ADBI Working Paper Series

DOES FINTECH CONTRIBUTE TO SYSTEMIC RISK? EVIDENCE FROM THE US AND EUROPE

Lavinia Franco, Ana Laura García,
Vigor Husetović, and Jessica Lassiter

No. 1132
May 2020

Asian Development Bank Institute

Lavinia Franco is a research student at the Cass Business School of the City University of London, United Kingdom. Ana Laura García is head of the Financial Research Department of Banco de México, Mexico. Vigor Husetović is a deals associate at PricewaterhouseCoopers, Croatia. Jessica Lassiter graduated from the Barcelona Graduate School of Economics.

Suggested citation:

Franco, L., A. L. García, V. Husetović, and J. Lassiter. 2020. Does Fintech Contribute to Systemic Risk? Evidence from the US and Europe. ADBI Working Paper 1132. Tokyo: Asian Development Bank Institute. Available: https://www.adb.org/publications/does-fintech-contribute-systemic-risk-evidence-us-europe

Please contact the authors for information about this paper.

Email: lavinia.franco@cass.city.ac.uk, agarcia@banxico.org.mx, vigor.h.husetovic@pwc.com, jessica.lassiter@barcelonagse.eu

We are grateful to Xavier Freixas for his helpful suggestions and conversations. We also appreciate the comments from the reviewers and participants at the 2019 Center for European Studies International Conference on European Studies, the International Finance and Banking Society 2019 Angers Conference, and the 2019 Asian Development Bank Institute and Sim Kee Boon Institute Conference on Macroeconomic Stabilization in the Digital Age. The views and conclusions in this paper are exclusively the responsibility of the authors and do not necessarily reflect those of their institutional affiliations.

Asian Development Bank Institute
Kasumigaseki Building, 8th Floor
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

Abstract

Fintech has increasingly become part of the global economy with the evolution of technology, increasing investments in fintech firms, and greater integration between traditional incumbent financial firms and fintech. Since the 2007–2009 financial crisis, research has also paid more attention to systemic risk and the impact of financial institutions on systemic risk. As fintech grows, so too should the concern about its possible impact on systemic risk. This paper analyzes two indices of public fintech firms (one for the United States and another for Europe) by computing the ΔCoVaR of the fintech firms against the financial system to measure their impact on systemic risk. Our results show that at this time fintech firms do not contribute greatly to systemic risk.

Keywords: fintech, systemic risk, financial crisis, regulation

JEL Classification: G01, G20, G28, O30

Contents

1. INTRODUCTION 1

2. REVIEW OF THE LITERATURE 1

3. THEORETICAL DISCUSSION AND HYPOTHESIS 3

4. DATA AND METHODOLOGY 5

4.1 Data 5
4.2 Estimation of CoVaR and ΔCoVaR Measures 7
4.3 Spearman's Rank Correlation 9

5. RESULTS 9

5.1 United States 10
5.2 Europe 11
5.3 Final Remarks on the Results 11

6. CONCLUSIONS 11

REFERENCES 14

APPENDIX A: TABLES 17

APPENDIX B: FIGURES 29

1. INTRODUCTION

Since the global financial crisis of 2007–2009, systemic risk, how to recognize it, how to evaluate it, and how firms (specifically financial firms) can contribute to it have received considerable attention. We define systemic risk here following Das and Uppal (2004, 2810), who stated that systemic risk is "the risk from infrequent events that are highly correlated across a large number of assets." Adrian and Brunnermeier (2016) developed a measure of systemic risk, ΔCoVaR, which shows the change in value at risk (VaR) of one institution or system based on the state of distress of another institution or system.

The purpose of this paper is to analyze the fintech industry's contribution to systemic risk in the United States and in Europe by conducting a ΔCoVaR analysis of a sample of publicly traded fintech firms. As important as it was to evaluate the landscape of the financial system and factors such as systemic risk that contributed to the financial crisis, it is also important to remember that the landscape of financial institutions prior to the financial crisis has changed since that event. This is due in large part to the rise of financial technology, which has the potential to disrupt business models, transform processes, redefine customer relations, bypass, enhance, or change regulatory oversight, and provide new innovative products (Depository Trust & Clearing Corporation 2017). It is imperative to study and evaluate this changing landscape, particularly its effect on systemic risk.

Fintech is a reference either to financial innovation itself—whether it emerged inside or outside the financial industry—or to institutional forms that engage in the use of fintech. In our analysis, we were interested in the second type: corporations utilizing fintech. Some recent innovations in fintech have been cryptocurrencies, blockchain, machine learning, artificial intelligence, robo-advising, peer-to-peer (P2P) lending, mobile payment systems, crowdfunding, and others (Philippon 2016). For the purposes of this paper, the fintech firms that we analyzed fall into seven categories: 1) alternative financing, 2) data analytics, 3) digital banks, 4) market and trading support, 5) payments and remittances, 6) robo-advisors and personal finance, and 7) software solutions and information technology. We will discuss these categories in greater detail in section 4.

The remainder of this paper is as follows: section 2 reviews the relevant literature, section 3 presents the theoretical discussion and hypothesis, section 4 describes the data and methodology, section 5 provides the results, and section 6 concludes the paper.

2. REVIEW OF THE LITERATURE

Fintech has grown significantly in recent years. According to an Ernst & Young (EY) (2017) report, which surveyed more than 22,000 consumers in 20 markets, consumers are becoming more aware of fintech: their awareness grew from 62% in 2015 to 84% in 2017. Additionally, the adoption (the movement from being a non-user to being a user) of fintech has grown to 33% across those 20 markets in the last 2 years, an increase of 16% from the previous study in 2015 (EY 2017, 7). In 2017, PricewaterhouseCoopers (PwC) also initiated a global survey regarding the use of fintech, but, rather than consumers, the survey focused on CEOs and other leaders in companies within the financial services industry in 71 countries. The survey found that 88% of the leaders of those businesses believe that they are losing revenue to innovative financial technology, 77% intend to increase their own efforts to innovate, and 82% expect

to increase their partnerships with fintech in the next 3 to 5 years (PwC 2017, 2). These reports, when taken together, show that both individuals and financial sector corporations are increasing their fintech usage. Lee and Teo (2015) further discussed the growth of fintech in reference to global investments in fintech ventures. From 2013 to 2014, investments grew more than three times, from $4.05 billion to $12.21 billion (Lee and Teo 2015). KPMG (2018) estimated that investments in fintech (ranging from mergers to venture capitalism) totaled roughly $31 billion in 2017.

Fintech has, alternatively, *evolved* significantly in the last century, and its last evolution has been recent and fast. It has seen three periods: the first was the analog era (telegraphs, railroads, etc.), the second was digitalization (technology for communications and transfers), and the third and current era began in 2008 (Arner, Barberis, and Buckley 2016).

> The critical difference in Fintech 3.0 [from the second era] lies in: first, who is providing financial services, with start-ups and technology firms supplanting banks in providing niche services to the public, business and the banks themselves; and second, the speed of development. In many markets, there has been a shift in customer mindset as to who has the resources and legitimacy to provide financial services, combined with an entirely new speed of evolution, particularly in emerging markets. (Arner, Barberis, and Buckley 2016, 24).

Both Lee and Teo (2015) and Arner, Barberis, and Buckley (2016) discussed the ever-increasing role of fintech in emerging markets. In these markets, where there is little to no access to banking, fintech has the potential to make large impacts.

Fintech has not only affected the financial sector but is also becoming increasingly integrated with it as financial institutions are partnering with fintech (PwC 2017). The past literature has found that the interconnectedness of the financial sector leads to spillover or contagion when one area experiences distress. Allen and Gale (2000), in fact, postured that the interconnectedness and whether it is complete can determine the strength of the spillover effects. According to Magnuson (2017, 22), interconnectedness becomes an issue because, "If firms in a market are highly dependent on each other, by for example relying on other participants for essential parts of their business or having contracts and agreements that require the cooperation (and solvency) of the others, then it will be more likely for shocks in one institution to spread to other institutions." Meanwhile, Allen, Babus, and Carletti (2012) suggested that the degree of contagion within a financial system is due to the degree to which institutions have overlapping portfolios.

Adrian and Brunnermeier (2016) developed the methodology that this paper used. ΔCoVaR is a measure of systemic risk that evaluates the tail dependency between one institution or system and another institution or system. In this measure, one might see that an institution is individually systemic or that a group of institutions is systemic as a whole, which the authors referred to as "systemic as a herd" (Adrian and Brunnermeier 2016, 1706). The CoVaR of a system is the VaR of the whole system given the particular state that the institution is experiencing. Then ΔCoVaR is the difference in the system given that the institution has moved from one state to another (generally from its median state of VaR to some lower state of VaR that represents distress). Essentially, ΔCoVaR captures the tail co-movements of the system and the institution.

Other researchers have taken Adrian and Brunnermeier's (2016) risk measurement and extended its application to other or more specific areas. Examples of this include extending ΔCoVaR to sovereign CDS (Fong and Wong 2011), to regional banks (Fong et al. 2011), and to risk spillovers (Adams, Füss, and Gropp 2014). There are many other types of systemic risk measures as well. Acharya, Engle, and Richardson (2012) and

Brownlees and Engle (2016) developed systemic risk indicators that measure the decrease in equity given the market stress condition. Billio et al. (2012) introduced a systemic risk measure that they based on Granger causality between companies.

3. THEORETICAL DISCUSSION AND HYPOTHESIS

Hypothesis: Fintech firms do not contribute greatly to systemic risk at this time.

The methodology that this study used, ΔCoVaR, is a measure of systemic risk that considers the co-movements of tail distributions of the institution and the financial system (Adrian and Brunnermeier 2016). Which factors can contribute to systemic risk and do fintech firms display those attributes? To define systemically important financial institutions (SIFIs), Thomson (2010) proposed five ways (size and the four Cs) in which institutions may have a systemic impact, and the Financial Stability Board (2017a) recommended an additional way, substitution:

- Size—while not the only factor to consider, institutions that make up at least 10% of activities or assets in any single financial sector may be large enough to be systemically important;
- Contagion—it is possible to consider institutions for which their failure could have real spillover effects on other institutions as systemically important. Examples include locking up of essential payment systems, creating illiquidity in institutions accounting for up to a third of the assets in the financial system, and collapsing important financial markets;
- Correlation—this factor of systemic risk occurs when institutions take risks that are highly correlated across many institutions. In this way, many smaller institutions can have a systemic impact akin to that of large institutions;
- Concentration—a small number of firms engaging in key financial activities (such as essential payment processes) can give rise to systemic importance, since the role of that firm is not easy for other firms that engage in the same activities to fill;
- Substitution—similar to the concept of concentration, if firms are engaging in key financial activities for which there are no easy substitutions, this can give rise to systemic risk; and
- Conditions/context—these refer to the phenomena of an institution becoming systemically important due to the state of the economy or financial market.

Fintech and Size

According to Statista (2018), the value of the total transactions in the fintech market amounted to over $4.22 trillion in 2018, as of May. The total transactions in the digital payment sector of fintech accounted for over $3.26 trillion of that total (approximately 77% of the total transactions in the fintech market), followed by the alternative lending sector with 12% of the total and personal finance with 10%. Similarly, in 2016 and 2017, the digital payment sector dominated the total transaction value. Therefore, in relation to the size factor, digital payment (as section 4.1 denominates, according to our categories, payments and remittances) is the sector that is more likely to have a systemic impact. On the other hand, while fintech institutions may have a large impact in the realm of digital transactions, their overall portion of assets in the financial sector remains relatively small, with Market Watch (French 2017) reporting that the largest fintech firm in the US at the end of 2017 was Stripe, with $9.2 billion in assets, while the largest financial

institution in the US was J.P. Morgan Chase & Co., with $2.5 trillion in assets, as Bankrate reported (Dixon 2018).

Fintech and Contagion

Fintech, through its mere existence, is increasing interconnectedness. Connections are easier and faster, particularly in payment processing, but there are also fintech firms that provide data analytic services to other corporations, which integrate that service into their own operations. Fintech firms undertake human resource activities (hiring, tax reporting, payroll management, etc.) to make these activities more expedient, more trackable, and more accurate. According to the Financial Stability Board (FSB 2017b), fintech increases the interconnectedness of the financial sector, and this effect carries macro-financial risks. On the other hand, the same report mentioned that the decentralization potential of some fintech activities, such as P2P lending, could have the effect of lessening interconnectedness by providing traditional financial activities outside of the traditional network.

Fintech and Correlation

The risks of financial institutions' portfolios might become highly correlated in a period of financial distress, as financial institutions might have an incentive "to take on risks that are highly correlated with other institutions because policymakers are less likely to close an institution if many other institutions would become decapitalized at the same time" (Thomson 2010, 140). This concept does not directly apply to the fintech sector; however, there are other factors that might matter in terms of correlation for the fintech industry. According to the FSB (2017b, 19), the cyber risk, on one side, can undermine some fintech companies, since a "greater use of technology and digital solutions expand the range and number of entry points cyber hackers might target". On the other side, the same work underlined how fintech can increase competition and reduce the systemic relevance of a single cyber-attack. We can therefore expect that, if the risks due to cyber-attacks are correlated, then the fintech sector faces strong exposure to that risk. Another factor related to correlation among fintech companies regards the possibility of taking correlated risks of unbanked consumers. "FinTech in many cases attempts to fill the gap by providing easy to understand and convenient services, which tend to lower costs of adoption and lower barriers to access for customers" (FSB 2017b, 35). Indeed, fintech can increase social inclusion, which might bring some correlated risks.

Fintech and Concentration

Fintech could affect the concentration of activities in the financial sector. The caveat is that fintech has the potential to change the concentration in the market. Fintech could increase the number of players in financial activities by providing alternatives to traditional players (Depository Trust & Clearing Corporation [DTCC] 2017), an example being P2P lending, which provides credit to borrowers as an alternative to a traditional bank. On the other hand, fintech could lead to a situation in which there is only a small number of players in key financial activities, as it potentially provides new services that other firms do not provide or, from a geographic standpoint, enters new markets in which there are not many players.

Fintech and Substitution

According to the DTCC (2017), people should consider the risk that the substitutability of fintech firms poses on a case-by-case basis. The concentration might be such that

one firm can easily substitute another, as is likely to be the case of electronic payment systems. P2P lending might be an area, however, in which substitutability is low, since the credit often supplies individuals or businesses that might have difficulty obtaining this service from a traditional bank (De Roure, Pelizzon, and Tasca 2016).

Fintech and Context/Conditions

As Thomson (2010, 142) put it, "Firms that might be made systemically important by conditions/context are probably the most difficult to identify in advance." Not only are they difficult to identify, but they are also dependent on the probability of occurrence of the condition that would cause said firms to become systemically important (Thomson 2010). Fintech would not necessarily be immune to conditional systemic importance, but there have not been instances of this occurring either.

Keeping these indicators of systemic importance in mind and relating them to the current and "historical" states of fintech, our hypothesis is that *fintech firms do not contribute greatly to systemic risk at this time.*

4. DATA AND METHODOLOGY

4.1 Data

In our analysis, we used a unique dataset composed of 75 fintech companies quoted on the Nasdaq and Frankfurt stock exchanges. We based the sample of companies on the KBW Nasdaq Financial Technology Index (KFTX) for the Nasdaq Stock Exchange and on the CedarIBS FinTech Index (CIFTI) for the Frankfurt Stock Exchange. According to Nasdaq (2017), the KFTX "is designed to track the performance of financial technology companies that are publicly traded in the U.S." The index began in July 2016, and it currently includes 50 companies. According to IBS Intelligence's website, "the CIFTI is a unique equity index comprising of selected FinTech companies from around the world, across 25 exchanges." The CIFTI comprises four key indexes that track the performance of 50 large fintech companies (CIFTI 50) and large-, medium-, and small-cap fintech companies (respectively CIFTI Large Cap, CIFTI Mid Cap, and CIFTI Small Cap). For the scope of our analysis, among these companies, we selected only the companies quoted on the Frankfurt Stock Exchange.

The final sample includes 39 fintech companies for the US stock exchange and 53 fintech companies for the European stock exchange[1]; 17 companies are quoted on both stock exchanges and therefore the panel comprises a total of 75 fintech companies. We obtained the estimations that section 4.2 reports separately for the US and the European sample. The panel of companies extends from January 2010 to December 2017 and is unbalanced, since, given the recent evolution of the fintech industry, it also includes companies that began operation and/or became publicly quoted after 2010. Table A.1 classifies the fintech companies according to the following categories:

- Alternative financing—firms that provide credit (loans) to individuals and/or businesses but do not fall into the bank classification because they do not engage in other traditional banking activities;

[1] Note that the number of companies that we included is smaller than the original number (48 companies for the Nasdaq index and 73 companies for the IBS index related to the Frankfurt Stock Exchange) due to data availability.

- Data analytics—firms that provide solutions via data analytics;
- Digital banks—firms that provide banking services without bricks and mortar;
- Market and trading support—markets that provide financial services and firms that provide support via technological solutions for trading activities;
- Payments and remittances—firms that provide payment systems and products;
- Robo-advisors and personal finance—firms that provide advice and/or management for financial assets for individuals; and
- Software solutions and IT—firms that provide software and information technology solutions for business processes, including HR, supply chain management, cloud-based services, security, and so on.

Since we chose to use stock indices in the market, we did not control the number of firms that fell into each category. As such, some categories contained relatively few (or no) firms; for example, in our analysis of European fintech firms, no firms fell into the category of alternative financing. In reality, regardless of the popularity of P2P lending, not many P2P lending firms have public listings, and none are listed on the Frankfurt Stock Exchange. Therefore, we had none in the category for alternative financing for Europe and only one in that category for the US. Other categories in our list included a relatively low number of firms (with the payment and remittances and the software solutions and information technology categories comprising the bulk) as a result of the indices that we used.

We also included a representative sample of the US and European financial industries to determine the impact that fintech companies have on systemic risk within the entire financial industry. We obtained the estimations in section 4.2 using the US and European fintech samples and their respective financial industry. We based the US financial industry sample on the panel of companies that Brownlees and Engle (2016) selected to measure the contribution of a financial firm to systemic risk. According to the authors, "the panel contains all US financial firms with a market capitalization greater than 5 bln USD as of the end of June 2007" (Brownlees and Engle 2016, 15). We based the European financial industry sample on the panel of companies that the Center for Risk Management (CRML) selected to measure systemic risk in Europe. The CRML's systemic risk measures follow the methodology that Engle, Jondeau, and Rockinger (2014) developed and the sample of "financial institutions involve several categories, including banks, insurance companies, and real estate firms".[2] The final sample of the US financial industry consists of 41 companies, and the final sample of the European financial industry contains 54 companies[3] (Table A.2 reports the list of companies).[4]

We obtained the daily adjusted closing prices, the daily market capitalization, and the daily beta from Thomson Reuters Eikon, and we obtained the quarterly balance sheet data for the book value (total assets and total shareholders' equity) from Orbis. We used the market capitalization, the total assets, and the total shareholders' equity to compute

[2] Center for Risk Management at Lausanne (CRML). 2018. http://www.crml.ch/index.php?id=39.

[3] The original sample of Brownlees and Engle (2016) contained 95 companies, and the original sample of the CRML consisted of 87 companies. Our samples are restricted due to data availability (in particular, our US sample is restricted with respect to the sample of Brownlees and Engle (2016), since a portion of companies merged or failed following the financial crisis).

[4] From now on, we will refer to the US financial system to indicate the representative sample of the US financial industry and those fintech firms that are part of the KBW Nasdaq Financial Technology Index. Similarly, we will refer to the European financial system to indicate the representative sample of the European financial industry and those fintech firms that are part of the CedarIBS FinTech Index and are quoted on the Frankfurt Stock Exchange.

the market value of assets (MVA) of each firm. We then took the growth rate of the MVA to estimate the ΔCoVaR. We computed the MVA of each firm as follows:

$$MVA_{it} = total\ assets_{it} * \frac{market\ capitalization_{it}}{shareholders'\ equity_{it}} \quad (1)$$

We used the total assets (as a proxy for the company's size) and the beta to estimate the correlation table (see Table A.3 for a detailed description of the variables). The estimations have a weekly frequency. We obtained the weekly data using the last available daily data point of each week. Following the Federal Reserve Bank of Cleveland's method for using quarterly data more frequently (Federal Reserve Bank of Cleveland 2016), we assigned to each week the respective quarter (therefore, quarterly data repeat over the 3-month period).

Tables A.4 and A.5 report the summary statistics for the set of variables that we used to estimate the ΔCoVaR measure, broken down by the type of firm—either from the traditional financial industry or from the corresponding fintech category—for the US and the European sample, respectively. Concerning the market capitalization of the US sample, we can classify the median fintech firm as mid-cap (between $5.9 billion and $8.6 billion), whereas the median financial industry firm corresponds to the large-cap category (about $15 billion). As for the European sample, the median market capitalization in each category ranges from $2.9 to $7.8 billion, thereby corresponding to mid-cap stocks. The higher market capitalization of firms in the traditional financial system, compared with fintech, reflects the degree of maturity of the two sectors; however, it is worth mentioning that, in the case of Europe, the maximum market capitalization is generally higher for fintech firms (about $23 billion) than for those in the traditional financial system. Similarly, shareholders' equity for the median fintech firm is smaller than for that in the traditional financial sector; the median shareholders' equity of fintech firms represents about 10% of that of the traditional financial companies.

As one might expect, since many fintech firms are in a relatively early stage of development with respect to the whole financial sector, the median of the weekly stock returns is higher for the former (apart from the alternative financing category). Thus, the median stock returns for the US (European) traditional financial firms is 0.2% (–0.1%) and about 0.4% (0.2%) for fintech firms.

In terms of total assets, fintech firms represent around 2% (1%) of the traditional financial firms in the US (European) sample. Indeed, as section 3 mentioned, the overall portion of assets of fintech institutions in the financial sector remains relatively small.

4.2 Estimation of CoVaR and ΔCoVaR Measures

As section 2 mentioned, CoVaR and ΔCoVaR became widely known measures of systemic risk after Adrian and Brunnermeier's (2016) seminal paper. We used their method for our purpose of assessing whether fintech firms contribute to systemic risk based on the observed average of these indicators within the period 2010–2017.

It is possible to interpret the CoVaR measure, which makes possible the calculation of the ΔCoVaR afterwards, as the value at risk (VaR) of a firm (or system) *x* conditional on firm *y* already being at its value at risk. This definition requires us to take one step back to explain what the latter is.

4.2.1 Value at Risk

There are different ways to estimate VaR; nevertheless, here we will just focus on the methodology that we used for our estimations. Estimating the historical empirical distribution of stock returns of a firm enables the calculation of a threshold at which the firm itself is in distress. It is worth mentioning that the researcher decides the level associated with distress, but it is typically 5%, which is the threshold that we utilized. Taking this into consideration, we can write VaR as:

$$Pr\left(Z^i \leq VaR^i_{0.05}\right) = 5\% \tag{2}$$

This means that we consider the observed stock return at the 5th percentile of the empirical distribution as a signal of concern regarding the performance of the firm, since this percentile contains the lowest returns observed during the period under consideration (see Figure B.1 for a graphical representation of VaR). Hence, identifying the VaR for each firm comprised in our sample represents the basis of the estimations to evaluate finally how a distressed fintech firm affects the entire financial system when the latter is also at its VaR.

4.2.2 Conditional Value at Risk

After identifying the 5% VaR of firm *i*, we must check how the VaR of the financial system comoves with (conditional on) each of the former, which is what the $CoVaR^{system|i_{0.05}}$ measure will indicate, as the following equations show:

$$Pr\left(Z^{system|i_{0.05}} \leq CoVaR^{system|i_{0.05}}_{0.05}\right) = 5\% \tag{3}$$

$$CoVaR^{system|i_{0.05}} = \hat{\alpha}^i_{0.05} + \hat{\beta}^i_{0.05} VaR^i_{0.05} \tag{4}$$

As one can observe, to calculate the CoVaR, we need the estimates of α and β at the 5th percentile, which we can obtain through a quantile regression of the form:

$$X^{sys} = \alpha^i_{0.05} + \beta^i_{0.05} X^i + \epsilon \tag{5}$$

Unlike ordinary least squares (OLS) regression, quantile regression coefficients capture the change in a specified quantile of the dependent variable that a one unit change in the regressors produces. As Bjarnadottir (2012, 9) stated, "when estimating CoVaR the focus is on a specific low quantile of a distribution and hence it is convenient to use quantile regression here."

Considering the data definitions that section 4.1 introduced, our specification for this estimation took into account the modification that Lopez-Espinosa et al. (2012) proposed of regressing the sum of the asset returns of each financial institution in the system, weighted by its lagged MVA (X^{sys}), on the asset returns of firm *i* (X^i), just as Adrian and Brunnermeier (2016) did but excluding firm *i* from X^{sys} to avoid a spurious relationship with the regressor. This means that we computed *N* (number of firms) different X^{sys} variables, each one omitting each firm *i* at a time.

4.2.3 ΔCoVaR

Having calculated the 5% CoVaR for each firm, we then estimated the median CoVaR, which represents the VaR of the financial system conditional on firm *i* being in its normal state.

Together, both CoVaR estimations allowed us to identify how much the fact that firm *i* is distressed contributes to the financial system VaR. Adrian and Brunnermeier (2016) estimated this as the difference between the 5% and the 50% CoVaR:

$$CoVaR_{0.05}^{system|i} = CoVaR_{0.05}^{system|VaR_{0.05}^{i}} - CoVaR_{0.05}^{system|VaR_{0.5}^{i}} \quad (6)$$

which it is possible to reduce to:

$$\Delta CoVaR_{0.05}^{system|i} = \hat{\beta}_{0.05}^{i}\left(VaR_{0.05}^{i} - VaR_{0.5}^{i}\right) \quad (7)$$

To sum up, the output obtained from these computations will yield the contribution of each firm to systemic risk, denoted as a negative ΔCoVaR, which we will ultimately rank from least to greatest.

4.3 Spearman's Rank Correlation

Finally, to evaluate whether the ranking that we derived from the ΔCoVaR estimation contributes to improving the systemic risk measurement—in addition to variables such as size or volatility associated with the systemic importance of firms—we computed Spearman's rank correlation coefficients.

This statistic calculates the level of association of two ranked variables using the following formula:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \quad (8)$$

where d_i is the difference in ranks for each firm and *n* is the number of firms in our final sample.

Afterwards, we needed to verify the significance of this correlation coefficient by testing the null hypothesis of no monotonic correlation. Section 5 presents both the correlation coefficients and the p-values.

5. RESULTS

Our results seem to be in line with previous evidence that has excluded the fintech industry from systemic risk estimations in the sense that the empirical literature, such as Brownlees and Engle (2016), and regulatory authorities, as in the case of the European Banking Authority, have already recognized many of the financial companies that our estimations identified as systemic—that is, Citigroup and Morgan Stanley in the US and Banco Bilbao Vizcaya Argentaria (BBVA) and Credit Suisse in Europe—as some of the most systemically risky financial firms.[5] Although identifying systemic financial firms is

[5] For the updated list of global systemically important institutions for 2017, see http://www.eba.europa.eu/risk-analysis-and-data/global-systemically-important-institutions/2017.

beyond the scope of this paper, those results ultimately allowed us to validate our findings for the fintech industry using the methodology proposed.

Having said this, the ΔCoVaR computations showed that we cannot consider fintech companies as systemically important according to their historical performance in comparison with other financial companies. In the remainder of this section, we will provide a detailed explanation of the results for each particular sample.

5.1 United States

Within the whole financial system, 20 fintech companies—out of 36 in our final sample—contribute to systemic risk, 0.03% being the maximum contribution of any individual fintech firm (see Table A.6). In fact, among the 10 fintech companies that contribute the most to systemic risk, the majority corresponds to firms of which the main business relates to payments and remittances and market and trading support. In addition, it is worth mentioning that LendingClub, the only fintech providing alternative financing in our sample, has the second-highest contribution within this "Top 10."

Another interesting result from our estimations is that the remaining 16 fintech firms alleviate systemic risk. We can consider this as partial evidence for the previous literature conceiving fintech as an emerging alternative to the traditional financial system.

The second step consisted of implementing the ΔCoVaR methodology while isolating the fintech industry in an attempt to identify those firms that are leading the sector's performance. The results in Table A.8 are very similar to those of the exercise for the whole financial system; indeed, fintech companies related to payments and remittances seem to be highly relevant when assessing the risk of the industry.

As we mentioned in section 4, we computed the Spearman's rank correlation to evaluate whether the ranking that we derived from the ΔCoVaR measure surpasses the identification of systemic firms based on their size (respectively beta) or whether the latter alone is sufficient; that is, the bigger (respectively the more volatile in relation to the market) the firm is, the more systemic it is and vice versa. Before discussing the overall correlation, Figures B.2 and B.3 present these relationships by firm and the corresponding category, and we can observe that it is not possible to associate greater size (respectively beta) with either high or low ΔCoVaR. As for the Spearman correlation, the results indicate that the two measures are positively and fairly correlated ($\rho = 0.51$), which means that the ΔCoVaR measure indeed contributes to a better identification of systemic risk rather than drawing conclusions based just on the size ranking. This supports previous advice from financial authorities, such as the Office of Financial Research in the US (2017, 6), which highlighted that "size is not always a good proxy for systemic importance." Additionally, we computed the Spearman correlation associating the ΔCoVaR ranking with that of the beta of the firms. In this case, the correlation between the two rankings was low, $\rho = 0.31$, meaning that a more volatile firm is not highly associated with its systemic importance (according to ΔCoVaR) and vice versa (see Table A.10 for a summary of the results).

5.2 Europe

In the European financial system, the results show that 32 fintech firms, out of 53, contribute to systemic risk. However, the individual contribution of each firm is nearly 0% (see Table A.7) and the aggregate contribution is roughly 0.05%. As in the US case, the remaining fintech firms (21) reduce systemic risk by 0.11%, which also supports their little relevance within the industry under our methodology. Table A.9 shows the results from the estimation of the ΔCoVaR within the fintech industry. Interestingly, contrary to the US industry, fintech firms providing software solutions and information technologies seem to contribute the most to the risk of the sector.

Finally, the Spearman's rank correlation between the ranking of the ΔCoVaR measure and the firm size indicates a slightly higher correlation between the two of them, $\rho = 0.58$, in comparison with the US results. Nevertheless, this still supports the contribution of our estimations to improving the assessment of systemic risk. Regarding the additional correlation with the beta, we found that the correlation is $\rho = 0.59$—slightly higher than that with size—suggesting that the volatility of European fintech firms could also help in evaluating their systemic importance (see Table A.8 for a summary of the results and Figures B.4 and B.5 for the disaggregated representation).

5.3 Final Remarks on the Results

Despite the fact that our results confirmed that fintech firms are not contributing significantly to systemic risk, we endeavored to conduct further research regarding the increase in partnering between them and financial companies. Since our main concern is systemic risk, we focused on those financial firms in the "Top 10" of the ΔCoVaR estimations, given that previous empirical research has already identified most of them as systemic.

With respect to the US sample, out of the 10 most systemic financial companies, seven of them are partnering and/or investing in fintech. For instance, according to the media company Bank Innovation (Kulkarni 2018), Citigroup Inc. is among the top global banks that invest in fintech and has 26 fintech firms in its portfolio; another example is Goldman Sachs, which owns 27 fintech firms, adding six new ones in 2017 (CB Insights 2018).

In the case of the top systemic European financial companies, six of them are partnering and/or investing in fintech. BBVA (2018), which has recently announced an investment in the UK online mortgage brokerage Trussle, is an example. In addition, Groupe Crédit Agricole (2018) has participated in the private fundraising of SETL—an institutional payment and settlement infrastructure provider that uses blockchain technology.

6. CONCLUSIONS

This paper tackles the role that fintech might have in systemic risk. Using a unique dataset of European and US fintech companies, we estimated the ΔCoVaR, which captures the tail dependency between the financial system and a specific institution. This allowed us to rank firms by how much their individual distress contributes to the VaR of the whole system. We conducted the exercise both for the fintech industry and for the entire financial system to capture, respectively, the fintech firms that are leading the risk of the industry and the position of the fintech firms within the entire financial sector.

The results that section 5 reported show that, for the US, the payment and remittances and the market and trading support categories contribute the most to the VaR of the fintech industry. Instead, in Europe, fintech firms that provide software solutions and information technologies seem to be contributing the most to the risk of the sector. The estimation that includes fintech firms and the representative sample of the financial sectors show that fintech firms are not systemically important. Within the US financial system, the fintech companies that do contribute to systemic risk increase it by around 0.03%, while, in Europe, fintech firms contribute very little to the systemic impact (close to 0%). The Spearman's rank correlation between a fintech firm's ΔCoVaR and its respective size and between a fintech firm's ΔCoVaR and its beta strengthens the importance of our estimations for a better assessment of systemic risk rather than just relying on the size and the beta of the firms to determine their likely contribution to systemic risk.

While our results show that these fintech firms do not contribute greatly to systemic risk, confirming our hypothesis of section 3, we should approach that conclusion with caution because of the interconnectedness of the financial industry with fintech and fintech firms. As the DTCC (2017, 4) stated, "The boundaries between fintech start-ups and traditional incumbents are blurring quickly as they become increasingly interconnected." As section 5 mentioned, financial companies such as Citigroup Inc. and BBVA are partnering with/investing in fintech, and there are many other examples.

Some limitations of our study include the scope of our analysis method (ΔCoVaR), the representation of the fintech sector, and the analysis of only two markets. ΔCoVaR represents "the increase in system-wide risk due to the distress of a financial institution" (Castro and Ferrari 2014, 12), but disregards some firm-specific factors, such as the capital shortfall or the leverage of a firm, since ΔCoVaR is the measure of tail co-movement between the system and the firm. Methods such as SRISK, which Brownlees and Engle (2016) proposed, and the leverage ratio exposure measure of the European Banking Authority (2017) take these into account. While we chose to use indices that theoretically should be representative of fintech in their respective markets, as we mentioned previously, some categories (i.e., alternative financing or digital banks) do not have a large representation among *public* fintech firms either because not many are publicly traded or they were simply not part of the indices. As such, it is difficult to draw safe conclusions on which categories of fintech companies have a greater potential impact on systemic risk because of the sample considered. Another limitation of our study is the fact that our analysis concerned only two markets, both of which are developed markets, but fintech has different potential in emerging markets (Lee and Teo 2015). This is apparent from the P2P lending and other fintech activities in the People's Republic of China (PRC), where the adoption rate of fintech for consumers is 69% while the global average is 33% (EY 2017).

Given the diversity of fintech firms, micro-level data analysis focusing on each individual fintech category could reveal the specific risks attached to each of them, highlighting key research lines. For instance, Buchak et al. (2017) analyzed lending fintech firms using loan-level data for the US, whereas, as section 2 mentioned, both EY (2017) and PwC (2017) have started implementing surveys to track fintech evolution.

Beyond further research, it is important to include fintech firms when considering the regulation of the financial industry. Even though our analysis did not show that fintech contributes greatly to systemic risk at this moment, we agree with the former Managing Director of the International Monetary Fund (Lagarde 2018) on fintech regulation. According to Lagarde (2018), it is necessary to consider and develop a regulatory framework now, before fintech contributes to risk in the financial system. On the other hand, she cautioned against regulating in such a way that hinders the evolution of technology, stating, “We must guard against emerging risks without stifling innovation” (Lagarde 2018, 9). We see that “regulatory sandboxes” are emerging in many economies to give fintech a place to “play.” In other words, a sandbox is a framework that regulators set up (generally for a limited period) and that allows fintech to grow, change, or evolve in a live but controlled setting (European Commission 2018). Given these considerations, our paper is an initial contribution giving policy makers and regulators a better understanding of fintech, which is necessary to regulate fintech firms without inhibiting innovation.

REFERENCES

Acharya, V., R.F. Engle, and M. Richardson. 2012. “Capital Shortfall: A New Approach to Ranking and Regulating Systemic Risks.” *American Economic Review* 102 (3): 59–64.

Adams, Z., R. Füss, and R. Gropp. 2014. “Spillover Effects among Financial Institutions: A State-Department Sensitivity Value-at-Risk Approach.” *Journal of Financial and Quantitative Analysis* 49 (3): 575–98.

Adrian, T., and M.K. Brunnermeier. 2016. CoVaR. *American Economic Review* 106 (7): 1705–41.

Allen, F., A. Babus, and E. Carletti. 2012. “Asset Commonality, Debt Maturity and Systemic Risk.” *Journal of Financial Economics* 104 (3): 519–34.

Allen, F., and D. Gale. 2000. “Financial Contagion.” *Journal of Political Economy* 108 (1): 1–33.

Arner, D.W., J. Barberis, and R.P. Buckley. 2016. “150 Years of FinTech: An Evolutionary Analysis.” *JASSA The Finsia Journal of Applied Finance* 3: 22–9.

Banco Bilbao Vizcaya Argentaria (BBVA). 2018. “Propel Invests into Disruptive Online Mortgage Broker Trussle.” Accessed 23 May 2018. https://www.bbva.com/en/propel-invests-disruptive-online-mortgage-broker-trussle/.

Billio, M., M. Getmansky, A.W. Lo, and L. Pelizzon. 2012. “Econometric Measures of Connectedness and Systemic Risk in the Finance and Insurance Sectors.” *Journal of Financial Economics* 104 (3): 535–59.

Bjarnadottir, F. 2012. “Implementation of CoVaR: A Measure for Systemic Risk.” DiVA. Accessed 30 April 2018. http://kth.diva-portal.org/smash/get/diva2:555813/FULLTEXT01.pdf.

Brownlees, C.T., and R.F. Engle. 2016. “SRISK: A Conditional Capital Shortfall Measure of Systemic Risk.” SSRN. Accessed 11 April 2018. https://ssrn.com/abstract=1611229.

Buchak, G., G. Matvos, T. Piskorski, and A. Seru. 2017. *Fintech, Regulatory Arbitrage, and the Rise of Shadow Banks* (No. w23288). National Bureau of Economic Research. Accessed 15 May 2018. http://www.nber.org/papers/w23288.

Castro, C., and S. Ferrari. 2014. “Measuring and Testing for the Systemically Important Financial Institutions.” *Journal of Empirical Finance* 25: 114.

CB Insights. 2018. “Where Top Banks are Betting on Fintech.” CB Insights. Accessed: 14 May 2018. https://www.cbinsights.com/research/fintech-investments-top-us-banks/.

Center for Risk Management Lausanne. 2018. “List of Systemically Important European Institutions.” Accessed 30 April 2018. http://www.crml.ch/index.php?id=39.

Das, S.R., and R. Uppal. 2004. “Systemic Risk and International Portfolio Choice.” *Journal of Finance* 59 (6): 2809–34.

De Roure, C., L. Pelizzon, and P. Tasca. 2016. *How Does P2P Lending Fit into the Consumer Credit Market?* Bundesbank Discussion Paper No. 30/2016. SSRN. Accessed 25 May 2018. https://ssrn.com/ abstract=2848043.

Depository Trust & Clearing Corporation. 2017. “Fintech and Financial Stability: Exploring How Technological Innovations Could Impact the Safety & Security of Global Markets.” New York City, NY. Accessed 25 April 2018. http://www.dtcc.com/news/2017/october/16/dtcc-unveils-framework-for-assessing-fintechs-impact-on-financial-stability-in-new-white-paper.

Dixon, A. 2018. “America’s 15 Largest Banks.” Bankrate. Accessed 6 May 2018. https://www.bankrate.com/banking/americas-top-10-biggest-banks/#slide=1.

Engle, R., E. Jondeau, and M. Rockinger. 2014. “Systemic Risk in Europe.” *Review of Finance* 19 (1): 145–90.

European Banking Authority. 2017. “Large Institutions with a Leverage Ratio Exposure Measure above 200bn EUR.” Accessed 14 May 2018. http://www.eba.europa.eu/risk-analysis-and-data/global-systemically-important-institutions/2017.

European Commission. 2018. “FinTech: Commission Takes Action for a More Competitive and Innovative Financial Market.” Press release. Accessed 1 May 2018. http://europa.eu/rapid/press-release_IP-18-1403_en.htm.

EY. 2017. “EY FinTech Adoption Index 2017: The Rapid Emergence of FinTech.” Accessed 11 April 2018. http://www.ey.com/gl/en/industries/financial-services/ey-fintech-adoption-index.

Federal Reserve Bank of Cleveland. 2016. “Systemic Risk Analysis Using Forward-Looking Distance-to-Default Series: An Application to US Banks, Model Documentation.” Accessed 5 March 2018. https://www.clevelandfed.org/our-research/indicators-and-data/systemic-risk-indicator.aspx.

Financial Stability Board. 2017a. “Fintech Credit: Market Structure, Business Models and Financial Stability Implications.” Accessed 8 May 2018. http://www.fsb.org/2017/05/fintech-credit-market-structure-business-models-and-financial-stability-implications/.

———. 2017b. “Financial Stability Implications from Fintech Supervisory and Regulatory Issues that Merit Authorities’ Attention.” Accessed 8 May 2018. http://www.fsb.org/2017/06/financial-stability-implications-from-fintech/.

Fong, T., and A. Wong. 2011. “Analysing Interconnectivity among Economies.” *Emerging Markets Review* 12 (4): 432–42.

Fong, T., L. Fung, L. Lam, and I. Yu. 2011. “Measuring the Interdependence of Banks in Hong Kong.” *Review of Futures Markets* 20 (1): 1–26.

French, S. 2017. “These Are the Most Valuable Fintech Companies in America.” Market Watch. Accessed 6 May 2018. https://www.marketwatch.com/story/these-are-the-most-valuable-fintech-companies-in-america-2017-11-15.

Groupe Crédit Agricole. 2018. “Crédit Agricole CIB Participated in the Private Fundraising of SETL. This Is the Bank’s First Equity Investment in a Fintech.” Accessed 22 May 2018. https://pressroom.credit-agricole.com/news/credit-agricole-cib-acquires-equity-stake-in-the-fintech-setl-the-financial-blockchain-specialist-9ff4-94727.html.

IBS Intelligence. “IBS Intelligence Launches the CedarIBS Fintech Index (CIFTI).” Accessed 12 March 2018. https://ibsintelligence.com/fintech-index/.

KPMG. 2018. “The Pulse of Fintech Q4 2017: Global Analysis of Investment in Fintech.” Accessed 23 May 2018.

https://home.kpmg.com/xx/en/home/insights/2018/02/
pulse-of- fintech-q4-2017.html.

Kulkarni, T. 2018. “Top U.S. Banks Are Investing Most in Personal Finance Fintechs.” Bank Innovation. Accessed 9 May 2018. https://bankinnovation.net/2018/02/
top-u-s-banks-are- investing-most-in-personal-finance-fintechs/.

Lagarde, C. 2018. “A Regulatory Approach to Fintech.” *Finance & Development* 55 (2): 9–10.

Lee, D.K.C., and G.S. Teo. 2015. “Emergence of FinTech and the LASIC Principles.” *Journal of Financial Perspectives* 3 (3): 1–26.

Lopez-Espinosa, G., A. Moreno, A.R. Serrano, and L. Valderrama. 2012. *Short-Term Wholesale Funding and Systemic Risk: A Global CoVaR Approach*. IMF Working Paper No. 12/46. SSRN. Accessed 5 May 2018. https://ssrn.com/
abstract=2012231.

Magnuson, W.J. 2017. “Regulating Fintech.” *Vanderbilt Law Review*, forthcoming. Texas A&M University School of Law Legal Studies Research Paper No. 17-55. SSRN. Accessed 14 May 2018. https://ssrn.com/abstract=3027525.

Nasdaq. 2017. “KBW Nasdaq Financial Technology Index Methodology.” Accessed 11 March 2018. https://indexes.nasdaqomx.com/Index/Overview/KFTX.

Office of Financial Research. 2017. “Size Alone is not Sufficient to Identify Systemically Important Banks.” *OFR Viewpoint*. Accessed 28 April 2018. https://www.financialresearch. gov/viewpoint-papers/2017/10/26/size-not-sufficient-to-identify-systemically-important-banks/.

Philippon, T. 2016. *The Fintech Opportunity*. NBER Working Paper No. w22476. SSRN. Accessed: 22 April 2018. https://ssrn.com/abstract=2819862.

PwC. 2017. “Redrawing the Lines: FinTech’s Growing Influence on Financial Services.” Accessed 5 March 2018. https://www.pwc.com/jg/en/issues/redrawing-the-lines-fintechs-growing-influence-on-the-financial-services-2017.html.

Statista. 2018. “FinTech.” Accessed 4 May 2018. https://www.statista.com/outlook/295/
100/fintech/worldwide#.

Thomson, J.B. 2010. “On Systemically Important Financial Institutions and Progressive Systemic Mitigation.” *DePaul Business Commercial Law Journal* 8 (2): 135–50.

APPENDIX A: TABLES

Table A.1: Fintech Samples

Alternative Financing	Data Analytics	Digital Banks	Market and Trading Support	Payments and Remittances	Robo-Advisors and Personal Finance	Software Solutions/IT
			U.S.			
LendingClub	FactSet IHS Markit Moody's S&P Global Verisk Analytics	Green Dot Corporation	Cboe CME Group Intercontinental Exchange MarketAxess Nasdaq Virtu Financial	ACI Worldwide American Express Blackhawk Network Holdings Cardtronics Euronet Worldwide Evertec, Inc. First Data Fiserv FLEETCOR Global Payments Mastercard PayPal Square Verifone Visa Western Union WEX, Inc. Worldpay	Envestnet MSCI SEI Investments Company	Broadridge Financial Solutions Equifax Jack Henry & Associates SS&C Technologies Thomson Reuters
			Europe			
	FactSet FICO IHS Markit PRGX Global, Inc. Teradata	Genpact	Amber Road Inc.	American Express Blackhawk Network Holdings Cognizant Euronet Worldwide Everi Evertec, Inc. First Data Fiserv FLEETCOR Global Payments Ingenico Mastercard MercadoLibre MoneyGram SafeCharge TSYS Verifone Western Union WEX, Inc. Wirecard	Envestnet Intuit IRESS	ADP CANCOM China Information Tech Diebold Nixdorf, AG Diebold Nixdorf, Inc. DST Systems DXC Technology Equifax FIS Jack Henry & Associates Luxoft Model N NCR PFSweb Points SAP ServiceSource Syntel Temenos Tungsten Corporation Virtusa Wipro Xero

Table A.2: Financial Industry Samples

US	Europe
Citigroup, Inc.	Aareal Bank
Legg Mason	Albaraka Turk Katilim Bankasi AS
Principal	Alpha Bank
Goldman Sachs	Banca Carige
BNY Mellon	Banca Monte dei Paschi di Siena
Morgan Stanley	Banca Popolare di Sondrio
T. Rowe Price	Banco Bilbao Vizcaya Argentaria
Janus Henderson Group	Banco BPI
Northern Trust	Banco BPM
AGNC Investment Corp.	Banco Comercial Portugues
PNC Financial Services	Banco de Sabadell
CBRE Group	Banco Santander
New York Community Bank	Bank of Ireland Group
Comerica	Bankia
U.S. Bancorp	Barclays
M&T Bank	BNP Paribas
State Street Corporation	BPER Banca
BB&T	CaixaBank
Marsh & McLennan Companies	Commerzbank
Fifth Third Bank	Crédit Agricole
KeyCorp	Credit Suisse
Synovus	Credito Emiliano
Western Union	Deutsche Bank
Bank of America	Dexia
Ameriprise Certificate Company	EFG International
Suntrust Banks	Erste Group
Wells Fargo Company	Eurobank Ergasias
TD Ameritrade	ING Group
Blackrock	Intesa Sanpaolo
E-Trade	Jyske Bank
Freddie Mac	London Stock Exchange Group
Charles Schwab	Marfin Investment Group
People's United Financial	National Bank of Greece
Fannie Mae	Nordea Bank
Franklin Resources	Oldenburgische Landesbank
Regions Financial Corporation	Permanent TSB Group
Zions Bancorporation	Piraeus Bank
Capital One	Plaza Centers N.V.
SLM Corporation	Raiffeisen Bank International
CIT Group	RBS Group
Huntington Bancshares	Sekerbank
	Skandinaviska Enskilda Banken
	Société Générale
	Standard Chartered
	Svenska Handelsbanken AB
	Swiss Life
	TP ICAP
	Turkiye Halk Bankasi
	Turkiye Vakiflar Bankasi
	UBS Group AG
	UniCredit
	UBI Banca
	VTB Bank
	Wuestenrot & Wuerttembergische

Table A.3: Variable Definitions

Variable	Formula	Fin. Statements	Definition	Source
Total Assets	Fixed Assets + Current Assets	Fixed Assets	Total amount (after depreciation) of non-current assets (intangible assets + tangible assets + other fixed assets)	Orbis
		Intangible Fixed Assets	*All intangible assets, such as formation expenses, research expenses, goodwill, development expenses, and all other expenses with a long-term effect*	
		Tangible Fixed Assets	*All tangible assets, such as buildings, machinery, and so on*	
		Other Fixed Assets	*All other fixed assets, such as long-term investments, shares and participations, pension funds, and so on*	
		Current Assets	Total amount of current assets (stocks + debtors + other current assets)	
		Stocks	*Total inventories (raw materials + in progress + finished goods)*	
		Debtors	*Trade receivables (from clients and customers only)*	
		Other Current Assets	*All other current assets, such as receivables from other sources (taxes, group companies), short-term investment of money and cash at bank and in hand*	
Total Shareholders' Equity	Capital + Other Shareholders' Funds	Capital	Issued share capital (authorized capital)	Orbis
		Other Shareholders' Funds	All shareholders' funds not linked with the issued capital, such as reserve capital and undistributed profit, also including minority interests if any	
Adjusted Stock Price	Closing Price	Closing Price	The latest available closing price. If there are no trades for the most recent completed tradable day, the most recent prior tradable day with trading activity is used, provided the last tradable day for the instrument is within 378 completed calendar days (54 weeks).	Thomson Reuters Eikon
Market Capitalization	Number of Outstanding Shares* Current Stock Price	Market Cap.	The company market capitalization represents the sum of market value for all relevant issue-level share types. The issue-level market value is calculated by multiplying the requested share type by the latest close price. This item supports default, free float, and outstanding share types. The default share type is the most widely reported outstanding shares for a market and is most commonly issued, outstanding, or listed shares.	Thomson Reuters Eikon
Beta	Covariance (r_i, r_m) / Variance (r_m)	Beta	CAPM beta: a measure of how much the stock moves for a given move in the market. It is the covariance of the security's price movement in relation to the market's price movement. Based on data availability, various look-back periods can be used to calculate it. In order of preference, the beta 5Y monthly, beta 3Y weekly, beta 2Y weekly, beta 180D daily, and beta 90D daily are used in the calculation.	Thomson Reuters Eikon

Note: The total assets and total shareholders' equity are book values.

Table A.4: Summary Statistics: US Financial System

	N	Mean	Median	Min.	Max.	SD
Financial Industry						
Market Capitalization	14,808	32.5	15.3	0.2	311.7	48.0
Stock Returns (%)	14,808	0.2	0.2	–48.5	79.4	4.2
Total Assets	14,808	384.8	105.8	2.5	3,345.5	686.0
Shareholders' Equity	14,808	31.8	9.8	0.1	272.5	55.9
Fintech						
Alternative Financing						
Market Capitalization	117	20.3	8.6	1.1	240.8	32.8
Stock Returns (%)	117	–1.0	–0.7	–70.4	23.2	10.2
Total Assets	117	5.4	5.6	4.6	5.9	0.4
Shareholders' Equity	117	1.0	1.0	0.9	1.1	0.0
Data Analytics						
Market Capitalization	1,576	17.4	6.6	0.3	253.8	30.5
Stock Returns (%)	1,576	0.3	0.3	–31.3	15.7	3.0
Total Assets	1,576	4.6	4.7	0.6	14.6	3.3
Shareholders' Equity	1,576	1.2	0.6	0.0	8.4	1.7
Digital Banks						
Market Capitalization	208	19.2	7.3	0.9	195.2	32.6
Stock Returns (%)	208	0.4	0.4	–27.0	26.9	4.9
Total Assets	208	1.6	1.7	1.1	2.2	0.3
Shareholders' Equity	208	0.6	0.7	0.4	0.8	0.1
Market Trading and Support						
Market Capitalization	1,514	16.1	6.4	0.3	250.9	29.3
Stock Returns (%)	1,514	0.4	0.4	–18.8	20.4	3.4
Total Assets	1,514	14.2	3.5	0.3	78.5	23.5
Shareholders' Equity	1,514	4.8	0.5	0.2	22.4	7.0
Payments and Remittances						
Market Capitalization	5,287	16.4	6.7	0.3	258.4	29.0
Stock Returns (%)	5,287	0.3	0.4	–54.8	22.8	4.0
Total Assets	5,287	8.5	3.6	0.5	68.0	12.0
Shareholders' Equity	5,287	3.2	0.9	0.0	32.9	6.6
Robo-Advisors and Personal Finance						
Market Capitalization	766	15.4	6.2	0.3	249.2	26.5
Stock Returns (%)	766	0.4	0.5	–28.7	22.1	4.2
Total Assets	766	1.7	0.9	0.1	3.4	1.3
Shareholders' Equity	766	0.7	0.4	0.1	1.7	0.6
Software Solutions/IT						
Market Capitalization	1,956	15.3	5.9	0.3	210.2	25.5
Stock Returns (%)	1,956	0.3	0.4	–28.2	13.3	2.9
Total Assets	1,956	9.0	3.0	1.2	36.0	11.7
Shareholders' Equity	1,956	4.5	1.3	0.7	20.2	6.0

Note: The table reports key characteristics, over the period 2010–2017, for the US financial industry and for the fintech firms that are part of the KBW Nasdaq Financial Technology Index. It presents the market capitalization, total assets, and shareholders' equity in billion USD. We calculated stock returns as the weekly difference of log stock prices.

Table A.5: Summary Statistics: European Financial System

	N	Mean	Median	Min.	Max.	SD
Financial Industry						
Market Capitalization	16,061	19.1	7.8	0.0	125.6	23.1
Stock Returns (%)	16,061	–0.2	–0.1	–188.8	142.9	7.5
Total Assets	16,061	531.1	197.6	0.3	2,800.1	662.4
Shareholders' Equity	16,061	27.5	11.9	0.0	128.4	32.0
Fintech						
Data Analytics						
Market Capitalization	1,730	10.5	3.2	0.0	162.4	21.1
Stock Returns (%)	1,730	0.2	0.2	–28.2	19.8	4.0
Total Assets	1,730	1.9	1.2	0.1	14.6	2.9
Shareholders' Equity	1,730	1.0	0.5	0.0	8.4	1.6
Digital Banks						
Market Capitalization	417	9.6	2.9	0.0	127.3	18.6
Stock Returns (%)	417	0.2	0.2	–20.3	12.5	3.4
Total Assets	417	2.6	2.7	1.8	3.4	0.4
Shareholders' Equity	417	1.3	1.3	1.2	1.6	0.1
Market Trading and Support						
Market Capitalization	194	10.5	3.7	0.1	157.2	22.3
Stock Returns (%)	194	–0.4	0.1	–25.3	25.3	7.0
Total Assets	194	0.1	0.1	0.1	0.1	0.0
Shareholders' Equity	194	0.0	0.0	0.0	0.1	0.0
Payments and Remittances						
Market Capitalization	6,921	10.1	3.1	0.0	159.7	19.7
Stock Returns (%)	6,921	0.3	0.3	–72.1	28.4	4.6
Total Assets	6,921	13.8	3.7	0.0	181.1	35.1
Shareholders' Equity	6,921	2.7	1.1	0.0	21.9	4.6
Robo-Advisors and Personal Finance						
Market Capitalization	960	9.3	3.2	0.0	121.0	17.1
Stock Returns (%)	960	0.3	0.2	–24.9	18.0	4.1
Total Assets	960	2.2	0.9	0.1	5.8	2.2
Shareholders' Equity	960	1.0	0.4	0.1	3.6	1.1
Software Solutions/IT						
Market Capitalization	8,213	9.7	3.0	0.0	161.7	18.7
Stock Returns (%)	8,213	0.2	0.3	–61.8	64.2	5.4
Total Assets	8,213	6.6	1.6	0.0	51.1	11.3
Shareholders' Equity	8,213	2.6	0.6	0.0	30.6	4.9

Note: The table reports key characteristics, over the period 2010–2017, for the European financial industry and for the fintech firms that are part of the CedarIBS FinTech Index and that are quoted on the Frankfurt Stock Exchange. It presents the market capitalization, total assets, and shareholders' equity in billion USD. We calculated the stock returns as the weekly difference of log stock prices.

Table A.6: ΔCoVaR Results: US Financial System

Rank	Company	Category	ΔCoVaR (%)
1	Citigroup, Inc.	Financial Industry	–2.297
2	Legg Mason	Financial Industry	–1.702
3	Principal	Financial Industry	–1.553
4	Goldman Sachs	Financial Industry	–1.453
5	BNY Mellon	Financial Industry	–1.393
6	Morgan Stanley	Financial Industry	–1.364
7	T. Rowe Price	Financial Industry	–1.198
8	Janus Henderson Group	Financial Industry	–1.191
9	Northern Trust	Financial Industry	–1.186
10	AGNC Investment Corp.	Financial Industry	–1.131
11	PNC Financial Services	Financial Industry	–1.113
12	CBRE Group	Financial Industry	–1.098
13	New York Community Bank	Financial Industry	–1.094
14	Comerica	Financial Industry	–1.074
15	U.S. Bancorp	Financial Industry	–1.065
16	M&T Bank	Financial Industry	–0.992
17	State Street Corporation	Financial Industry	–0.937
18	BB&T	Financial Industry	–0.928
19	Marsh & McLennan Companies	Financial Industry	–0.925
20	Fifth Third Bank	Financial Industry	–0.915
21	KeyCorp	Financial Industry	–0.902
22	Synovus	Financial Industry	–0.752
23	Western Union	Financial Industry	–0.721
24	Bank of America	Financial Industry	–0.713
25	Ameriprise Certificate Company	Financial Industry	–0.616
26	Suntrust Banks	Financial Industry	–0.593
27	Wells Fargo Company	Financial Industry	–0.581
28	TD Ameritrade	Financial Industry	–0.487
29	Blackrock	Financial Industry	–0.455
30	E-Trade	Financial Industry	–0.422
31	Freddie Mac	Financial Industry	–0.405
32	Charles Schwab	Financial Industry	–0.381
33	People's United Financial	Financial Industry	–0.212
34	Fannie Mae	Financial Industry	–0.186
35	First Data	Payments and Remittances	–0.027
36	LendingClub	Alternative Financing	–0.026
37	Virtu Financial	Market and Trading Support	–0.014
38	Square	Payments and Remittances	–0.009
39	CME Group	Market and Trading Support	–0.007
40	Blackhawk Network Holdings	Payments and Remittances	–0.006
41	MarketAxess	Market and Trading Support	–0.006
42	Mastercard	Payments and Remittances	–0.005
43	IHS Markit	Data Analytics	–0.005

continued on next page

Table A.6 *continued*

Rank	Company	Category	ΔCoVaR (%)
44	PayPal	Payments and Remittances	–0.004
45	Jack Henry & Associates	Software Solutions/IT	–0.003
46	WEX, Inc.	Payments and Remittances	–0.003
47	Global Payments	Payments and Remittances	–0.003
48	Cboe	Market and Trading Support	–0.003
49	Broadridge Financial Solutions	Software Solutions/IT	–0.003
50	Equifax	Software Solutions/IT	–0.002
51	Thomson Reuters	Software Solutions/IT	–0.002
52	Fiserv	Payments and Remittances	–0.001
53	S&P Global	Data Analytics	–0.001
54	MSCI	Robo-Advisors and Personal Finance	0.000
55	Verifone	Payments and Remittances	0.001
56	Verisk Analytics	Data Analytics	0.001
57	ACI Worldwide	Payments and Remittances	0.001
58	Western Union	Payments and Remittances	0.001
59	Cardtronics	Payments and Remittances	0.001
60	Nasdaq	Market and Trading Support	0.001
61	Visa	Payments and Remittances	0.002
62	Evertec, Inc.	Payments and Remittances	0.002
63	Worldpay	Payments and Remittances	0.003
64	Moody's	Data Analytics	0.004
65	FactSet	Data Analytics	0.004
66	FLEETCOR	Payments and Remittances	0.009
67	SS&C Technologies	Software Solutions/IT	0.011
68	Euronet Worldwide	Payments and Remittances	0.022
69	Envestnet	Robo-Advisors and Personal Finance	0.036
70	Green Dot Corporation	Digital Banks	0.041
71	Franklin Resources	Financial Industry	0.109
72	Regions Financial Corporation	Financial Industry	0.178
73	Zions Bancorporation	Financial Industry	0.182
74	Capital One	Financial Industry	0.220
75	SLM Corporation	Financial Industry	0.258
76	CIT Group	Financial Industry	0.529
77	Huntington Bancshares	Financial Industry	1.273

Table A.7: ΔCoVaR Results: European Financial System

Rank	Company	Category	ΔCoVaR (%)
1	Turkiye Vakiflar Bankasi	Financial Industry	–6.667
2	Turkiye Halk Bankasi	Financial Industry	–5.863
3	Credito Emiliano	Financial Industry	–5.796
4	Banco Bilbao Vizcaya Argentaria	Financial Industry	–5.434
5	Credit Suisse	Financial Industry	–4.996
6	CaixaBank	Financial Industry	–4.874
7	Raiffeisen Bank International	Financial Industry	–4.838
8	ING Group	Financial Industry	–4.282
9	Crédit Agricole	Financial Industry	–4.061
10	Plaza Centers N.V.	Financial Industry	–3.733
11	Nordea Bank	Financial Industry	–3.640
12	Albaraka Turk Katilim Bankasi AS	Financial Industry	–3.260
13	Intesa Sanpaolo	Financial Industry	–3.040
14	Commerzbank	Financial Industry	–2.789
15	Marfin Investment Group	Financial Industry	–2.784
16	Société Générale	Financial Industry	–2.760
17	Skandinaviska Enskilda Banken	Financial Industry	–2.724
18	BNP Paribas	Financial Industry	–2.443
19	Banco Santander	Financial Industry	–2.378
20	Jyske Bank	Financial Industry	–2.328
21	Svenska Handelsbanken AB	Financial Industry	–2.040
22	Banco de Sabadell	Financial Industry	–1.917
23	UniCredit	Financial Industry	–1.852
24	Banca Popolare di Sondrio	Financial Industry	–1.804
25	Permanent TSB Group	Financial Industry	–1.538
26	London Stock Exchange Group	Financial Industry	–1.483
27	Sekerbank	Financial Industry	–1.340
28	Piraeus Bank	Financial Industry	–1.114
29	RBS Group	Financial Industry	–1.049
30	Swiss Life	Financial Industry	–0.989
31	Banco Comercial Portugues	Financial Industry	–0.829
32	Dexia	Financial Industry	–0.781
33	Banco BPM	Financial Industry	–0.662
34	Standard Chartered	Financial Industry	–0.614
35	UBI Banca	Financial Industry	–0.604
36	Banca Carige	Financial Industry	–0.450
37	Alpha Bank	Financial Industry	–0.445
38	Aareal Bank	Financial Industry	–0.407
39	Erste Group	Financial Industry	–0.401
40	Oldenburgische Landesbank	Financial Industry	–0.323
41	UBS Group AG	Financial Industry	–0.286
42	Bank of Ireland Group	Financial Industry	–0.237
43	VTB Bank	Financial Industry	–0.196
44	Banca Monte dei Paschi di Siena	Financial Industry	–0.188
45	TP ICAP	Financial Industry	–0.080
46	Eurobank Ergasias	Financial Industry	–0.019
47	Barclays	Financial Industry	–0.011
48	Bankia	Financial Industry	–0.009
49	Envestnet	Robo-Advisors and Personal Finance	–0.005
50	Points	Software Solutions/IT	–0.004
51	Blackhawk Network Holdings	Payments and Remittances	–0.002
52	Verifone	Payments and Remittances	–0.002
53	FICO	Data Analytics	–0.002

continued on next page

Table A.7 *continued*

Rank	Company	Category	ΔCoVaR (%)
54	China Information Tech	Software Solutions/IT	–0.002
55	Cognizant	Payments and Remittances	–0.002
56	DXC Technology	Software Solutions/IT	–0.002
57	Tungsten Corporation	Software Solutions/IT	–0.002
58	MercadoLibre	Payments and Remittances	–0.002
59	CANCOM	Software Solutions/IT	–0.002
60	Diebold Nixdorf, AG	Software Solutions/IT	–0.002
61	Xero	Software Solutions/IT	–0.001
62	DST Systems	Software Solutions/IT	–0.001
63	Model N	Software Solutions/IT	–0.001
64	NCR	Software Solutions/IT	–0.001
65	TSYS	Payments and Remittances	–0.001
66	SafeCharge	Payments and Remittances	–0.001
67	American Express	Payments and Remittances	–0.001
68	Wirecard	Payments and Remittances	–0.001
69	PFSweb	Software Solutions/IT	–0.001
70	ServiceSource	Software Solutions/IT	–0.001
71	Virtusa	Software Solutions/IT	–0.001
72	WEX, Inc.	Payments and Remittances	–0.001
73	FactSet	Data Analytics	–0.001
74	First Data	Payments and Remittances	–0.001
75	Ingenico	Payments and Remittances	–0.001
76	Euronet Worldwide	Payments and Remittances	0.000
77	SAP	Software Solutions/IT	0.000
78	Intuit	Robo-Advisors and Personal Finance	0.000
79	IHS Markit	Data Analytics	0.000
80	Global Payments	Payments and Remittances	0.000
81	Syntel	Software Solutions/IT	0.000
82	Jack Henry & Associates	Software Solutions/IT	0.000
83	FLEETCOR	Payments and Remittances	0.000
84	Luxoft	Software Solutions/IT	0.001
85	FIS	Software Solutions/IT	0.001
86	Everi	Payments and Remittances	0.002
87	Wipro	Software Solutions/IT	0.002
88	MoneyGram	Payments and Remittances	0.002
89	Fiserv	Payments and Remittances	0.002
90	Western Union	Payments and Remittances	0.002
91	Genpact	Digital Banks	0.002
92	IRESS	Robo-Advisors and Personal Finance	0.003
93	Mastercard	Payments and Remittances	0.004
94	Teradata	Data Analytics	0.004
95	ADP	Software Solutions/IT	0.004
96	Temenos	Software Solutions/IT	0.006
97	PRGX Global, Inc.	Data Analytics	0.010
98	Amber Road Inc.	Market and Trading Support	0.010
99	Diebold Nixdorf, Inc.	Software Solutions/IT	0.012
100	Evertec, Inc.	Payments and Remittances	0.021
101	Equifax	Software Solutions/IT	0.025
102	National Bank of Greece	Financial Industry	0.062
103	Banco BPI	Financial Industry	0.227
104	Wuestenrot & Wuerttembergische	Financial Industry	0.379
105	EFG International	Financial Industry	0.483
106	BPER Banca	Financial Industry	1.154
107	Deutsche Bank	Financial Industry	1.170

Table A.8: ΔCoVaR Results: US Fintech Industry

Rank	Company	Category	ΔCoVaR (%)
1	First Data	Payments and Remittances	–0.107
2	LendingClub	Alternative Financing	–0.039
3	MarketAxess	Market and Trading Support	–0.030
4	CME Group	Market and Trading Support	–0.024
5	Square	Payments and Remittances	–0.019
6	Global Payments	Payments and Remittances	–0.018
7	Thomson Reuters	Software Solutions/IT	–0.015
8	WEX, Inc.	Payments and Remittances	–0.015
9	PayPal	Payments and Remittances	–0.013
10	Western Union	Payments and Remittances	–0.007
11	Equifax	Software Solutions/IT	–0.005
12	Blackhawk Network Holdings	Payments and Remittances	–0.003
13	Jack Henry & Associates	Software Solutions/IT	0.000
14	Intercontinental Exchange	Market and Trading Support	0.000
15	MSCI	Robo-Advisors and Personal Finance	0.000
16	Evertec, Inc.	Payments and Remittances	0.001
17	American Express	Payments and Remittances	0.001
18	SEI Investments Company	Robo-Advisors and Personal Finance	0.002
19	Worldpay	Payments and Remittances	0.003
20	Visa	Payments and Remittances	0.003
21	Virtu Financial	Market and Trading Support	0.003
22	Broadridge Financial Solutions	Software Solutions/IT	0.004
23	Fiserv	Payments and Remittances	0.004
24	FLEETCOR	Payments and Remittances	0.006
25	Mastercard	Payments and Remittances	0.006
26	ACI Worldwide	Payments and Remittances	0.008
27	Verisk Analytics	Data Analytics	0.008
28	Nasdaq	Market and Trading Support	0.009
29	Cardtronics	Payments and Remittances	0.010
30	Cboe	Market and Trading Support	0.011
31	SS&C Technologies	Software Solutions/IT	0.011
32	IHS Markit	Data Analytics	0.012
33	S&P Global	Data Analytics	0.014
34	Green Dot Corporation	Digital Banks	0.019
35	Moody's	Data Analytics	0.021
36	FactSet	Data Analytics	0.025
37	Euronet Worldwide	Payments and Remittances	0.034
38	Envestnet	Robo-Advisors and Personal Finance	0.041
39	Verifone	Payments and Remittances	0.074

Table A.9: ΔCoVaR Results: European Fintech Industry

Rank	Company	Category	ΔCoVaR (%)
1	PFSweb	Software Solutions/IT	–0.013
2	Blackhawk Network Holdings	Payments and Remittances	–0.012
3	DXC Technology	Software Solutions/IT	–0.009
4	ServiceSource	Software Solutions/IT	–0.008
5	MercadoLibre	Payments and Remittances	–0.007
6	Tungsten Corporation	Software Solutions/IT	–0.007
7	China Information Tech	Software Solutions/IT	–0.006
8	Intuit	Robo-Advisors and Personal Finance	–0.005
9	Diebold Nixdorf, AG	Software Solutions/IT	–0.005
10	Xero	Software Solutions/IT	–0.005
11	Cognizant	Payments and Remittances	–0.005
12	Points	Software Solutions/IT	–0.004
13	SafeCharge	Payments and Remittances	–0.004
14	Verifone	Payments and Remittances	–0.004
15	TSYS	Payments and Remittances	–0.004
16	DST Systems	Software Solutions/IT	–0.002
17	NCR	Software Solutions/IT	–0.002
18	FactSet	Data Analytics	–0.002
19	Mastercard	Payments and Remittances	–0.002
20	First Data	Payments and Remittances	–0.001
21	FIS	Software Solutions/IT	–0.001
22	Euronet Worldwide	Payments and Remittances	–0.001
23	SAP	Software Solutions/IT	–0.001
24	ADP	Software Solutions/IT	–0.001
25	Teradata	Data Analytics	–0.001
26	Ingenico	Payments and Remittances	–0.001
27	WEX, Inc.	Payments and Remittances	–0.001
28	IHS Markit	Data Analytics	–0.001
29	Wipro	Software Solutions/IT	–0.001
30	Virtusa	Software Solutions/IT	–0.001
31	FICO	Data Analytics	–0.001
32	Global Payments	Payments and Remittances	0.000
33	FLEETCOR	Payments and Remittances	0.000
34	Temenos	Software Solutions/IT	0.001
35	Syntel	Software Solutions/IT	0.001
36	Genpact	Digital Banks	0.001
37	Fiserv	Payments and Remittances	0.001
38	Luxoft	Software Solutions/IT	0.001
39	American Express	Payments and Remittances	0.002
40	Jack Henry & Associates	Software Solutions/IT	0.002
41	Envestnet	Robo-Advisors and Personal Finance	0.002
42	MoneyGram	Payments and Remittances	0.003
43	Model N	Software Solutions/IT	0.004
44	Equifax	Software Solutions/IT	0.004
45	PRGX Global, Inc.	Data Analytics	0.005
46	Diebold Nixdorf, Inc.	Software Solutions/IT	0.005
47	Western Union	Payments and Remittances	0.006
48	Evertec, Inc.	Payments and Remittances	0.006
49	CANCOM	Software Solutions/IT	0.006
50	Wirecard	Payments and Remittances	0.008
51	IRESS	Robo-Advisors and Personal Finance	0.010
52	Amber Road Inc.	Market and Trading Support	0.016
53	Everi	Payments and Remittances	0.018

Table A.10: Spearman's Rank Correlation with ΔCoVaR

Sample	Size	Beta
United States		
Coefficient	0.505	0.305
p-value	0.000	0.042
Europe		
Coefficient	0.581	0.591
p-value	0.000	0.000

APPENDIX B: FIGURES

Figure B.1: Value at Risk

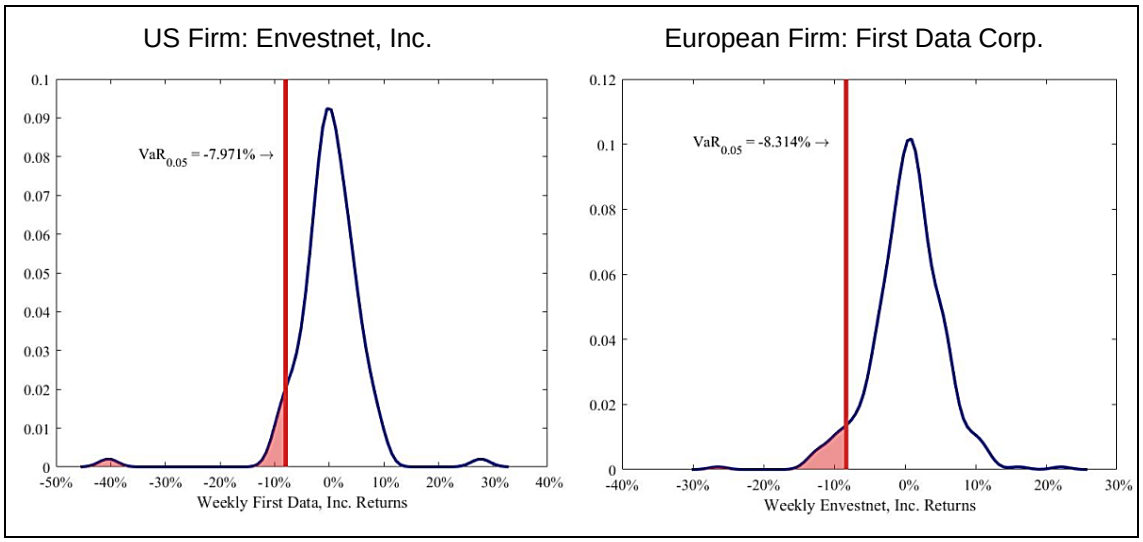

Figure B.2: US Fintech: ΔCoVaR and Size

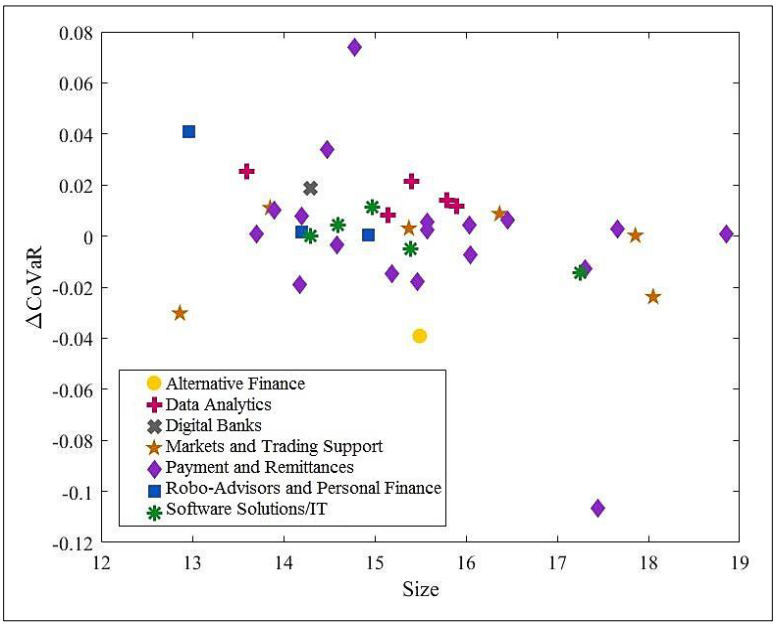

Figure B.3: US Fintech: ΔCoVaR and Beta

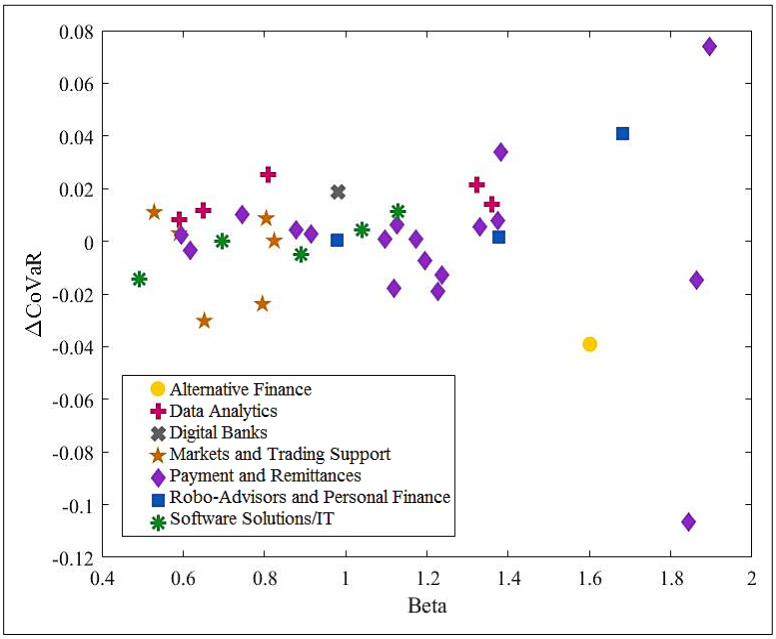

Figure B.4: European Fintech: ΔCoVaR and Size

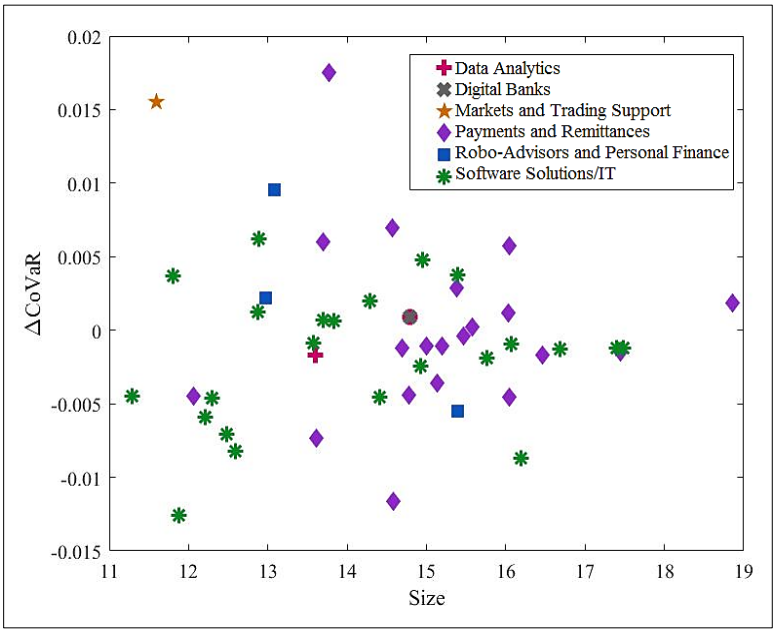

Figure B.5: European Fintech: ΔCoVaR and Beta