Technology spillovers, asset redeployability, and corporate financial policies

Phuong-Anh Nguyen

Ambrus Kecskés

Motivation

- Innovation is an essential driver of productivity and growth
- Corporate innovation isn't undertaken in isolation but rather as part of an ecosystem of technologically related firms
- Recent work shows empirically that spillovers of technologies across firms affect firm innovation, productivity, and value: Bloom, Schankerman, and Van Reenen (2013) ("BSV")
- As technologies spill over from one firm to another, they stimulate investment and generate assets for technologically related firms
  - Assets that are intangible or tangible
  - Spillovers that are voluntary (e.g., firms choose to mergers) or involuntary (e.g., knowledge transfer through patents, research papers, conferences, social networks, job changes, etc.)
  - E.g., Bena and Li (2014), Akcigit, Celik, and Greenwood (2016), etc.

Hypothesis

- Take as given the previously documented impact of technology spillovers on corporate assets
- We ask: How do firms choose their mix of debt and equity to finance their assets?
- Hypothesis: Technology spillovers to a firm increase the redeployability of its assets, which ultimately leads the firm to increase its leverage
  - Part #1: Technology spillovers and asset redeployability
  - Part #2: Asset redeployability and leverage

Mechanism

- A key determinant of corporate leverage is asset redeployability, i.e., value in alternative use (e.g., Williamson (1988), Shleifer and Vishny (1992), etc.)
- Asset redeployability is a problem for innovative firms because their assets are firm-specific and intangible, which increases losses to lenders in bankruptcy, and limits lending
- Forces that increase asset redeployability also relax limits on leverage. Examples:
  - Greater product market activity in common (e.g., Shleifer and Vishny (1992))
  - But also greater common activity in technology space!
- Our insight: Firms with similar technologies may be willing to buy assets from each other because their assets incorporate technologies from each other, so their assets are useful and valuable to each other
- There is prior evidence consistent with technology spillovers improving asset redeployability and facilitating borrowing
  - Bena and Li (2014): Technology overlap encourages mergers
  - Mann (2018): Patents are used as collateral for borrowing
  - Hochberg, Serrano, and Ziedonis (2018): Firms are able to borrow more when their patents have a more liquid secondary market

Empirical strategy: Motivation

- Hypothesis: Technology spillovers to a firm increase the redeployability of its assets, which ultimately leads the firm to increase its leverage
- Ideally, want technology spillovers that *actually* happened
  - But: No data because technology spillovers generate a wide variety of assets many of which can't be measured
  - And: Actual spillovers are virtually impossible to measure
- Instead, measure *potential* technology spillovers
  - Because: Possible using new measures in recent empirical literature
  - And: Plausible that these potential measures capture actual technology spillovers because these measures result in higher corporate innovation (same literature)

Empirical strategy: Summary

- Want (potential) technology spillovers to a given firm from all other firms
- Capture technology spillovers by taking into account:
  - Technological similarity between a given firm and all other firms, and
  - Stock of knowledge of all other firms
- Use, respectively:
  - Technological proximities (weights) between a given firm i and another firm j
  - R&D stock of another firm j
- Measure technological proximity of two firms as distance between the technology activities of the firms, in the same technology space ("Jaffe") or similar technology spaces ("Mahalanobis")
- Measure R&D stock by capitalizing R&D expenditures
- Use: Patents and patent classes, respectively, to capture technology activities and technology spaces (NBER patent database)
- Sum up weighted R&D stocks across all other firms j ($j \neq i$) $\rightarrow$ Technology spillovers

Empirical strategy: Additional details

- Technological proximity is vector distance, with vectors constructed from the patent share of a firm in each of 426 possible patent classes
  - The patent share of a firm is the firm's share of the patents in a given technology class over a period of time, adjusted for the duration of the firm's existence
- Use: Jaffe and Mahalanobis distance measures
  - Jaffe measure is calculated assuming technology spillovers are possible only within the same patent class
  - Mahalanobis measure is calculated assuming technology spillovers are possible both within and across patent classes (use patent class weighting matrix based on all firms)
- R&D stock of firm j: $G_t=R_t+(1-\delta)G_{t-1}$, where R_t is R&D expenditure in year t, and δ is the depreciation rate set equal 0.15
- Product market spillovers are constructed analogously, but using product market proximity instead (industry sales instead of patent shares, Compustat industry segments instead of patent classes)

Identification

- Want to identify effect of technology spillovers on financial policies
- Use: Exogenous variation in federal and state R&D tax credits
  - Tax credit calculations: Hall and Jorgensen (1967)
  - Exogeneity: Lots of empirical evidence in the literature
- Approach
  - For a panel of firm-years, first project R&D expenditures on R&D tax credits, and calculate projected R&D expenditures
  - Then, for each firm-year, calculate technology spillovers using projected R&D expenditures (rather than actual R&D expenditures)
- Upshot: Identify technology spillovers to a given firm using the projected R&D of other firms based on their R&D tax credits

Other empirical details

- Use a sample of publicly traded firms with requisite data (694 firms, 1981-2001 sample period, 12,118 firm-year observations)
- In main regressions, always control for:
  - Product market spillovers (to separate positive effect of technological peer firms from negative effect of product market competitors)
  - The firm's own R&D stock
  - The firm's own tax credits
- Identify only off time-series variation within firms
  - Firm FEs to sweep out variation across firms
  - Industry-year FEs to sweep out variation across a given industry at a given time

Findings: Summary

- Technology spillovers increase leverage
  - ↑ Leverage by 6 p.p.
  - Stronger for firms with greater debt market access
  - Also: ↑ Debt issuance, ↓ Equity issuance
- Technology spillovers increase asset redeployability
  - ↑ Asset collateralization (collateralized debt, patent collateralizations)
  - ↑ Asset liquidity (patent sales, number of M&As, value of M&As)
- Technology spillovers decrease the cost of debt
  - ↓ Bond spreads by 6 bps, ↓ Bank loan spreads by 9 bps

General regression specifications

- Four specifications based on four measures of technology spillovers
  - Raw Jaffe, purged Jaffe, raw Mahalanobis, and purged Mahalanobis
- Control variables
  - Product market spillovers, R&D, federal and state R&D tax credits (only for purged spillover measures), firm age, etc.
- Fixed effects
  - Firm-year regressions: Firm and industry-year
  - Firm-deal regressions: Industry and year fixed effects
- Standard errors: Clustered by industry-year

Analysis: Capital structure

- Outcomes
  - Leverage (Panel A)
  - Debt issuance (Panel B)
  - Equity issuance (Panel C)
  - All scaled by total assets
- Specification
  - Firm-year observations
  - Controls
  - Fixed effects for firms and industry-years
- Controls
  - Technology and product market spillovers
  - R&D
  - Federal and state R&D tax credits (only for purged spillover measures)
  - Firm age
  - Sales
  - Market-to-book of assets
  - Cash flow
  - Asset tangibility
  - Cash flow volatility

[T3] The effect of technology spillovers on capital structure

Tech. spill. var.	Dependent variable		
	Leverage	Debt issuance	Equity issuance
Raw Jaffe	6.30***	3.15**	-1.38**
	(3.51)	(2.37)	(-2.21)
Purged Jaffe	5.87**	4.11**	-1.69**
	(2.22)	(2.26)	(-2.00)
Raw Mahalanobis	5.38***	2.50*	-1.60**
	(3.17)	(1.82)	(-2.31)
Purged Mahalanobis	6.68***	2.67*	-0.91
	(3.17)	(1.69)	(-1.14)

- Leverage: ↑ 6 p.p. of total assets vs. mean (median) of 22% (21%)
- Debt issuance: ↑ 3-4 p.p. of total assets
- Equity issuance: ↓ 1-2 p.p. of total assets

[T4] The moderating role of debt market access

- Motivation: Financing frictions, particularly debt market access, could moderate the effect of technology spillovers on leverage
- Test: Interact our main effect (technology spillovers on leverage) with the firm's credit rating
- Results: Main effect is stronger for firms with higher credit ratings (greater access to relatively cheap debt financing compared to equity)

Analysis: Asset collateralization

- Motivation
  - If: Technology spillovers increase the productivity and value of the firm's assets in alternative use
  - Then: There should be greater collateralization of the firm's assets
- Outcomes
  - Collateralized debt scaled by total assets (Panel A)
  - Patent collateralizations (Panel B)
- Specification
  - Firm-year observations
  - Controls
  - Fixed effects for firms and industry-years
- Controls for all panels
  - Technology and product market spillovers
  - R&D
  - Federal and state R&D tax credits (only for purged spillover measures)
  - Market-to-book of assets
  - Cash flow
- Controls for Panel A
  - Sales
  - Asset tangibility
  - Cash flow volatility
- Controls for Panel B
  - Total assets
  - Leverage
  - Asset tangibility
  - Cash flow volatility
  - Stock of patents

[T5] The effect of technology spillovers on asset collateralization

Tech. spill. var.	Dependent variable	
	Collateralized debt	Patent collateralizations
Raw Jaffe	3.20***	22.30***
	(4.12)	(2.74)
Purged Jaffe	2.31**	18.91**
	(2.19)	(2.06)
Raw Mahalanobis	2.67***	20.00***
	(3.19)	(2.59)
Purged Mahalanobis	2.46**	25.19***
	(2.45)	(2.95)

- Collateralized debt: ↑ 3 p.p. of total assets vs. total increase in leverage of 6 p.p.
- Patent collateralizations: ↑ 20%-25%

Analysis: Asset liquidity

- Motivation
  - If: Technology spillovers increase the productivity and value of the firm's assets in alternative use
  - Then: There should be greater market liquidity for the firm's assets
- Outcomes
  - Patent sales (Panel A)
  - Number of M&As (Panel B)
  - Value of M&As scaled by total assets (Panel C)
- Specification
  - Firm-year observations
  - Controls
  - Fixed effects for firms and industry-years
- Controls for all panels
  - Technology and product market spillovers
  - R&D
  - Federal and state R&D tax credits (only for purged spillover measures)
  - Market-to-book of assets
  - Cash flow
- Controls for Panel A
  - Total assets
  - Leverage
  - Asset tangibility
  - Cash flow volatility
  - Stock of patents
- Controls for Panels B and C
  - Total assets
  - Stock returns
  - Leverage
  - Cash holdings

[T6] The effect of technology spillovers on asset liquidity

Tech. spill. var.	Dependent variable		
	Patent sales	Number of M&As	Value of M&As
Raw Jaffe	25.55***	4.99	1.77*
	(3.46)	(1.59)	(1.76)
Purged Jaffe	16.94*	12.25***	3.80***
	(1.80)	(2.73)	(2.77)
Raw Mahalanobis	21.89***	8.30**	3.18***
	(3.15)	(2.50)	(3.01)
Purged Mahalanobis	26.08***	10.06**	4.23***
	(2.90)	(2.44)	(3.33)

- Patent sales: ↑ 15%-25%
- Number of M&As: ↑ 5%-10%
- Value of M&As: ↑ 2-4 p.p. of total assets vs. unconditional mean of 1.8%

Analysis: Cost of debt

- Motivation
  - Greater asset redeployability implies lower borrowing costs
- Outcomes
  - Bond issue spreads (Panel A)
  - Bank loan spreads (Panel B)
- Specification
  - Firm-deal observations
  - Controls
  - Fixed effects for industries and years

- Controls at firm level
  - Technology and product market spillovers
  - R&D
  - Federal and state R&D tax credits (only for purged spillover measures)
  - Firm age
  - Total assets
  - Leverage
  - Market-to-book of assets
  - Cash flow
  - Asset tangibility
  - Cash flow volatility
- Controls at firm-deal level
  - Proceeds / amount of issue / loan
  - Maturity of bond / loan
  - Credit rating of issue / firm
  - Dummy for credit rating missing
  - Dummy for issue is private or public / loan is term loan or credit line

[T7] The effect of technology spillovers on the cost of debt

Tech. spill. var.	Dependent variable is spread	
	Bond issues	Bank loans
Raw Jaffe	-6.55**	-9.52***
	(-2.09)	(-2.92)
Purged Jaffe	-5.91**	-9.63***
	(-2.21)	(-3.08)
Raw Mahalanobis	-6.63**	-8.76***
	(-2.21)	(-2.75)
Purged Mahalanobis	-6.35**	-8.95***
	(-2.10)	(-2.85)

- Bond spreads: ↓ 6 bps vs. mean (median) of 107 bps (83 bps)
- Loan spreads: ↓ 9 bps vs. mean (median) of 126 bps (75 bps)
- Similar results for years +2 to +5

Alternative interpretations

- Increase in future profitability
  - Effect of technology spillovers on leverage is unaffected by controlling for realized or expected future profitability ([AT2])
- Debt as a disciplinary mechanism
- Increase in information asymmetry
- Decrease in cash flow risk

Summary

- Technology spillovers across firms affect corporate financial policies
  - Technology spillovers lead to higher leverage
    - More so for firms with greater debt market access
  - Mechanism: Technology spillovers increase asset redeployability
    - Evidenced by more asset collateralization and asset liquidity
    - And lower borrowing costs

Cardiff Business School
Ysgol Busnes Caerdydd

Technology Spillovers, Asset Redeployability, and Corporate Financial Policies

Discussion by Arman Eshraghi

Conference on Financial Stability and Sustainability

20-21 January 2020

Paper in brief

Paper examines growth stimulated by **technology spillovers**

Finding: Greater spillover leads to higher leverage

Channel: Asset redeployability

Identification of **causal** effects

Technology spillovers

Unintentional technological benefits

coming from the R&D efforts of other firms

without the costs being shared

Example: Laser

Invented in the 1960s by Hughes Aircraft Company

Originally to amplify visible light

Currently: drives, printers, barcode scanners, medicine, construction, military, manufacturing, …

Comments/suggestions

The *contribution* of the study relative to the existing literature can be clarified further.

Is the main contribution in the finding about leverage or the channel identification?

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Is the main contribution in the finding about leverage or the channel identification?

What can be said about the economic magnitude of the finding?

Comments/suggestions

More can/should be said about how this happens on the ground.

Comments/suggestions

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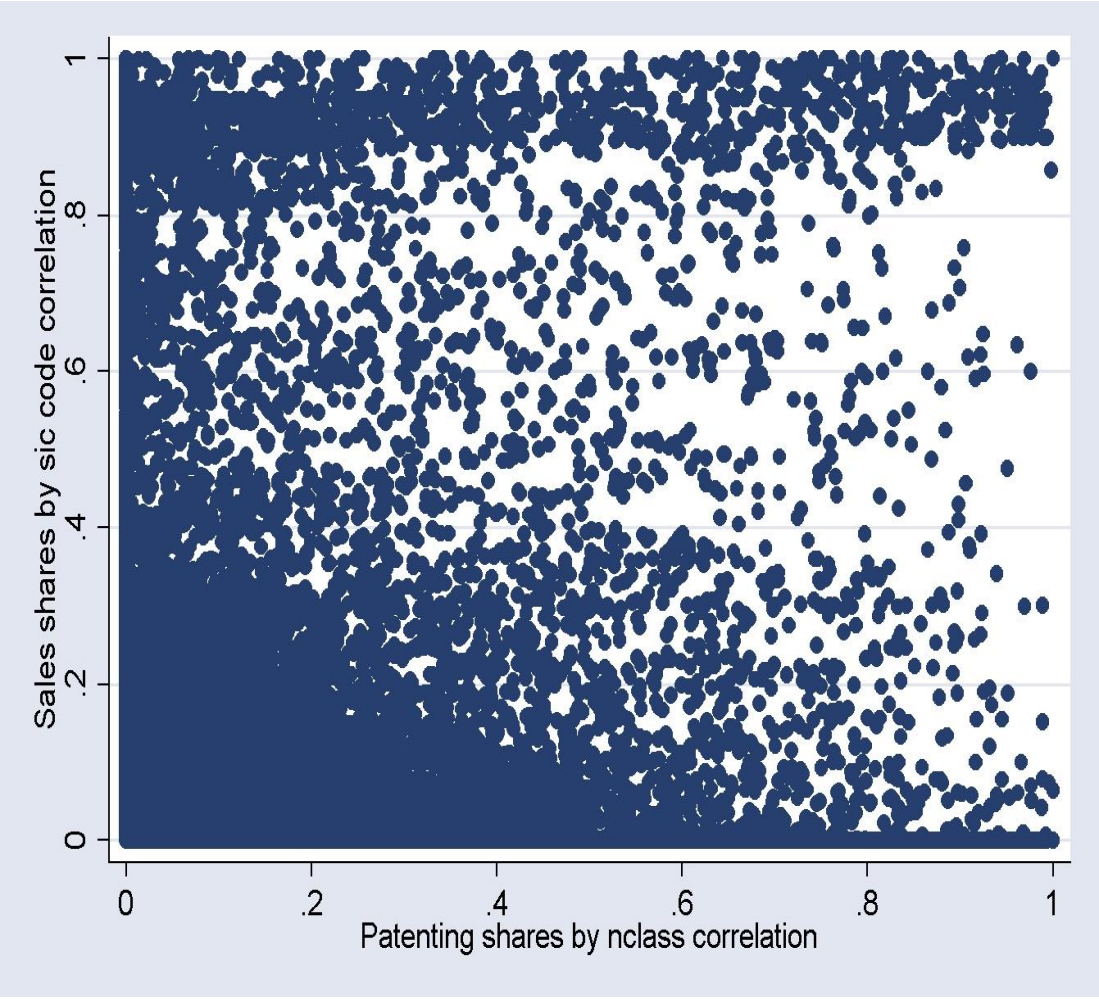
How do banks and other creditors find out about asset redeployability?

How long does it take them to adjust?

Comments/suggestions



Comments/suggestions

IBM, Apple, Motorola and Intel all close in TECH

But a) IBM close to Apple in product market

b) IBM not close to Motorola or Intel in product market

What is the impact of this on your findings?

Read this paper!

1. Well-written, engaging and topical

2. The financial implications of technology spillovers

3. Clever identification of channel and causality