Economic Links and the Cross-Section of Option Returns

Ramazan Gençay, Erwin Hansen, Xiao Yu*

Sunday 14$^{\text{th}}$ May, 2017

ABSTRACT

In this paper, we investigate how economic linkages - proxied by customer-supplier sales relationships among firms help to explain the cross-section variation of expected stock option (delta hedged) returns. Our main hypothesis is that customer's volatility shocks spill over on supplier firm's volatility through (real sales-based) network's links, and as consequence, a priced risk factor emerges for options issued by these firms. We empirically document that these economic links are statistically and economically significant for a representative sample of US firms. The results are not explained neither by other risk factors identified in the literature idiosyncratic volatility and volatility risk premium nor by firm characteristics. Finally, the results are also robust to control for industry variation.

JEL classification: G12, G13.

Keywords: Networks in Production, Customer-Supplier Links, Stock Option Returns.

*Gençay and Yu are in the Department of Economics, Simon Fraser University, 8888 University Drive, Burnaby, British Columbia, V5A 1S6, Canada. Email: rgencay@sfu.ca (R. Gençay) and yuxiaoy@sfu.ca (X. Yu). Hansen is in the School of Economics and Business at the University of Chile, Diagonal Paraguay 257, Of. 1204, Santiago, Chile. Email: ehansen@fen.uchile.cl

I. Introduction

Recent literature has stressed out the role of networks in production in explaining systematic risk and equilibrium asset prices (See Acemoglu, 2015; Herskovic, 2016; Ramirez, 2016; and Rossi et al., 2015). Networks in production, measured through costumer-supplier relations between firms in a particular economic sector or between firms in different economic sectors, act as a propagation mechanism of firms shocks and becomes a source of systematic risk in the aggregate. This literature has documented empirically that characteristics of the network such as concentration and sparsity are priced in the cross-section of the stock returns. In more specific studies, Kelly, Lustig and Nieuwerburgh (2014) and Yu, Zhang and Gençay (2016) have shown that costumer-supplier links between firms help to explain firms total volatility. In this paper, we aim to extend the literature looking at the effects of network in production on financial markets by studying how these economic links help to explain the cross-section of stock option returns, an unexplored asset in this literature so far.

The main motivation to connect customer-supplier networks and stock options comes from two sources: first, the evidence documenting that customer-supplier networks are a statistical significant determinant of firms volatility, and second, the well-established fact that firms volatility is a price factor in the cross-section of option returns (See Black-Scholes, 1973). In this context, our main hypothesis in this article is that costumers volatility shocks spill over on supplier firms volatility through networks links, and as a consequence, a risk priced factor emerges for options issued by these firms.

This study is naturally connected with the small literature aiming to identify priced factors in the cross-section of stock option returns (See Goyal and Saretto, 2009; Cao and

Han, 2013; and Aramonte, 2014). This literature has identified firm's total volatility and its idiosyncratic and systemic components as significant priced factors in the cross-section of option returns. Also, a variance risk premium variable, defined as the difference between realized volatility and (option) implied volatility, and a measure of macroeconomic uncertainty has been found to be priced factors explaining stock option heterogeneity as well. In this literature, our work study an unexplored source of systematic risk for stock options, namely, economic links through costumer-supplier networks.

To test our main hypothesis we build a monthly sample of US stock options for the period 1996 to 2015. The dataset contains two main types of information: customer-supplier data and option data. Costumer-supplier data at the firm level comes from Compustat Segment Customer data. US regulation forces firms to report all customers representing more than 10% of their sales revenues, indicating the customers name and the amount of sales revenues from that customer. We use this information to build a customer-supplier network.[1] Using the network, we build a measure of costumer-supplier volatility that we use as the main regressor in the empirical analysis below. The second main source of information is individual stock option data from Ivy DB from OptionMetrics which is a representative dataset of option markets in the US. The final sample only includes firms that appear in the Compustat Segment Curstomer data, either as a costumer or as a supplier at least once in the analyzed period, and have issued stock options.

We apply standard Fama-McBeth regressions to test the effect of customer-supplier network volatility measures on stock option returns. We use delta-hedged option returns in the analysis to avoid that changes in the underlying stock influence stock option returns as customary in the literature (Cao and Han, 2013). By exploring alternative empirical

[1]See details about the concept and the construction of the Costumer-supplier network in section 2.

specifications, we find a strong inverse relation between our measure of customer-supplier volatility and (delta-hedged) option returns. This relationship is statistically significant at standard significance level. Our estimation results show that the customer's volatility reduces expected (delta-hedged) option returns in around 2.5% approximately. The negative relation can be rationalized using the standard Black-Sholes formula, in which, total volatility affect positively the option price, and therefore, negatively the expected return of the option. The estimated effect is economically significant as well as it represents around half of the impact of total volatility, a standard priced factor in the literature, on (delta-hedged) option returns. Our results point out the relevance of networks effects on asset pricing, in particular, in stock option markets. Volatility spill overs through the network play a first order role in explaining cross-sectional variation in option markets.

Our main result survives several robustness tests. First, the estimated costumer-supply network volatility effect is robust to the inclusion of other priced factors. As we mentioned, total firm's volatility is considered a standard priced factor for stock option returns, therefore, we include it as a control in our regressions and the main results do not seem to be affected. Later, we control for a measure of Variance Risk Premium (Goyal and Saretto, 2009). We find that VRP is priced in the cross-section of option returns as in Goyal and Saretto (2009) and that the costumer-supplier network volatility factor is still significant. Finally, following the discussion in Cao and Han (2013), we replace firm's total volatility by its idiosyncratic component, and we still find a robust negative statistical significant effect. Indeed, consistent with the evidence in Cao and Han (2013), we find that the idiosyncratic component of the firm's volatility is more important than its systematic component in explaining the cross-sectional variation of option returns. Second, our results survive the inclusion of firm's characteristics as additional control variables in the model. Goyal and Saretto (2009) and

Cao and Han (2013) do a similar analysis. Thus, our evidence is consistent with their results, and show that our main result is not driven by the omission of these characteristics. For example, Xiao and Vazquez (2016) show that firm characteristics like leverage is a significant determinant of equity option returns. Third, our results are robust to control for industry effects. To some extent, it is intuitive to think that network effects may be masking industry variation instead of capturing a real spillover effect from costumers to suppliers. To coping with this issue, we add as control variable a measure of industry volatility based on a 17-industry classification scheme and we find that our results are robust to their inclusion.

The rest of the paper is organized as follows. In Section 2, we define and describe Customer-supplier networks. In Section 3, we describe our dataset and main variables. The empirical model and the results are presented in Section 4. Finally, we conclude in Section 5.

II. Customer-Supplier Networks

[2]

Networks, which are generally understood as collections of nodes and links between nodes, can be useful representations of economic or financial systems. Nodes represent entities in the system; links describe certain relationships between the entities.

In this paper, we examine customer-supplier networks, where each firm is a "node", and a customer-supplier relationship is a "link" between two firms. The structure of the network can be characterized by an adjacency matrix, G, which is a square matrix with dimension of the number of nodes (i.e., firms) in the network. The entry in the ith row and jth column of G, $(G)_{ij}$, is one if and only if i (j) is the supplier (customer) of j (i), zero otherwise.

[2] This section is extensively based on Yu et al. (2015)

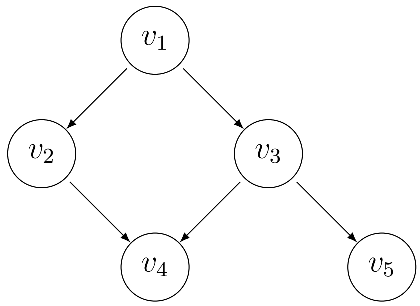

Figure 1. Example of a customer-supplier network. v_i, $i = 1, ..., 5$, denotes the firm; the arrow indicates the flow of output. For example, the arrow between v_1 and v_2 indicates that firm 1 (2) is the supplier (customer) of firm 2 (1).

Consider the simple network depicted in Figure 1, v_i, $i = 1, ..., 5$, denotes the firm; the arrow indicates the flow of output. For example, the arrow between v_1 and v_2 indicates that firm 1 (2) is the supplier (customer) of firm 2 (1). Matrix G characterizing the structure of this network is therefore

$$G = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

The second row of G, for example, refers to firm 2, which indicates that firm 2 has only one customer, which is firm 4, as only the fourth entry is one. More generally, the ith row of G captures firm i's first-order (i.e., immediate) customer linkages.

The adjacency matrix G we have referred to thus far is unweighted, in the sense that it has entries of either one or zero. In some applications, it is useful to introduce the concept of the *strength* of a link. For example, it would be possible to construct a sales-weighted matrix G to capture the relative importance of customers. In this case, for each supplier (i.e., each row) in G, links (i.e., entries that have a value of one) are weighted by the amount of sales made to the target customer, normalized by the observed total amount of sales (i.e., the sum of all sales to customers) of this supplier in this period. The sum of the entries in each row of the sales-weighted G is equal to one. Using this weighting, from a supplier's perspective, greater importance is assigned to customers that account for a larger shares of trades.[3]

III. Data and Variables

A. Data

The dataset is built from several sources. The two main variables in the analysis are stock option returns and customer-supplier volatity measures (firm's network volatility). US individual stock option data comes from Ivy DB database provided by Optionmetrics, and costumer-supplier data at the firm level comes from Compustat Customer Segment files. It is worth noting that this dataset only contains information for costumers representing at least 10% of firm's sales. Additionally, we incorporate several firm level control variables in the analysis. Firm's stock price data comes from CRPS database and firm's balance sheet data comes from Compustat database. Industry portfolios used to build (17-sector) industry volatility measures come from Kenneth Frenchs online data library.

B. Variables

B.B.1. Stock Option Returns

We build delta-hedged portfolio returns as in Cao and Han (2013)[4]. Let the delta-hedge option gain be the change in the value of a self-financing portfolio consistent of a long call

[3]The adjacency matrices that characterize customer-supplier networks are constructed as in Yu et al. (2016).

[4]Coval and Shumway (2001) and Goyal and Saretto (2009) uses straddle portfolio returns (zero-delta and zero-beta straddle).

position, hedge by a short position in the underlying stock so that the portfolio is not sensitive to stock price movement, with the net investment earning the risk-free rate. Consider a portfolio of a call option that is hedged discretely N times over a period $[t, t+\tau]$, where the hedge is rebalanced at each of the dates $t_n, n = 0, ..., N-1$ (where $t_0 = t, t_N = t + \tau$). The discrete delta-hedged call option return over the period $[t, t+\tau]$ is:

$$\Pi(t, t+\tau) = C_{t+\tau} - C_t - \sum_{n=0}^{N-1} \Delta_{C,t_n}[S(t_{n+1}) - S(t_n)] - \sum_{n=0}^{N-1} \frac{a_n r_{tn}}{365}[C(t_n) - \Delta_{C,t_n} S(t_n)] \quad (1)$$

where Δ_{C,t_n} is the delta of the call option on date t_n, r_{tn} is the annualized risk-free rate on date t_n, and a_n is the number of calendar days between t_n and t_{n+1}.

B.B.2. Realized Volatility and Customer-Supplier Network Volatility

In order to compute firm's customer-supplier network volatility, we need to compute firm's realized volatility in advance. Following the standard in the literature, we compute the realized volatility of firm i in month t as the squared root of the demeaning daily stock returns over the previous month. Specifically, the realized stock return volatility of firm i in month t, $RV_{i,t}$, is given by

$$RV_{i,t} = \sqrt{\frac{1}{T_{i,t} - 1} \sum_{\tau=1}^{T_{i,t}} (DailyRet_{i,t,\tau} - \overline{DailyRet_{i,t}})^2}, \quad (2)$$

where, for firm i, $T_{i,t}$ is the number of trading days observed in month t; $DailyRet_{i,t,\tau}$ is the daily return on the τth trading day of month t (i.e., $DailyRet_{i,t,\tau} = \frac{P_{i,t,\tau} - P_{i,t,\tau-1}}{P_{i,t,\tau-1}}$, where $P_{i,t,\tau}$ is the closing stock price on the τth trading day of month t); and $\overline{DailyRet_{i,t}}$ is the sample average of daily returns in month t.

For each firm i, its customers' stock return volatility in month t is measured and denoted by $(G \cdot RV)_{i,t} = (G_t \cdot RV_t)_i$. Suppose that there are n firms in the customer-supplier network in month t, G_t is the $n \times n$ adjacency matrix in month t, RV_t is the $n \times 1$ vector containing each firm's return volatility in month t, and $(G_t \cdot RV_t)$ is therefore a vector capturing the return volatility of each firm's customers in month t. Specifically, the ith entry in $(G_t \cdot RV_t)$ is the average of the return volatilities of firm i's customers in month t. In this study, we focus on the component of firm's realized volatility that it is transferred from customers to suppliers. The customer-supplier realized volatility component (CS-RV) for firm i at time t is given by:

$$RV_{i,t}^{CS} = (G \cdot RV)_{i,t-1} \tag{3}$$

where G is an adjacency matrix characterizing the structure of the customer-supplier network and RV is a vector of realized volatilities of the firms in the network. For example, if there are n firms in the customer-supplier network in month t, G is an nxn adjacency matrix and RV_t is the $nx1$ vector containing firms return volatility in the network for month t.

B.B.3. Control Variables

We include several control variables in our regressions to be sure that our results are not driven by ommited variables. In particular, we include two pricing factors identified in the prior literature as significant pricing factors for the cross-section of option returns: volatility risk premium and idiosyncratic volatility. We also considered a set of firm specific control variables and 17-sector industry volatility variable.

As pointed out by Goyal and Saretto (2009), the volatility risk premium, defined as the difference between realized volatility and the option-implied volatility, is priced in the cross-section of option returns. We build this variable as the difference between the square root of realized variance estimated from daily stock returns over the previous month and the option-implied volatility on the last trading day of month t.

Cao and Han (2013) have pointed out that the idiosyncratic component of total volatility is more important in explaining the cross-sectional of stock option returns than total volatility. Following these authors, we build idiosyncratic and systemic volatility component as follows. Idiosyncratic volatility is the standard deviation of the residuals of a Fama-French three-factor model estimated using daily stock returns over the previous month, and systemic volatility is the square root of the difference between squared total volatility and squared idiosyncratic volatility.

We include several firm specific variables that allow us to discard that our results are driven by firm heterogeneity. In particular we include leverage, measured as the ratio of total liabilities to total assets, size, measured as market capitalization, the earning price ratio, the dividend price ratio, average turnover, measured as the average daily turnover rate over the month, volume, measured as the average daily trading volume over a month, and trading value, measured as the volume times stock price.

IV. Estimation Results

In this section, we present our empirical model and results.

A. Empirical Model

In order to verify whether the costumer-supplier network volatility is priced in the cross-section of (delta-hedged) option returns, we estimate several specifications of the following model

$$\Pi_{i,t+\tau} = \beta_0 + \beta_1 \left(G \cdot RV\right)_{i,t} + \delta X_{i,t} + \epsilon_{i,t} \tag{4}$$

where $\Pi_{i,t+\tau}$ are (delta-hedged) option returns of firm i between t and $t+\tau$, $(G \cdot RV)_{i,t-1}$ is the measure of costumer-supplier network volatility of firm i at time t, $X_{i,t}$ is a set of control variables and $\epsilon_{i,t}$ is a random error term. We use the Fama-McBeth method to estimate the model for our sample of stock option returns. We expect that the estimated coefficient for the costumer-supplier network volatility variable, our main variable of interest, be negatively related to (delta-hedged) stock option returns in the cross-section. This implies that the estimated coefficient for β_1 be negative and statistically significant.

B. Results

In Table 1, we report our estimation results. In columns (1) to (4), we report estimates for the full sample and in columns (5) to (8) we report estimates for a restricted sample that only include firm-month observations in which the CS network volatility measure is positive. As explained in the data section, the number of observations of our sample is reduced due to the sparsity of costumer-supplier data. This feature of the data put some limitations in the empirical analysis that we try to overcome, to some extent, by checking the robustness of our results to this sub-sample analysis. Beside the reported variables in the table, we control across the board by a set of firms characteristics and by industry effects. In particular, we include as additional control variables in the regressions firm's leverage (measured as total debt over total assets) and size (measured as market capitalization), earnings and dividends per share ratios, and stocks volume, turnover and trading value. To control for industry effects, we add as a control variable an industry volatility variable based on a 17-industry classification scheme.

In column (1), the estimated coefficient of the costumer-supplier network volatility, our variable of interest, is negative and statistically significant as expected. The estimated coefficient is -0.028. This evidence is consistent with the idea that network effects, captured by costumer-supplier relations across firms are priced in the cross-section of option returns. The negative coefficient indicates that higher volatility transmitted from customers to suppliers through the network increases the supplier's total volatility, and therefore, both a higher option price and a lower expected option return are expected. In column (2), we extend the previous specification by including a measure of total firm volatility and variance risk premium (VRP). These two variables has been identified as priced factors of the cross-section of stock option returns in the literature (See Goyal and Saretto, 2009; and Cao and Han, 2013). We observe that the network volatility variable remains negative (-0.0253) and statistically significant after controlling for these two priced factors. The estimats of both total volatility and variance risk premium are significant as well. The signs of the estimated coefficients are in line with the prior literature: negative for total volatility and positive for variance risk premium. This evidence indicates that network effects seem to be capturing a source of risk which is not fully captured by these two standard price factors.

Motivated by the evidence in Cao and Han (2013), in column (3) we replace total volatility by its idiosyncratic component. Cao and Han (2013) present robust evidence that the idiosyncratic component of volatility, as opposed to its systematic component, is priced in the cross-section of option returns. Our results show that after replacing total volatility by idiosyncratic volatility, the consumer-supplier network volatility variable remains negative and statistically significant (-0.025). The variance risk premium variable is also positive and significant as in the previous specifications and the idiosyncratic volatility variable is negative and statistically significant as well. For completeness, in column (4), we add as control variable both idiosyncratic and systemic volatility simultaneously. Our variable of interest is still statistically significant (-0.0278), and both the variance risk premium and the idiosyncratic volatility are significant as well. The estimated coefficient of the systematic component of the total volatility is negative but not significant in line with the evidence in Cao and Han (2013) results. In our sample, we confirm the finding that idiosyncratic volatility instead of systemic volatility is a priced factor in the cross-section of option returns.

In columns (5) to (8) we reestimate specifications (1) to (4) for the sub-sample of observations for which the costumer-supplier network volatility variable has positive values. In general, we observe that in this sub-sample our results are slightly weaker than those presented previously but still we find that our variable of interest is significant in half of the specifications. For example, in column (5), the estimated coefficient of the costumer-supplier network volatility variable is negative and statistically significant as expected (-0.085). The estimated coefficient is larger than the one estimated with the full sample. A similar effect for the variable of interest in found in column (7) where the estimated coefficient is higher (-0.099) than previous one and significant as well. In columns (6) and (8), the estimated coefficient of costumer-supplier network volatility variable are negative, as expected, but not statistically significant.

It is worth noting that in this subsample not only the estimates of the costumer-supplier network volatility coefficients appear less statistically significant: most of the estimated coefficient of the additional control variables are not significant as well. Most of the estimates of these variables have the expected sign though. For example, the estimated coefficient of the variance risk premium is only significant in column (8) and the estimated coefficient of the idiosyncratic volatility variable is not significant at all.

Overall, the results reported in this section show evidence that network volatility effects, measured through costumer-supplier links, help to explain the cross-sectional variation of (delta-hedged) option returns. This effect is not only statistically significant in Fama-McBeth regressions but also economically significant as the size of the estimated coefficient is around half of the estimated coefficient for total volatility. The effect of costumer-supplier network volatility is robust to the inclusion of other priced factor previously identified in the literature such as total volatility, variance risk premium, idiosyncratic volatility and systemic volatility. Note also that our results are not driven by neither firm characteristics nor industry effects as we control for them across specifications.

V. Conclusions

In this paper, we study how economic links, measured through customer-supplier (sales-based) relations, help to explain the cross-section of (delta-hedged) stock option returns. Our main hypothesis is that customers volatility shocks spill over to suppliers through an economic based network, affecting then their total volatility, a well know priced risk factor for stock option returns.

By using a sample of US firms for the period 1996 to 2015, we find evidence that a costumer-supplier network volatility variable help to explain the cross-sectional variation of stock option returns. Fama-McBeth regressions for alternative specifications show that the relation between costumer-supplier network volatility and stock option returns is negative, as expected, and statistically significant at standard levels of confidence. This relationship is also economically meaningful considering that the estimated coefficient of the costumer-supplier network volatility variable is around half of the estimated coefficient of the total volatility of the firm. This result is robust to control for firm characteristics and other priced factor identified in the literature such variance risk premium and idiosyncratic volatility. The results are also robust to control for industry volatility effects.

This paper contributes to the recent literature looking at the effects of Network in production on the pricing of financial assets by studying the effects of Network in production on individual stock options, an unexplored financial asset in this literature so far. We also contribute to the small literature aiming to identify priced factors in the cross-section of option returns by exploring a new source of systemic risk transmitted through costumer-supplier networks.

Table 1: Regressions of Stock Option Returns on Customer-Supplier Network Volatility

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Network Vol.	-0.028*	-0.025*	-0.025*	-0.028**	-0.086*	-0.150	-0.099*	-0.083
	(0.015)	(0.013)	(0.013)	(0.013)	(0.045)	(0.099)	(0.059)	(0.140)
Volatility		-0.048***				-0.037		
		(0.018)				(0.078)		
Var.Risk.Prem.		0.055***	0.053***	0.055***		-0.037	0.891	0.184*
		(0.019)	(0.018)	(0.019)		(0.082)	(0.854)	(0.103)
Idiosync. Vol.			-0.057***	-0.047***			-0.540	-0.033
			(0.019)	(0.018)			(0.548)	(0.097)
Syst.Vol.				-0.020				-0.088
				(0.014)				(0.083)
Firm Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind. Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	38,218	38,218	38,218	38,218	2,707	2,707	2,707	2,707
R^2	0.108	0.163	0.160	0.174	0.834	0.876	0.875	0.887

Note: Standard errors in parentheses.

References

[1] Acemoglu, D., Ozdaglar, A. E., and Tahbaz-Salehi, A. Systemic risk in endogenous financial networks.

[2] Aramonte, S. Macroeconomic uncertainty and the cross-section of option returns. *Journal of Financial Markets 21* (2014), 25–49.

[3] Cao, J., and Han, B. Cross section of option returns and idiosyncratic stock volatility. *Journal of Financial Economics 108*, 1 (2013), 231–249.

[4] Coval, J. D., and Shumway, T. Expected option returns. *The journal of Finance 56*, 3 (2001), 983–1009.

[5] Goyal, A., and Saretto, A. Cross-section of option returns and volatility. *Journal of Financial Economics 94*, 2 (2009), 310–326.

[6] Herskovic, B. Networks in production: Asset pricing implications. *Working Paper* (2016).

[7] Ramirez, C. Inter-firm relationships and asset prices.

[8] Rossi, A. G., Blake, D. P., Timmermann, A. G., Tonks, I., and Wermers, R. Network centrality and delegated investment performance.

[9] Xiao, X., and Vasquez, A. Firm leverage and equity option returns.

[10] Yu, X., Zhang, K., and Gencay, R. Economic links and return volatility. *Working Paper, Simon Fraser University* (2016).