Financial Shocks in Production Chains

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Production networks in economics

Plan of paper:

- Outline stylized model of trade credit and moral hazard in production chains
- Test if broad empirical predictions hold in the data
- Preliminary and incomplete!

Production networks in economics

Technological stories:

- Kremer (1993), Jones (2009)
  - ➢ Complementarity between high productivity workers
  - ➢ Weakest link in chain important for total output
- Disorganization in the former Soviet Union (Blanchard and Kremer (1997), Marin and Schnitzer (2004))
  - ➢ Loss of suppliers after break down of command economy

Production networks in economics

Financial stories:

- Bigio and La'O (2013)
  - ➢ Complementarity plus financing contraints
  - ➢ Large financial multiplier

Trade credit

Empirical observations:

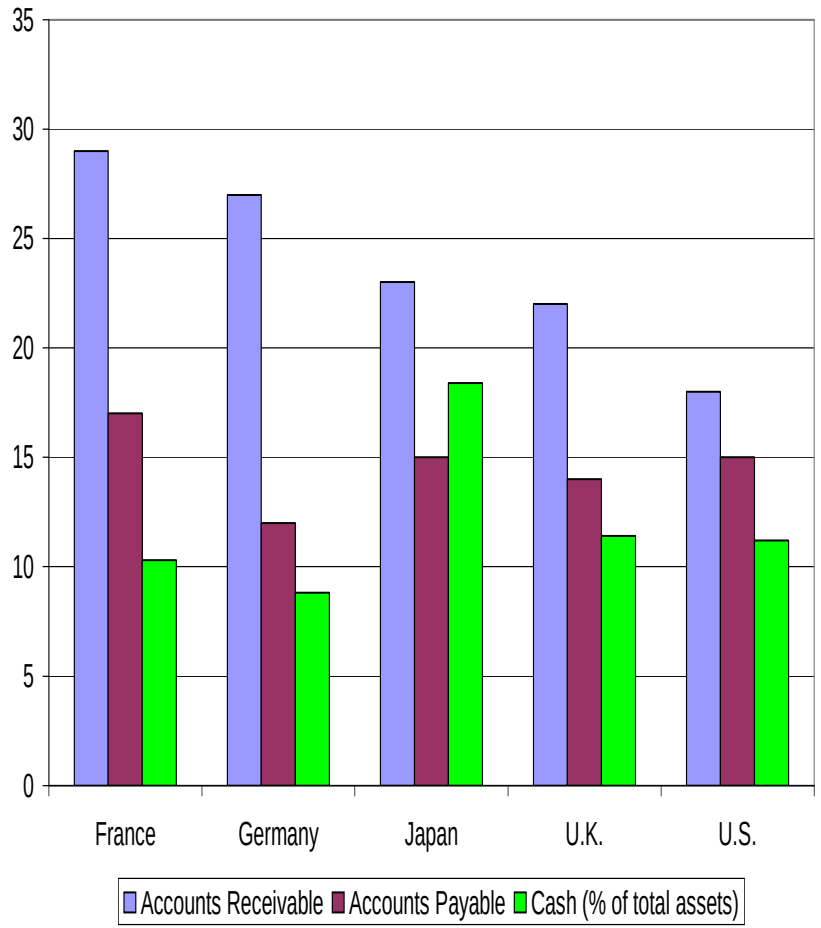
- Many firms have accounts payable even if the apparently have good access to (cheaper) credit
- Firms typically have large accounts payable and receivable at the same time
- Some theories extant: informed lenders to customers, insurance against bad products,...
- Kim and Shin (2012)—theory for current paper
- Accounts payable transfers rent to suppliers—overcomes moral hazard
  - ➢ Suppliers may have other options
  - ➢ Departure of supplier disrupts the whole production chain

This paper

Broad intuition:

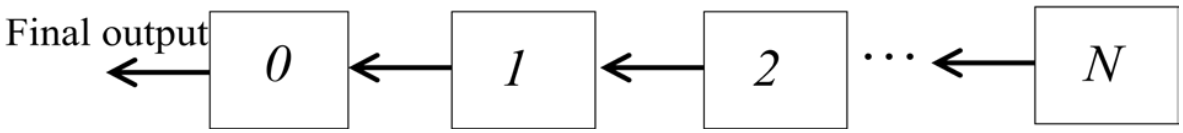
- Net working capital is the "glue" that binds firms in a production chain
- Net working capital is equity stake in the production chain as a whole
- Delay in payment builds up net working capital
- Working capital varies across countries:

Developed Country Corporate Balance Sheets



Production chain

- Final output sold by firm 0 at price q.



- Firm $i+1$ supplies intermediate good to firm i.
- It takes time to build in production process.
- Success of project depends on effort of all firms in the production chain.

Cash Flows before Transfers

		Firms				
		0	1	$\cdots$	$N-1$	N
date t	0					$-w_N$
	1				$-w_{N-1}$	$-w_N$
	$\vdots$			$\cdots$	$-w_{N-1}$	$-w_N$
	$N-1$		$-w_1$	$\cdots$	$-w_{N-1}$	$-w_N$
	N	$-w_0$	$-w_1$	$\cdots$	$-w_{N-1}$	$-w_N$
	$N+1$	$q-w_0$	$-w_1$	$\cdots$	$-w_{N-1}$	$-w_N$
	$N+2$	$q-w_0$	$-w_1$	$\cdots$	$-w_{N-1}$	$-w_N$
	$\vdots$	$\vdots$	$\vdots$		$\vdots$	$\vdots$

Wage cost w_i cannot be deferred, and must draw on firm i's cash holdings. Working capital needed to start production chain.

Model

Technology

- In each period, firm i chooses from {high effort, low effort}
- Private benefit from low effort, bw_i $(b > 0)$
- Probability of failure
  - ➢ 0 if all exert high effort, ε if one or more exert low effort
  - ➢ Borrowing rate r used to discount cash flows
  - ➢ Zero liquidation value of firms
- Payment p_i to firm i by firm $i-1$ for intermediate good.
- Deviations from high effort deterred by large enough "skin in the game" (Kim and Shin (2012), multi-firm version of Holmstrom and Tirole (1997))

Recursive Moral Hazard

- Payoff from consistent high effort

$$(p_i - p_{i+1} - w_i) \sum_{\tau=0}^{\infty} \frac{1}{(1+r)^{\tau}} \tag{1}$$

Model

The expected payoff to producer i from deviating to low effort today for one period is:

- Instant reward bw_i
- Payment for i periods for sure until substandard product reaches consumer:

$$(p_i - p_{i+1} - w_i)\,(\,1 + 1/(1+r) + ... + 1/(1+r)^i)$$

- After i periods payments stop with probability ϵ, otherwise continue

So total expected payoff is

$$bw_i + (p_i - p_{i+1} - w_i)\left(\sum_{\tau=0}^{i} \frac{1}{(1+r)^\tau} + (1-\varepsilon)\sum_{\tau=i+1}^{\infty} \frac{1}{(1+r)^\tau}\right) \tag{2}$$

Recursive Moral Hazard

Comparing (1) and (2), the incentive compatibility constraint against a one period deviation to low effort is

$$p_i \geq p_{i+1} + (1 + b_i)\, w_i \tag{3}$$

where b_i is the positive constant

$$b_i = \frac{b \cdot r\,(1+r)^i}{\varepsilon} \tag{4}$$

Recursive Moral Hazard

- Substituting terms in the recursion gives condition:

$$p_i \geq \sum_{k=i}^{N} (1 + b_k)\, w_k$$

- Prices $\{p_i\}$ incorporate rents $\{b_k w_k\}$ for all the upstream firms k along the production chain
- Chain unravels unless $q \geq \sum_{k=0}^{N} (1 + b_k)\, w_k$
- Parallels "disorganization" of Blanchard and Kremer (1997)

Working Capital as "Glue"

Firm i receives payment from firm $i-1$ after delay.
Accounts payable amortized at constant rate $a_i p_i$ (actuarially fair).

Distinction between

- *invoice price* $(1+a_i)\,p_i$
- Now p_i *fundamental price* .

The fundamental price covers cost of production:

$$p_i = \sum_{k=i}^{N} (1+r)^{k-i+1}\, w_k$$

or

$$p_i = (1+r)w_i + (1+r)p_{i+1} \tag{5}$$

Incentive compatibility constraint with accounts receivable/payable

$$(1 + a_i)\, p_i \geq (1 + a_{i+1})\, p_{i+1} + (1 + b_i)\, w_i \tag{6}$$

Here, the interpretation of a_i is the rent transfered via late payment, price plus rent has to cover cost of input plus provide incentives.

Model

Production chain is *sustainable* if expected profit of firm 0 is non-negative under the optimal contract, p_i covers cost of production, and IC constraint holds. Combining (5) and (6):

$$\begin{aligned} a_i p_i - a_{i+1} p_{i+1} &= -(1+r) w_i - r p_{i+1} + (1+b_i) w_i \\ &= \left(b_i - r \frac{p_{i+1}}{w_i} - r \right) w_i \\ &= \left(\frac{b (1+r)^i}{\varepsilon} - \frac{p_{i+1}}{w_i} - 1 \right) r w_i \end{aligned}$$

Model

Net Working Capital

Evaluating flows as perpetuities, accounts receivables (R_i) and payables (P_i) satisfy $(R_i - P_i)r = a_i p_i - a_{i+1} p_{i+1}$ or

$$R_i - P_i = \left(\frac{b\,(1+r)^i}{\varepsilon} - \frac{p_{i+1}}{w_i} - 1 \right) w_i$$

Expression in brackets is

- increasing in i ("upstreamness")
- increasing in r (financial tightness)
- non-linear in i and r

Model predictions:

Empirical Hypotheses

Proposition 1. Net receivables relative to w_i is higher for upstream firms

Proposition 2. Net receivables is increasing in r for low values of r and high values of i. However, if $r > r^*$ for threshold r^*, net receivables is declining in r.

Measure of upstreamness (by sector)

Fally (2011), Antras, Chor, Fally and Hillberry (2012) and Antras and Chor (2013)
Input-Output matrix with coefficients d_{ij}; sector-level measure of upstreamness satisfies

$$U_i = 1 + \sum_{j=1}^{N} \frac{d_{ij} Y_j}{Y_i} U_j.$$

$d_{ij} Y_j / Y_i$ is share of sector i's total output purchased by sector j.

Then find U by matrix inversion.

Data

IO matrices

- OECD input-output tables for 16 countries
- Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Hungary, Italy, Netherlands, Portugal, Slovakia, Slovenia, Spain, and United States
- 18 sub-industries of manufacturing

Data

Firm-level data

- Annual firm-level data from ORBIS; sample 2000 $\sim$ 2009
- $>$ 150,000 firms, $>$ 600,000 firm-year observations

Firms Across Countries, 2000-2009: Number of Observations/Firms by Country (not all)

Country	Firm-Year	Number of Firms
Austria	1247	665
Belgium	30343	5495
Czech Republic	27792	7528
Denmark	4887	1515
Estonia	9141	1613
Finland	30633	5407
Germany	38527	14335
Greece	22128	6451
Hungary	10886	3539
Italy	282404	67605
Netherlands	3504	1076
Portugal	44378	11358
Spain	52436	10357
United States	40929	15723
Total	616354	156868

Table 1: Firms Across Countries, 2000-2009: Number of Observations/Firms by Type

Type	Firm-Year	Number of Firms
All	616354	156868
Medium	436963	114400
Large	140208	33742
Very Large	39183	8726
Listed	13094	2834
Unlisted	451594	107732
Young	72260	30107
Mature	530662	124472

Descriptive Statistics: OECD Sample, 2000–2009

Table 2: Descriptive Statistics: OECD Sample, 2000–2009

Variable	Mean	Median	St. dev.	Min.	Max	Kurtosis
Payable/TA	0.23	0.20	0.16	0.01	0.67	3.15
Receivable/TA	0.33	0.31	0.19	0.02	0.76	2.45
Working Capital/TA	0.28	0.28	0.19	-0.10	0.7	2.45
Short-term Debt/TA	0.36	0.33	0.23	0.02	0.85	2.16
Bank Debt/TA	0.22	0.20	0.19	0.00	0.68	2.25
Total Debt/TA	0.46	0.47	0.24	0.03	0.91	1.99
Payable/OR	0.18	0.16	0.12	0.01	0.52	3.2
Receivable/OR	0.26	0.24	0.16	0.02	0.67	2.78
Net Receivable/OR	0.08	0.07	0.13	-0.19	0.42	3.15
Working Capital/OR	0.23	0.21	0.18	-0.07	0.74	3.33

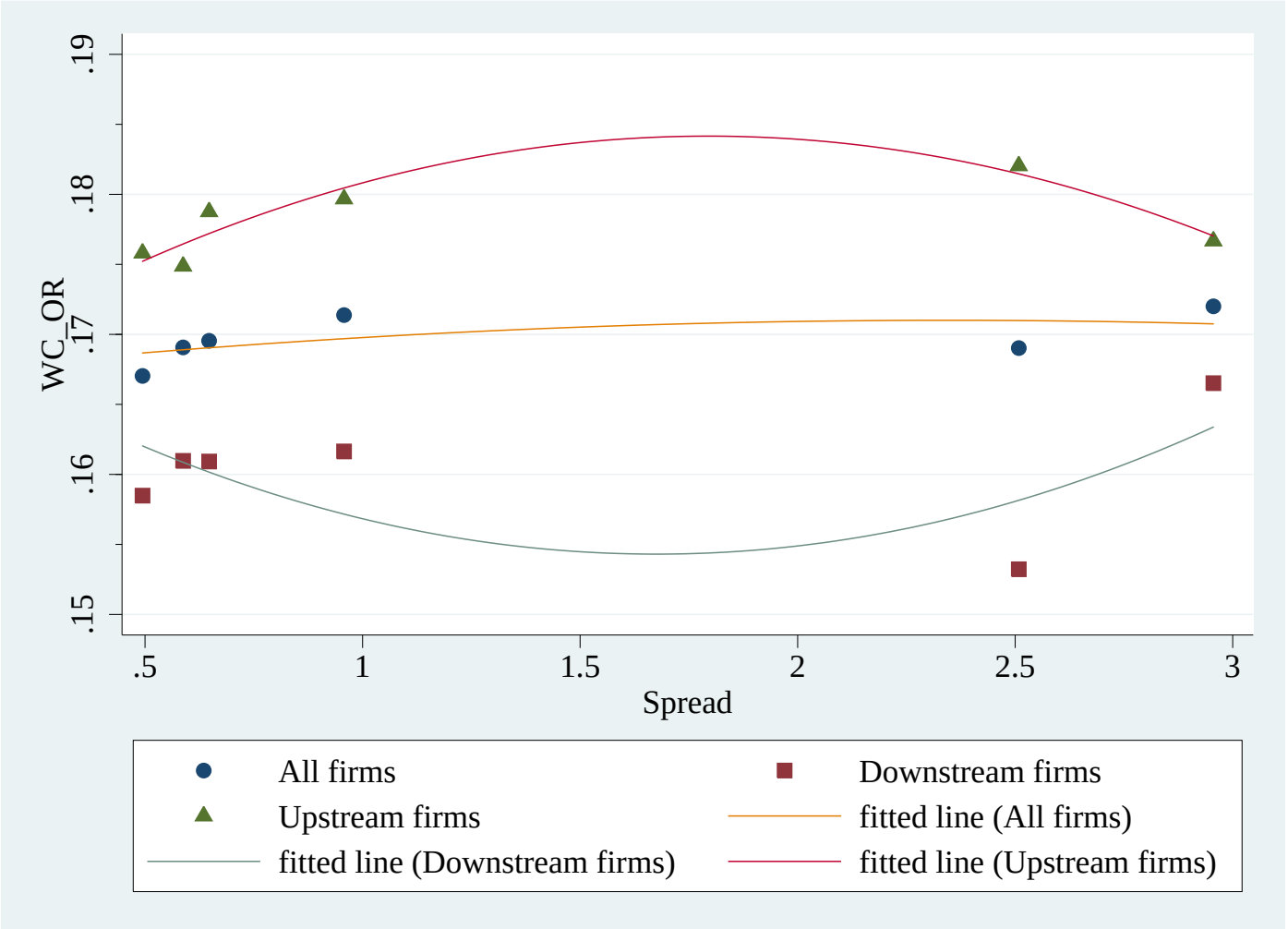
Descriptive Statistics by Firm Types

Firm Type	Variable	Obs.	Mean	Med	St.dev.	Min	Max
Medium	Receivable/TA	436423	0.34	0.32	0.19	0.02	0.76
	Payable/TA	430238	0.24	0.21	0.16	0.01	0.67
Large	Receivable/TA	140093	0.31	0.29	0.18	0.02	0.76
	Payable/TA	137753	0.21	0.19	0.14	0.01	0.67
Very Large	Receivable/TA	39134	0.21	0.18	0.16	0.02	0.76
	Payable/TA	38567	0.14	0.1	0.13	0.01	0.67
Unlisted	Receivable/TA	451376	0.33	0.32	0.19	0.02	0.76
	Payable/TA	443721	0.23	0.21	0.16	0.01	0.67
Listed	Receivable/TA	13072	0.16	0.14	0.11	0.02	0.76
	Payable/TA	12930	0.09	0.07	0.09	0.01	0.67
Young	Receivable/TA	72095	0.35	0.34	0.21	0.02	0.76
	Payable/TA	71004	0.28	0.25	0.19	0.01	0.67
Mature	Receivable/TA	530142	0.32	0.3	0.18	0.02	0.76
	Payable/TA	522173	0.22	0.2	0.15	0.01	0.67

Testing Proposition 1

Dependent variables				
	$(\frac{REC}{OR})$	$(\frac{PAY}{OR})$	$(\frac{N\_REC}{OR})$	$(\frac{WC}{OR})$
UPS	0.014***	0.005***	0.009***	0.013***
	(47.29)	(21.23)	(31.65)	(32.62)
country fixed effects	yes	yes	yes	yes
year fixed effects	yes	yes	yes	yes
Adjusted R^2	0.335	0.318	0.079	0.097
Obs.	609497	600425	599886	599032

"Testing" Proposition 2 (US only)



Median normalized end-year working capital of US firms into upstream, downstream and

Testing Proposition 2

Dependent variables						
	$(\frac{REC}{OR})$		$(\frac{PAY}{OR})$		$(\frac{N\_REC}{OR})$	
UPS	0.015***		0.005***		0.010***	
	(47.77)		(20.13)		(33.24)	
UPS×spread	0.018***	0.017***	0.010***	0.010***	0.008***	0.007***
	(8.52)	(8.32)	(6.23)	(6.25)	(3.70)	(3.46)
UPS×spread^2	-0.004***	-0.004***	-0.003***	-0.003***	-0.001*	-0.001**
	(-6.87)	(-7.13)	(-6.32)	(-6.20)	(-1.96)	(-2.29)
country fixed effects	yes	yes	yes	yes	yes	yes
year fixed effects	yes	yes	yes	yes	yes	yes
sector fixed effects	no	yes	no	yes	no	yes
Adjusted R^2	0.335	0.342	0.318	0.320	0.079	0.086
Obs.	609497	609497	600425	600425	599886	599886

Working capital in great recession and run-up

Panel A: Dependent variable, average growth of $\frac{WC}{OR}$ (04–06)	
UPS	0.029*
	(1.80)
Adjusted R^2	0.018
Panel B: Dependent variable, average growth of $\frac{WC}{OR}$ (07–09)	
UPS	-0.045***
	(-2.83)
Adjusted R^2	0.017
Obs.	47414
Country effects	yes

Cyclical pattern at the firm level

Dependent variable, average growth of $\frac{WC}{OR}$ (07–09)		
average growth of $\frac{WC}{OR}$ (04–06)	-0.013**	-0.012**
	(-2.57)	(-2.43)
Country fixed effects	yes	yes
Sector fixed effects	no	yes
Clustered std. errors by	no	no
Adjusted R^2	0.011	0.018
Obs.	47860	47860

Conclusion

- Financial interlinkages in supply chains through accounts receivables and payables may mitigate inefficiency due to bargaining and incentives
- Efficiency through delayed settlement
  - ➢ Possible explanation for why accounts receivable and payable are so large?
- Downside of delayed settlement is large demands on working capital

Conlusions: Development

How can developing countries with poorly capitalized firms achieve lengthening of production chain?
Two hurdles:

- Working capital to finance the initial "triangle of costs"
- Sustaining long production chain

Both can be solved if firms have sufficient initial capital

Both are problematic when firms are poorly capitalized

Vertical integration may be a (second best) solution