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Correlation in corporate defaults: Contagion or conditional independence?

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Risk Transfer Mechanisms and Financial Stability
Basel May 29-30, 2008

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Motivation for studying default dependence

- Understanding portfolio loss distributions
- Critical for understanding pricing of CDOs
- 'Bank contagion' is a critical concern of regulators
- Can we distinguish types of dependence empirically?
- Can we find evidence of contagion in actual default data?

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Overview

- Conditional independence versus contagion - the intuition
- A test devised to detect contagion from default data
- The limitations of the test
- The alternative specification of the intensity
- A source of contagion not captured by the test
- Testing for indirect contagion

The intuition

- With an analogue form medicine, we are asking whether firm defaults are more like asthma or more like the flu
- Pollution levels increase the number of asthma attacks in a city but conditionally on the level of pollution onsets are independent
- The flu, on the contrary, is contagious, and onset in one individual is likely to cause onsets in family members, colleagues etc.
- For companies: Business cycles (as expressed through macro variables and firm specific ratios) influence the probability of default
- But are defaults conditionally independent given the state of the business cycle?
- We discuss a test for this!

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Testing the conditional independence assumption

- We are looking to test if defaults are independent given an 'exogenous' process
- In intensity models of default, this conditional assumption is captured via the Cox process specification
- One may think of the Cox process as a standard Poisson process run at random speed

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Testing the conditional independence assumption

- Formally, let J be a unit rate Poisson process
- Define $\Lambda(t) = \int_0^t \lambda(s)ds$ and think of this as the integrated intensity of firm defaults
- λ is a stochastic process which determines the arrival rate of jumps
- Assume J, λ independent
- Define

$$N(t) = J(\Lambda(t))$$

- The higher the λ, the quicker the integral grows, the faster jumps arrive
- The arrival of defaults is affected by, but does not affect, the intensity of default
- The arrivals of defaults are conditionally independent given the intensities
- Buy can we test for this property?

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The test

- The idea of Das, Duffie, Kapadia and Saita (2007) (DDKS) is to try to go the other way:
- If we know the intensity, i.e. the change of speed, we should be able to transform the observed default arrivals into a standard Poisson process
- Mathematically formulated: $N(\Lambda^{-1}(s)) = J(s)$ is a Poisson process, so we should be able to get a Poisson process by using the observed defaults as the N process, transform the time scale using the estimated cumulative default intensity as Λ.
- We do not know the cumulative default intensities, but we can estimate them using (say) proportional hazard regressions

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Testing Poisson property of transformed data

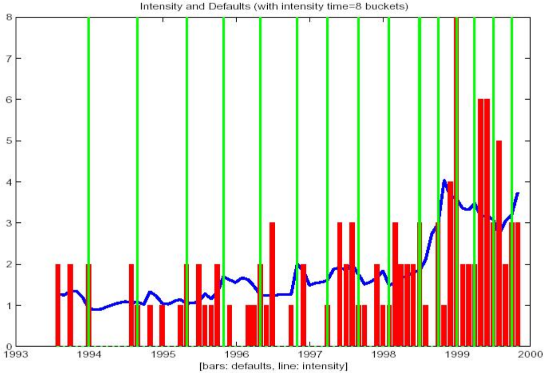

Figure 3. Time rescaled intensity bins. Aggregate intensities and defaults by month, 1994-2000, with time bin delimiters marked for intervals that include a total accumulated default intensity of $c = 8$ per bin. The vertical bars represent the number of defaults, and the line depicts the intensities.

Source: Das, Duffie, Kapadia, Saita (2007)

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The limitations of the test I

- The test is (as pointed out in DDKS) a joint test of the conditional independence assumption and the specification of the intensity
- If we reject, we do not know whether it was just because we used the wrong intensity
- We show, using almost the same data as DDKS that it is possible to specify the intensity of default such that the DDKS tests (plus additional tests) do not lead to rejection of conditional independence
- Before we turn to the actual specification, let us look at some real default histories

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Conclusion of these tests

- The real default histories of the rated firms make it hard to identify instances of 'contagion'
- The source for our default data (including the default histories) is Moody's default database, US corporates, from Jan 1, 1982- Dec 31, 2005.
- Later, we pair with compustat and other data (to be explained) but first we just look at the stories

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What we were looking for

"On June 21, 1970, the Penn Central declared bankruptcy and sought bankruptcy protection. As a result, **the PC was relieved of its obligation to pay fees to various Northeastern railroads—the Lehigh Valley included**—for the use of their railcars and other operations. Conversely, **the other railroads' obligations to pay those fees to the Penn Central were not waived**. This **imbalance in payments** would prove fatal to the financially frail Lehigh Valley, and it declared bankruptcy three days after the Penn Central, on June 24, 1970."
(Source: Wikipedia)
Caveat: Penn Central was in fact a majority shareholder, so listed as in the same corporate family by Moody's

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What we found: A typical default history

Alliance Entertainment Corp.: Alliance Entertainment Corp., headquartered in New York City, is the nation's largest wholesale distributor of pre-recorded music and music related products. The company markets its products and services to retail music chains and other wholesalers worldwide. Alliance's **aggressive growth through acquisition resulted in the accumulation of burdensome levels of debt** and interest expense at a time of little or no growth in the domestic music industry. Rapid expansion in a **stagnant market** coupled with **significant changes in music consumption demographics** led to decreasing sales. Alliance recorded a net loss of $23.1 million in the first quarter of 1997 versus a net loss of $4.6 million in the same period a year ago on sales of $126.3 million and $176.2 million, respectively. Having missed the amortization payments on bank loans on July 1, 1997, Alliance filed for Chapter 11 protection against all creditors on July 14, 1997.

(my emphasis)

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Typical causes of default - viewed qualitatively

- High leverage
- Acquisitions (often debt financed) gone bad
- Competition
- Price fluctuations in product markets (either on sell side or buy side)
- Law suits (asbestos), changed regulation (medicare)

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Methodology

- We inspect default histories for the majority of firms in Moody's default database
- We eliminate defaults in a family, where another firm with same parent has defaulted within a month
- We do not supplement with additional default events as in DDKS
- We therefore have to carry out both our tests and those of DDKS to determine whether the intensity is the reason for rejection

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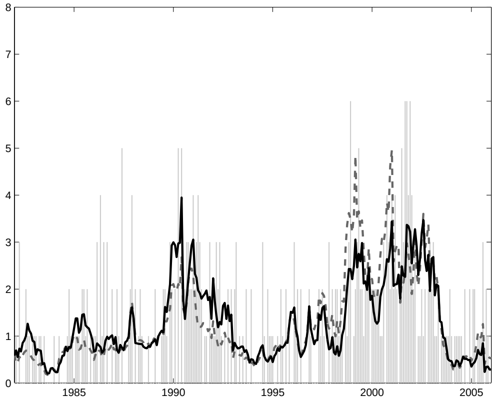
The proportional hazard specification

- We use the proportional hazard specification for the firm's default intensity

$$\lambda_{it} = R_{it} e^{\beta_W' W_t + \beta_X' X_{it}} \qquad t \geq 0.$$

- $(W_t)_{t\geq 0}$ is a vector of macro-economic variables
- $(X_{it})_{t\geq 0}$ is a vector of firm-specific variables
- R_{it} is a zero-one-variable indicating whether the firm is operating at time $t-$ (i.e. just before t) and thus exposed to default risk at time t.

Aggregate default intensity 1982-2005



Monthly number of U.S. industrial defaults recorded in Moody's DRSD in the period 1982-2005 and estimated default intensities for the simple (Model I, dashed) and the expanded (Model II, solid) model.

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Which covariates are significant?

- Macro: **1 yr-lagged SP500 return**, industrial production growth, Treasury term spread
- Firm specific: **1-yr equity return, Distance-to-default**, quick ratio, short-to-long debt, book asset value
- Those in bold are common to both DDKS and LN
- We do *not* use 3-month treasury rate (used by DDKS)

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Which covariates were tested out?

- unemployment rate
- wages of production workers
- CPI (consumer price index)
- GDP growth (both real and nominal)
- oil price (Many oil related defaults in 1986)
- Spread between Moody's Aaa- and Baa-rated bonds
- A number of firm specific variables from Altman (1968) and Zmijewski (1984),

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Level of covariates

Table 1. Descriptive statistics for covariates

The table reports empirical averages and standard deviations (in parenthesis) for the explanatory variables used in the Cox regressions.

Macro variables:		
1-year S&P500 return	0.110	(0.164)
3-month treasury rate	5.469	(2.671)
Industrial production	0.027	(0.029)
Treasury term spread	1.371	(0.955)

Firm specific variables:	*Defaulting firms*		*Non-def. firms*		*All firms*	
1-year equity return	0.044	(0.497)	0.119	(0.526)	0.109	(0.523)
1-year "Distance to Default"	0.612	(1.356)	2.063	(2.854)	1.867	(2.746)
Quick ratio	0.507	(6.237)	0.682	(3.091)	0.658	(3.677)
Short-to-long term debt	0.057	(0.154)	0.094	(0.185)	0.089	(0.181)
Book asset value (log)	1.835	(2.882)	3.170	(3.582)	2.990	(3.526)

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Parameter estimates

	Model I	Model II
Constant	-3.735 ***	-3.480 ***
	(0.179)	(0.299)
Macro variables:		
1-year S&P500 return	1.566 ***	1.886 ***
	(0.318)	(0.353)
3-month treasury rate	-0.040	
	(0.024)	
Industry production		-5.723 **
		(1.956)
Treasury term spread		0.209 ***
		(0.055)
Firm specific variables:		
1-year equity return	-3.131 ***	-3.151 ***
	(0.202)	(0.213)
1-year "Distance to Default"	-0.842 ***	-0.794 ***
	(0.039)	(0.043)
Quick ratio		-0.263 ***
		(0.085)
Short-to-long term debt		0.651 ***
		(0.177)
Book asset value (log)		-0.095 **
		(0.031)

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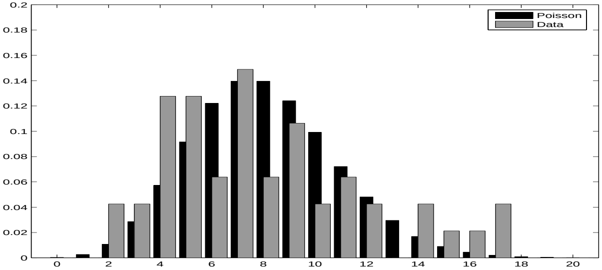
Empirical vs Poisson - bin size 8 - DDKS



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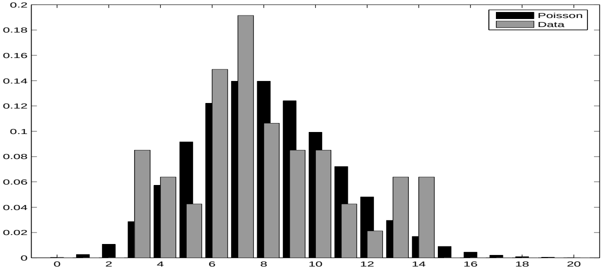
Empirical vs Poisson - bin size 8 - LN



Testing the Poisson property

Table 3. Binned data tests (doubly stochastic models)

The table reports $p-$values for tests of the fit of the transformed default data sorted into bins to the Poisson distribution. The employed test statistics are: Fisher dispersion (FD), Upper tail mean (UT1), Upper tail median (UT2), Böhning dispersion (BD), Cramer von Mises (CVM), Kocherlakota-Kocherlakota with parameter $t = 0.9$ (KK), Nakamura-Perez-Abreu (NPA), and the serial correlation statistics (3)-(4) (SC1-SC2). $p-$values (rounded to 3rd decimal) are calculated with 2-sided alternatives for the BD, KK, and SC statistics and 1-sided otherwise following Karlis and Xekalaki (2000), and statistical significance is indicated at 10% (*), 5% (**), and 1% (***) levels.

	FD	UT1	UT2	BD	CVM	KK	NPA	SC1	SC2
Model I									
Bin size 1	0.131	0.117	1.000	0.134	0.485	0.122	0.204	0.081 *	0.077 *
Bin size 2	0.091 *	0.311	0.738	0.108	0.629	0.100	0.528	0.071 *	0.009 ***
Bin size 4	0.052 *	0.222	0.226	0.065 *	0.336	0.063 *	0.132	0.017 **	0.000 ***
Bin size 6	0.013 **	0.033 **	0.072 *	0.012 **	0.090 *	0.013 **	0.002 ***	0.004 ***	0.000 ***
Bin size 8	0.007 ***	0.046 **	0.256	0.005 ***	0.135	0.006 ***	0.007 ***	0.007 ***	0.001 ***
Bin size 10	0.042 **	0.143	0.403	0.051 *	0.299	0.053 *	0.090 *	0.018 **	0.000 ***
Model II									
Bin size 1	0.250	0.275	1.000	0.334	0.808	0.317	0.811	0.532	0.935
Bin size 2	0.752	0.673	0.736	0.574	0.963	0.632	0.350	0.723	0.229
Bin size 4	0.493	0.551	0.975	0.842	0.964	0.836	0.944	0.395	0.113
Bin size 6	0.060 *	0.181	0.621	0.073 *	0.300	0.063 *	0.069 *	0.171	0.664
Bin size 8	0.309	0.405	0.773	0.474	0.622	0.530	0.591	0.874	0.605
Bin size 10	0.103	0.276	0.825	0.136	0.671	0.172	0.305	0.402	0.242

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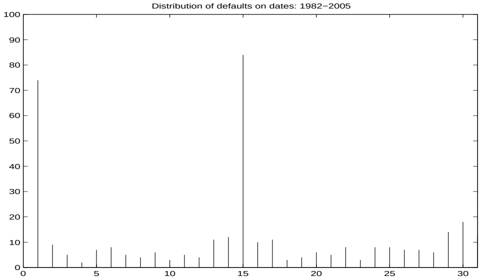
Calendar day effects



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A different test based on Hawkes processes

- We also try to specify a contagion alternative:

$$\lambda_{it}^{c} = R_{it}\left(e^{\beta_W' W_t + \beta_X' X_{it}} + \int_0^t \left(\alpha_0 + \alpha_1 Y_s\right) e^{-\alpha_2 (t-s)} dN_s + \delta\right)$$

- Y_s is the log asset value of firm defaulting at time s
- The interpretation is that the intensity of default jumps when a default occurs.
  In addition there is a constant term allowing us to modify the proportional hazard specification
- The jump size may depend on the asset value of the defaulting firm
- The effect decays with time since last default

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Table 5. Parameter estimates (contagion models)

The explanatory variables in the table are the same as appearing in table 2. Asymptotic standard errors are reported in parenthesis and statistical significance is indicated at 5% (*), 1% (**), and 0.1% (***) levels, respectively[14].

	Model II				
	Without level ($\delta = 0$)		With level ($\delta \neq 0$)		
Macro variables:					
Constant	-3.077 ***	-3.077 ***	-3.086 ***	-3.085 ***	-3.099 ***
	(0.318)	(0.318)	(0.318)	(0.318)	(0.317)
1-year S&P500 return	1.833 ***	1.833 ***	1.832 ***	1.832 ***	1.830 ***
	(0.361)	(0.361)	(0.361)	(0.361)	(0.361)
3-month treasury rate					
Industrial production	-5.833 **	-5.832 **	-5.834 **	-5.838 **	-5.874 **
	(2.008)	(2.008)	(2.008)	(2.008)	(2.007)
Treasury term spread	0.207 ***	0.207 ***	0.207 ***	0.207 ***	0.208 ***
	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)
Firm specific variables:					
1-year equity return	-3.236 ***	-3.236 ***	-3.244 ***	-3.244 ***	-3.254 ***
	(0.237)	(0.236)	(0.236)	(0.237)	(0.234)
1-year "Distance to Default"	-0.799 ***	-0.799 ***	-0.797 ***	-0.798 ***	-0.796 ***
	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)
Quick ratio	-0.765 ***	-0.765 ***	-0.764 ***	-0.765 ***	-0.762 ***
	(0.130)	(0.130)	(0.131)	(0.131)	(0.132)
Short-to-long term debt	0.389 *	0.389 *	0.390 *	0.390 *	0.392 *
	(0.182)	(0.182)	(0.183)	(0.183)	(0.183)
Book asset value (log)	-0.103 **	-0.103 **	-0.102 **	-0.102 **	-0.101 **
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
Contagion effects:					
Constant (α_0)	$2.1 \cdot 10^{-5}$	$2.1 \cdot 10^{-5}$ ***	$1.5 \cdot 10^{-6}$	$1.4 \cdot 10^{-5}$	
	($8.7 \cdot 10^{-5}$)	($2.1 \cdot 10^{-5}$)	($1.1 \cdot 10^{-4}$)	($2.5 \cdot 10^{-5}$)	
Firm size (α_1)	$2.4 \cdot 10^{-14}$		$1.7 \cdot 10^{-6}$		
	($1.3 \cdot 10^{-5}$)		($1.4 \cdot 10^{-5}$)		
Decay rate (α_2)	0.868 *	0.869 *	0.737	0.803	
	(0.837)	(0.813)	(1.063)	(0.894)	
Level (δ)			$1.2 \cdot 10^{-4}$	$8.9 \cdot 10^{-5}$	$3.5 \cdot 10^{-4}$ ***
			($3.9 \cdot 10^{-4}$)	($2.9 \cdot 10^{-4}$)	($1.4 \cdot 10^{-4}$)

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The limitations of the test II

- With our specification of the intensity, no rejection of conditional independence
- Even if we do not reject, it is still possible that there is genuine contagion
- We show that the test does not detect contagion 'through covariates'
- If default of one firm stresses the balance sheet of another, then if we condition on balance sheet information, we do not capture the contagion
- We show, that if we let ratings proxy for firm specific variables, and test whether defaults affect ratings of others, then defaults *are* contagious

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A result of Meyer and its implications

Consider a multivariate point process $(N_1, \ldots, N_n)$ and assume that every coordinate process N_i has a continuous compensator Λ_i satisfying $\lim_{t\to\infty} \Lambda_i(t) = \infty$. Then

$$\left(\sum_{j\in\mathbb{N}} 1_{(\Lambda_1(\tau_{1,j})\le t)}\right)_{t\ge 0}, \ldots, \left(\sum_{j\in\mathbb{N}} 1_{(\Lambda_n(\tau_{n,j})\le t)}\right)_{t\ge 0}$$

are independent unit Poisson processes where $\tau_{i,j}$ denotes the j'th jump of N_i.

The bottom line: As long as the firms do not simultaneously default, and all have default intensities, then we can transform into Poisson processes. The 'doubly stochastic' property is not needed.

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An example where DDKS test does not detect contagion

- Assume firms' default risk is entirely determined by their rating which can be either A or B
- Firms with rating A have a default intensity of 0.001 and firms in rating class B have a default intensity of 0.01
- Assume that there is a 'basic' migration intensity of 0.1 from A to B and the same intensity from B to A
- In addition, there is a contagion effect in ratings: Every time a firm defaults from rating class B, it causes 1% of the A-rated firms to be instantaneously downgraded into B
- No A or B-rated firm is thrown directly into default because of the default of another firm, but some downgrades from A to B are due to a contagion effect from the defaults of B-rated firms.

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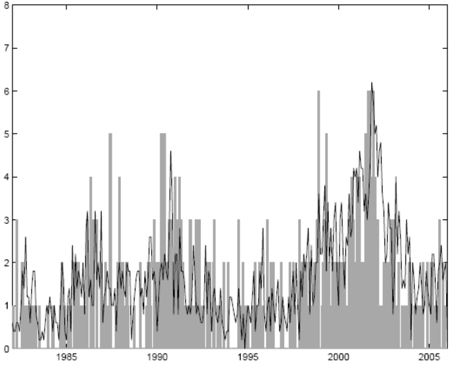
The Hawkes specification

- Ideally, we want to test for contagion by checking if defaults cause covariates of other firms to change
- We proxy the state of the covariates by the rating and ask whether defaults cause subsequent downgrades
- The specification uses a Hawkes process the aggregate downgrade intensity

$$\eta_t = \sum_{i=1}^{n} R_{it} 1_{(\tau_i \geq t)} \left(e^{\tilde{\beta}'_W W_t} + \int_0^t (\tilde{\alpha}_0 + \tilde{\alpha}_1 Y_s) e^{-\tilde{\alpha}_2 (t-s)} dN_s + \tilde{\delta} \right)$$

- Using macro-variables as 'exogenous' explanatory variables, we find significant effects
- Missing variables, rating policy issues call for robustness checks here

Downgrade intensity and subsequent downgrades



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Contagion through covariates

- Does the number of defaults in a period cause firm-specific covariates to change beyond what can be explained by other 'macro'-variables?
- We run regressions on the significant, firm-specific variables to test if this is the case
- Examples included in the following tables are quick ratio and distance-to-default
- Levels and changes

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Contagion through covariates

- Quick ratio: Significant in (median) level, but insignificant in changes
- Distance-to-default: Both levels and changes have mixed results:
  Longer default window gives significance
- Lower R-squared in changes

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Distance-to-default and defaults

Table 7. Effect of previous defaults on 1-year "Distance to Default" (mean)

The table reports estimation results for the time series regression

$$(\text{1-year "Distance to Default"})_t = \eta_0 + \eta_1(\text{1-year S\&P500 return})_t + \eta_2(\text{Industrial production})_t + \eta_3(\text{Treasury term spread})_t + \eta_4(\text{Defaults in } k \text{ mths.})_t$$

based on monthly observations. (1-year "Distance to Default")$_t$ is the cross-sectional mean across all firms at risk at time t, and (Defaults in k mths.)$_t$ is the aggregate number of observed defaults within the last k months prior to t. Asymptotic standard errors are Newey-West-corrected, and statistical significance is indicated at 10% (*), 5% (**), and 1% (***) levels.

Constant	3.789 ***	3.816 ***	3.871 ***	4.027 ***	4.083 ***
1-year S&P500 return	1.293 ***	1.277 ***	1.232 ***	1.095 ***	1.004 ***
Industrial production	4.163 ***	3.957 ***	3.513 ***	2.244 **	2.254 **
Treasury term spread	0.116 ***	0.115 ***	0.114 ***	0.116 ***	0.142 ***
Defaults in 1 mth.	-0.020 *				
Defaults in 3 mths.		-0.012			
Defaults in 6 mths.			-0.010		
Defaults in 12 mths.				-0.012 ***	
Defaults in 24 mths.					-0.008 ***
R^2	0.563	0.554	0.537	0.543	0.543
Obs.	288	286	283	277	265

Δ(Distance-to-default) and defaults

Table 8. Effect of previous defaults on changes in 1-year "Distance to Default" (mean)

The table reports estimation results for the time series regression

$$\Delta(\text{1-year "Distance to Default"})_t = \eta_0 + \eta_1(\text{1-year S\&P500 return})_t + \eta_2(\text{Industrial production})_t + \eta_3(\text{Treasury term spread})_t + \eta_4(\text{Defaults in } k \text{ mths.})_t$$

based on monthly observations. Δ(1-year "Distance to Default")$_t$ is the change from t to $t+1$ in the cross-sectional mean across all firms at risk, and (Defaults in k mths.)$_t$ is the aggregate number of observed defaults within the last k months prior to t. Asymptotic standard errors are Newey-West-corrected, and statistical significance is indicated at 10% (*), 5% (**), and 1% (***) levels.

Constant	0.010	0.034 *	0.071 ***	0.074 **	0.048
1-year S&P500 return	-0.035	-0.054	-0.081	-0.086	-0.090
Industrial production	-0.594 **	-0.784 ***	-1.072 ***	-1.038 ***	-0.731 **
Treasury term spread	0.008	0.005	0.004	0.006	0.007
Defaults in 1 mth.	0.003				
Defaults in 3 mths.		-0.002			
Defaults in 6 mths.			-0.004 ***		
Defaults in 12 mths.				-0.003 **	
Defaults in 24 mths.					-0.001
R^2	0.042	0.048	0.067	0.057	0.039
Obs.	287	285	282	276	264

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QR and defaults

Table 11. Effect of previous defaults on quick ratio (median)

The table reports estimation results for the time series regression

$$(\text{Quick ratio})_t = \eta_0 + \eta_1(\text{1-year S\&P500 return})_t + \eta_2(\text{Industrial production})_t + \eta_3(\text{Treasury term spread})_t + \eta_4(\text{Defaults in } k \text{ mths.})_t$$

based on monthly observations. $(\text{Quick ratio})_t$ is the cross-sectional median across all firms at risk at time t, and $(\text{Defaults in } k \text{ mths.})_t$ is the aggregate number of observed defaults within the last k months prior to t. Asymptotic standard errors are Newey-West-corrected, and statistical significance is indicated at 10% (*), 5% (**), and 1% (***) levels.

Constant	0.968 ***	0.993 ***	1.010 ***	1.029 ***	1.044 ***
1-year S&P500 return	0.086 **	0.075 *	0.069 *	0.049	-0.007
Industrial production	0.496 **	0.323	0.175	0.076	0.163
Treasury term spread	0.008	0.009	0.012 *	0.017 ***	0.024 ***
Defaults in 1 mth.	-0.013 ***				
Defaults in 3 mths.		-0.010 ***			
Defaults in 6 mths.			-0.007 ***		
Defaults in 12 mths.				-0.005 ***	
Defaults in 24 mths.					-0.003 ***
R^2	0.255	0.344	0.416	0.506	0.563
Obs.	288	286	283	277	265

Δ(QR) and defaults

Table 12. Effect of previous defaults on changes in quick ratio (median)

The table reports estimation results for the time series regression

$$\Delta(\text{Quick ratio})_t = \eta_0 + \eta_1(\text{1-year S\&P500 return})_t + \eta_2(\text{Industrial production})_t + \eta_3(\text{Treasury term spread})_t + \eta_4(\text{Defaults in } k \text{ mths.})_t$$

based on monthly observations. $\Delta(\text{Quick ratio})_t$ is the change from t to $t+1$ in the cross-sectional median across all firms at risk, and $(\text{Defaults in } k \text{ mths.})_t$ is the aggregate number of observed defaults within the last k months prior to t. Asymptotic standard errors are Newey-West-corrected, and statistical significance is indicated at 10% (*), 5% (**), and 1% (***) levels.

Constant	-0.002 *	-0.002	-0.001	-0.004	-0.004 *
1-year S&P500 return	0.006 *	0.005	0.004	0.007 *	0.005
Industrial production	-0.039 **	-0.039 *	-0.050 **	-0.021	-0.015
Treasury term spread	0.002 ***	0.002 ***	0.002 ***	0.002 ***	0.002 **
Defaults in 1 mth.	0.000				
Defaults in 3 mths.		0.000			
Defaults in 6 mths.			-0.000		
Defaults in 12 mths.				0.000	
Defaults in 24 mths.					0.000
R^2	0.041	0.038	0.038	0.036	0.033
Obs.	287	285	282	276	264

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Concluding remarks

- We find that (on a smaller data set than that used in DDKS) we reject the conditional independence assumption using their specification
- We do not reject using our specification - hence specification of the intensities is a likely cause for rejection in DDKS
- Even if we do not reject, we have not ruled out contagion
- We explain why this is and conduct tests for this using ratings and using firm specific variables
- Our (rough) tests do not rule out contagion effects in this case, but evidence is mixed
- Are contagion effects mainly 'informational' for larger firms?