage of information accessibility. In Table 6 we examine whether international flights have different effects on syndication investment compared to standalone investment. Consistent with our expectation, both investment events significantly increase if more flights connect the city pairs, and the effect is a little larger for standalone investment than it is for syndications. The findings are robust with different investment measures and empirical methods. There are two main explanations for this finding. First, it is much easier for VCs to conduct due diligence on local investee firms. Frequent meetings and communication can mitigate information asymmetries between investors and investees, which is helpful in solving the principle-agent problem. As a result, syndication with local VC firms is a beneficial way to screen potential investee candidates and make better investment decisions. On the other hand, VC firms making standalone investment rely more on international flights to collect information about investee firms. Second, VC firms also provide value-added service for invested start-ups. In addition to financial support, VC firms usually help start-ups acquire expertise, strengthen their social ties and actively participate in their management activities, which help start-ups develop. As geographical proximity makes these activities more convenient, VC firms making stand-alone investments must depend more on international flights to provide this value-added service.

4.3.4. Geographic distance

Our main results imply that flights have different effect on VC flows according to distance. To check the heterogeneous effect, we divide our sample into three groups based on the distance of city-pairs: within 3000 miles, between 3000 miles and 6000 miles and larger than 6000 miles. As is shown in Table 7, VC flows with longer geographical reach tend to benefit more from international flights. Specifically, one more flight per day gives rise to an increase in VC investment deals between city-pairs within 3000 miles by 0.072, from 3000 miles to 6000 miles by 0.33, and larger than 6000 miles by 0.60 respectively. The findings make

Table 5
Heterogeneous effects by development stage.

PANEL A: DID Regressions						
Dep. var.	*deals*		*firms*		ln (*value*)	
Development stage	*Early*	*Later*	*Early*	*Later*	*Early*	*Later*
	(1)	(2)	(3)	(4)	(5)	(6)
flights	0.000210***	0.000164***	0.000185***	0.000148***	0.0000487***	0.000106***
	(0.0000295)	(0.0000250)	(0.0000244)	(0.0000205)	(0.00000497)	(0.0000107)
Controls	YES	YES	YES	YES	YES	YES
Observations	428,160	428,160	428,160	428,160	428,160	428,160
Adj. R^2	0.206	0.390	0.217	0.379	0.188	0.252
PANEL B: RD Regressions						
Dep. var.	Δ*deals*		Δ*firms*		Δln (*value*)	
Development stage	*Early*	*Later*	*Early*	*Later*	*Early*	*Later*
	(7)	(8)	(9)	(10)	(11)	(12)
Distance > 6000 Miles	−0.346*	−0.400*	−0.309*	−0.358*	−0.0864	−0.183
	(0.201)	(0.209)	(0.172)	(0.188)	(0.0547)	(0.125)
Controls	YES	YES	YES	YES	YES	YES
Polynomial order	3	3	3	3	3	3
Observations	36,999	36,999	36,999	36,999	36,999	36,999

Notes: Detail information of the specification is the same as Table 3.

Table 6
Heterogeneous effects by syndication.

PANEL A: DID Regressions						
Dep. var.	*deals*		*firms*		ln (*value*)	
Syndication	*Syndication*	*Standalone*	*Syndication*	*Standalone*	*Syndication*	*Standalone*
	(1)	(2)	(3)	(4)	(5)	(6)
flights	0.000176***	0.000198***	0.000152***	0.000180***	0.0000695***	0.0000935***
	(0.0000311)	(0.0000251)	(0.0000246)	(0.0000217)	(0.00000794)	(0.00000915)
Controls	YES	YES	YES	YES	YES	YES
Observations	428,160	428,160	428,160	428,160	428,160	428,160
Adj. R^2	0.320	0.271	0.340	0.257	0.306	0.160
PANEL B: RD Regressions						
Dep. var.	Δ*deals*		Δ*firms*		Δln (*value*)	
Syndication	*Syndication*	*Standalone*	*Syndication*	*Standalone*	*Syndication*	*Standalone*
	(7)	(8)	(9)	(10)	(11)	(12)
Distance > 6000 Miles	−0.340	−0.411**	−0.294	−0.375**	−0.131	−0.176*
	(0.260)	(0.176)	(0.225)	(0.153)	(0.0846)	(0.105)
Controls	YES	YES	YES	YES	YES	YES
Polynomial order	3	3	3	3	3	3
Observations	36,999	36,999	36,999	36,999	36,999	36,999

Notes: Detail information of the specification is the same as Table 3.

Table 7
Heterogeneous effects by geographic distance.

Dep. var.	*deals*			*firms*			ln (*value*)		
Distance	<3000 miles	3000–6000 miles	>6000 miles	<3000 miles	3000–6000 miles	>6000 miles	<3000 miles	3000–6000 miles	>6000 miles
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
flights	0.000196***	0.000906***	0.00165***	0.000177***	0.000786***	0.00149***	0.0000793***	0.000261***	0.000547***
	(0.0000251)	(0.000241)	(0.000382)	(0.0000220)	(0.000194)	(0.000354)	(0.00000994)	(0.0000378)	(0.000111)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	226,496	132,434	64,147	226,496	132,434	64,147	226,496	132,434	64,147
Adj. R^2	0.317	0.339	0.318	0.347	0.332	0.307	0.336	0.273	0.236

Notes: Detail information of the specification is the same as Table 3.

sense for two reasons. First, cities geographically located in close proximity are more likely to share the same language, history and culture. Therefore, communication among these cities is more efficient, and negotiations are more likely to lead to better outcomes. The marginal incremental effects of international flights are relatively smaller than that of cities at greater distance from each other. Second, VC firms may prefer other kinds of transportation (e.g., train, car, ship) for short distance travel due to lower expense, even though flights may be much faster. But air travel seems to be the only choice for long distance trips, especially those tips that exceed 6000 miles. The heterogeneity on distance directly reveals the mechanism of the global air network's impact on VC flows, that is, the reduction in transportation cost made possible

by international flight connections.

4.3.5. Direction of VC

The city-pair in our empirical analysis is directional, which means VC flows from city A to city B are treated differently than flows from city B to city A. This characteristic gives us opportunities to dive into the heterogeneity on VC investment with different city pairs. We first separate cities into wealthier cities and poorer cities according to the GDP per capita of their home country. Then, we reclassify each city-pair into four types: from wealther to wealther, from wealther to poorer, from poorer to wealther and from poorer to poorer. The empirical results shown in Table 8 reveal two main findings. First, the global air network has a larger impact on VC flows originating in wealthier cities. One contributory factor is that VC firms located in wealthier cities are usually more experienced and more likely to seek foreign investment opportunities. VC firms in poorer cities tend to avoid overseas investment risk due to capacity constraints, even though international flights provide good opportunities to access overseas market information. Second, the effects on VC flow from wealtheir to poorer and from poorer to wealtheir is significantly stronger than those in the same city group, which indicates the existence of a diversification effect. The high-risk nature of VC investment encourages VC firms to hedge regional risk by building their portfolio in different countries. This finding sheds light on the incentives of VC firms to make cross-border investments, which is consistent with previous theories (Poterba and French, 1991). And this finding is also consistent with Campante and Yanagizawa-Drott (2017) who found that international flights can only facilitate capital flows between "high income" and "middle income" countries, while countries classified as "low income" are essentially shut out of this process because they are too poor for there to be a demand for connections in the first place. In this way, the analysis offers suggestive evidence of the global air network's potential role in widening regional inequality.

5. Conclusion

The global air network that connects cities in different countries greatly facilitates the speed of travel and information transmission, which largely broadens the boundaries of agglomeration economies and promotes the enhancement of urban vibrancy. Recently, a large amount of literature in urban economics and regional science empirically estimates the impacts of transportation cost on the evolution of economic activities. However, very few papers study the role of international flights in VC mobility. In practice, VC firms which are specialized financial intermediaries invest in and provide value-added service to high risk innovative start-ups, thus play an essential role in promoting urban vibrancy and economic evolution. In this paper, we seek to fill this gap by examining the effects of the global air network on cross-border VC flows.

Using 23-year panel data of cross-border venture capital investment and employing difference-in-differences and regression discontinuity methods, our analysis reveals two central findings. First, we find that being connected to the global air network significantly increases a city's VC mobility. Based on the DID estimate, one more daily flight will lead to an increase in annual VC investment between the city pairs by 0.14 deals, 0.12 firms being invested in by VCs, and 4.63% in total value of VC flows, respectively. Second, the heterogeneous analyses indicate that firms in emerging industries such as high-tech industries, and firms in earlier developmental stages receive more investment. Non-syndication investment increases more than syndication investment with growth in international air links. In addition, the effects significantly increase with geographical distance: city pairs that are far away from each other experience a larger increase in VC flows. Most of these results confirm the role of the global transportation network in reducing the cost of information transmission and raising the expectation of connected-city's growth potential. At last, the evidence suggests that most of this increase in capital flows happens with wealthier cities. The air network

Table 8
Direction of VC: between wealthier and poorer countries.

Dep. var.	*deals*				*firms*				ln (*value*)			
Distance	Wealthier→ Wealthier	Wealthier→ Poorer	Poorer→ Wealthier	Poorer→ Poorer	Wealthier→ Wealthier	Wealthier→ Poorer	Poorer→ Wealthier	Poorer→ Poorer	Wealthier→ Wealthier	Wealthier→ Poorer	Poorer→ Wealthier	Poorer→ Poorer
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
flights	0.000384***	0.000472***	0.000246***	0.0000428	0.000339***	0.000429***	0.000222***	0.0000427	0.0000998***	0.000251***	0.000130***	0.0000708
	(0.0000709)	(0.000102)	(0.0000624)	(0.0000420)	(0.0000578)	(0.0000895)	(0.0000551)	(0.0000407)	(0.0000115)	(0.0000437)	(0.0000228)	(0.0000801)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	294,952	65,592	56,921	10,695	294,952	65,592	56,921	10,695	294,952	65,592	56,921	10,695
Adj. R^2	0.341	0.301	0.180	0.135	0.351	0.297	0.186	0.145	0.309	0.244	0.172	0.098

Notes: Detail information of the specification is the same as Table 3.

connections within poorer cities show little effect on VC flows, implying the global air network's potential role in deepening spatial inequality.

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Appendix 1. List of emerging industries

ID	Industry Name	ID	Industry Name	ID	Industry Name
1	3D Printing	17	Cloud Security	33	Medical
2	Analytics	18	Computer Vision	34	Medical Device
3	Apps	19	Cryptocurrency	35	Natural Language Processing
4	Artificial Intelligence	20	E-Commerce	36	Pharmaceutical
5	Augmented Reality	21	Enterprise Software	37	Private Cloud
6	Big Data	22	Facial Recognition	38	Renewable Energy
7	Bioinformatics	23	Finance	39	Robotics
8	Biometrics	24	Financial Services	40	SaaS
9	Biopharma	25	FinTech	41	Semiconductor
10	Biotechnology	26	Genetics	42	Social Media
11	Bitcoin	27	Health Diagnostics	43	Speech Recognition
12	Blockchain	28	Image Recognition	44	Text Analytics
13	CleanTech	29	Information Services	45	Therapeutics
14	Cloud Computing	30	Information Technology	46	Virtual Currency
15	Cloud Data Services	31	Internet	47	Virtual Reality
16	Cloud Management	32	Machine Learning		

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