Top management team tenure, competitive repertoires, and firm performance in the 3D printing industry (1988 – 2015)

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What is a competitive repertoire?

Definition: "[A]ctions used by an organization during a given year to attract, serve, and keep customers, composed of concrete market decisions such as price changes, product line or service alterations, and changes in the scope of operations" and "is made up of the entire range of the firm's competitive moves".

In brief: An observable record of all the firm's actions in a given year.

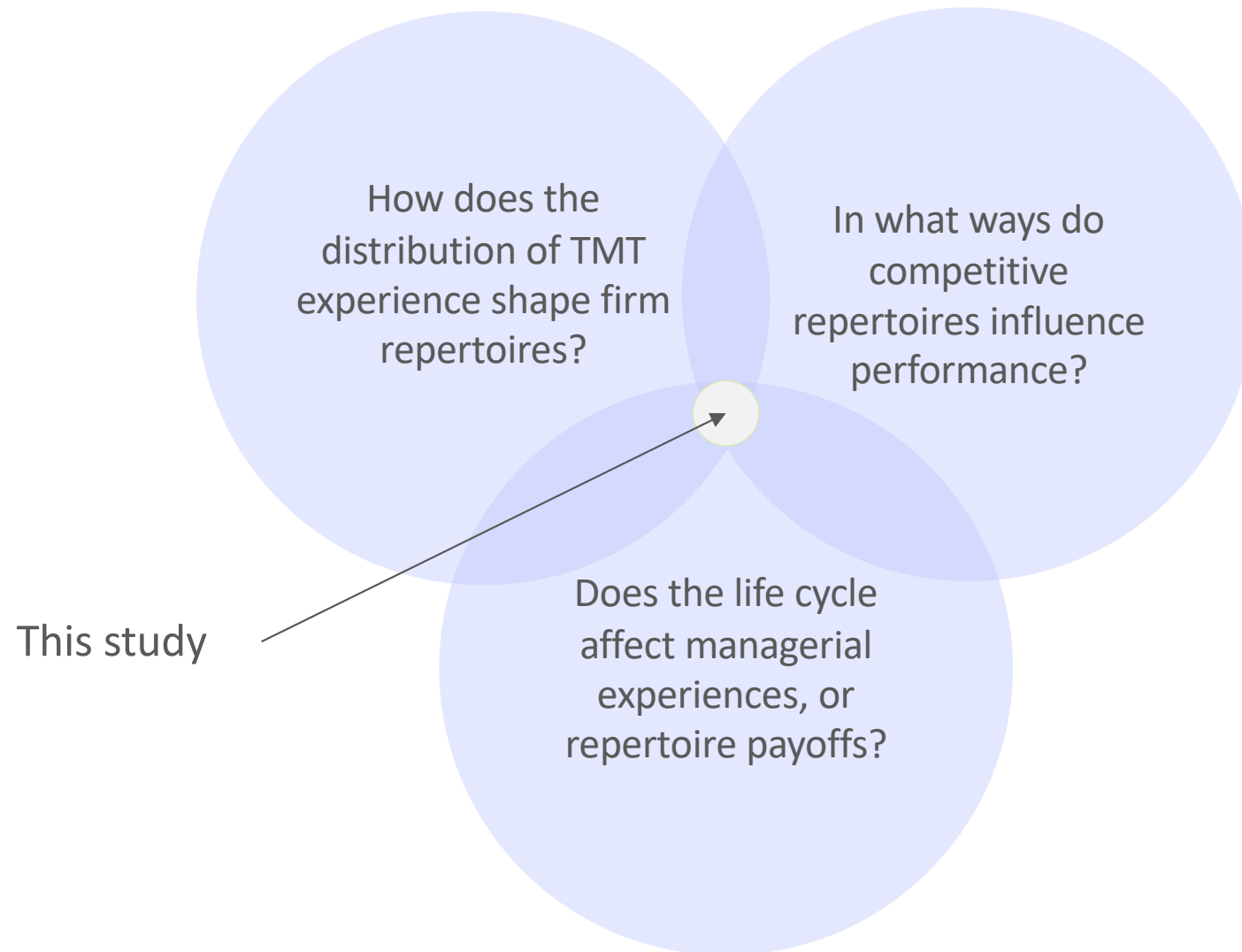Two salient aspects:
Complexity: Variety of actions performed
Consistency: Year-to-year stability of the repertoire

Sources: Miller & Chen, 1996: 420; Chen & Miller, 2012: 145
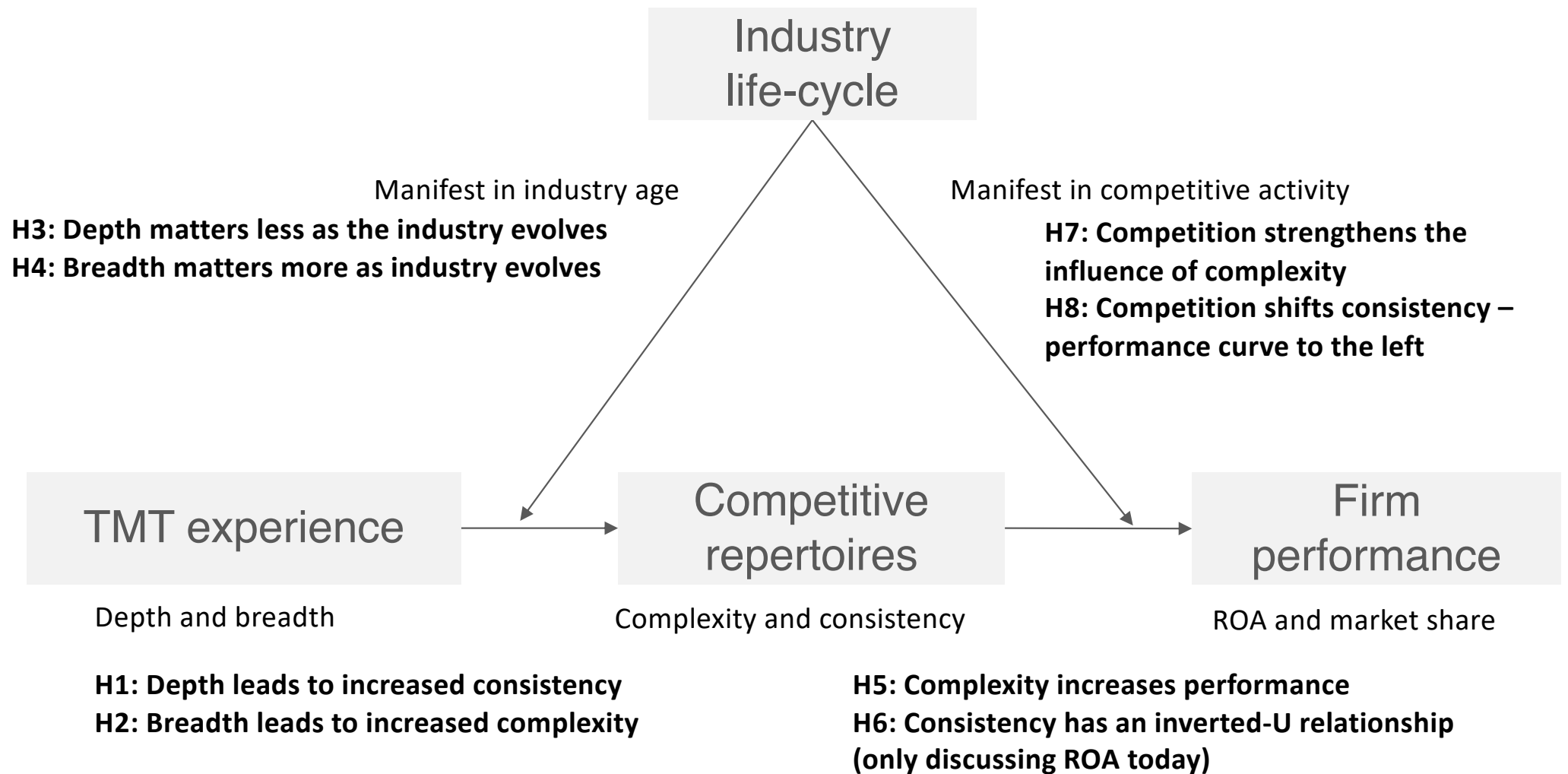
Details

Why are repertoires interesting?

- **Repertoires capture variations in firm performance**
  - Count and variety of actions related to several key outcomes
  - But we don't know whether internal or competitive factors predominate

- **TMTs shape repertoires**
  - How do depth and breadth of industry experience jointly shape repertoire formation?

- **Repertoires change over time**
  - How does the industry life cycle affect how repertoires change?
  - Prior research sheds little light

Sources: Young et al., 1996, Ferrier et al.,1999, Bridoux et al., 2013; Ferrier, 2001, Andrevski et al., 2014, Fern, Cardinal, & O'Neill, 2012; Grimm, Lee & Smith, 2006; Chen & Miller, 2012; 2015.
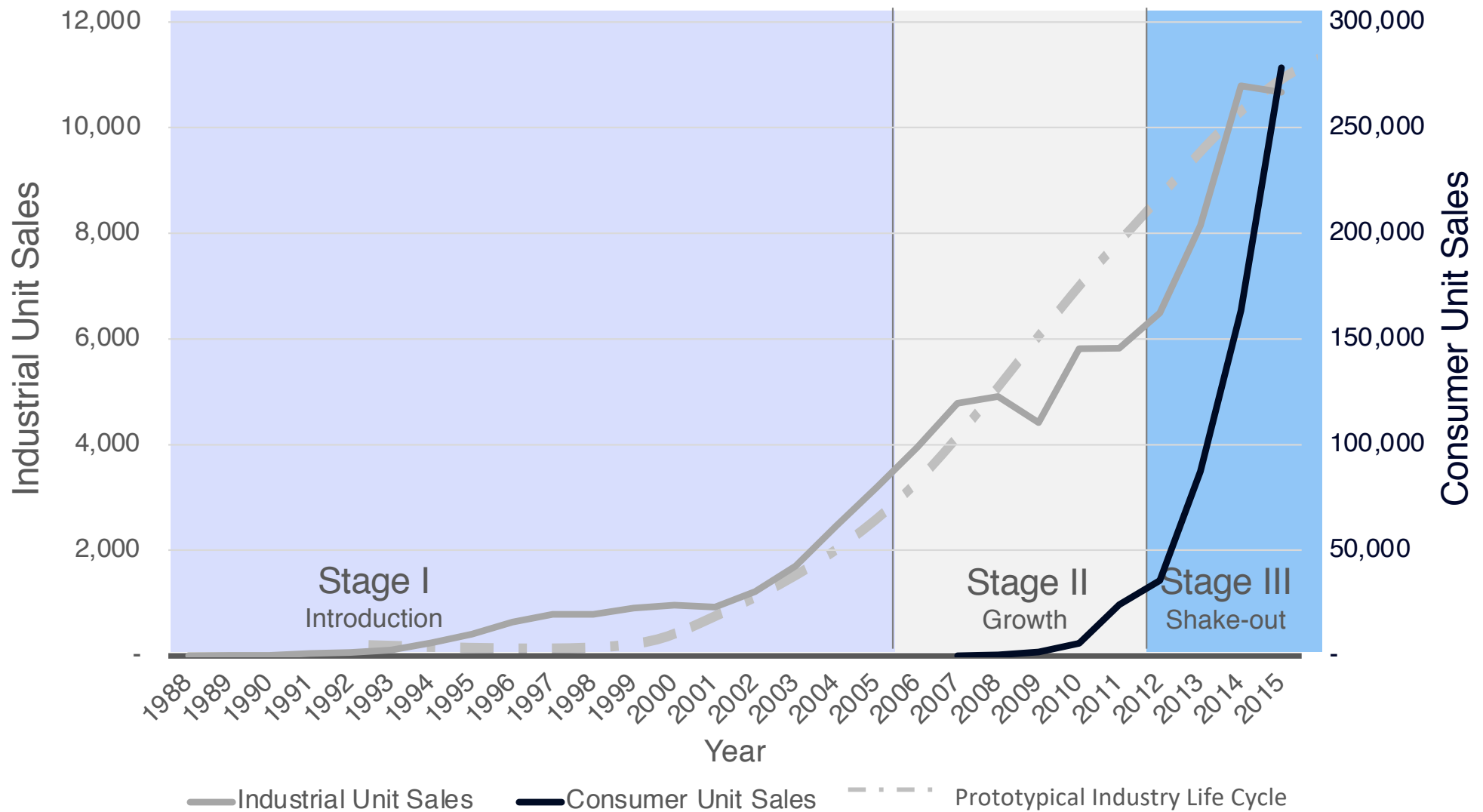
Research questions

How does the distribution of TMT experience shape firm repertoires?

In what ways do competitive repertoires influence performance?

Does the life cycle affect managerial experiences, or repertoire payoffs?

This study

The industry life cycle shapes the causes and consequences of competitive repertoires.

Industry life-cycle

Manifest in industry age

H3: Depth matters less as the industry evolves
H4: Breadth matters more as industry evolves

Manifest in competitive activity

H7: Competition strengthens the influence of complexity
H8: Competition shifts consistency – performance curve to the left

TMT experience

Competitive repertoires

Firm performance

Depth and breadth

H1: Depth leads to increased consistency
H2: Breadth leads to increased complexity

Complexity and consistency

ROA and market share

H5: Complexity increases performance
H6: Consistency has an inverted-U relationship (only discussing ROA today)

The 3D printing industry life cycle

Source: Wohler's Reports 1993 – 2015.
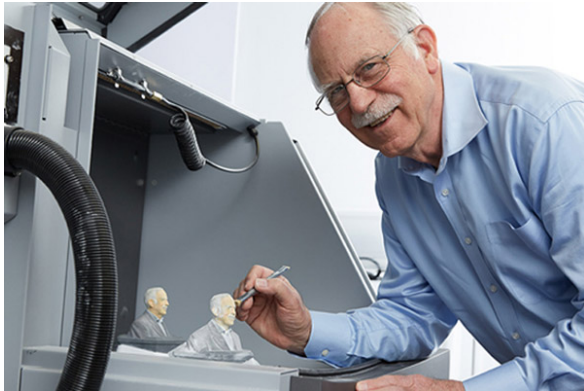
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Appropriateness of context

- Access to competitive repertoire information

- Variability in actions taken by industry participants

- Identification of a near census of a variety of firms

- Range of prior managerial backgrounds

- Multiple stages of life cycle observable

Meet the managers of 3D printing companies

(Data as of 2015)

Kevin McAlea, COO, 3D Systems
Formerly VP Marketing, DTM

Ind. Mgr. Exp. (At entry): 10 years
Ind. Mgr. Exp. (Accrued): 1 year
Outside Experience: 15 years

Charles Hull, Founder & CTO, 3D Systems

Ind. Mgr. Exp. (At entry): 3 years
Ind. Mgr. Exp. (Accrued): 27 years
Outside Experience: 22 years

Hans Sack, President, exOne

Ind. Mgr. Exp. (At entry): 0 years
Ind. Mgr. Exp. (Accrued): 0 years
Outside Experience: 37 years
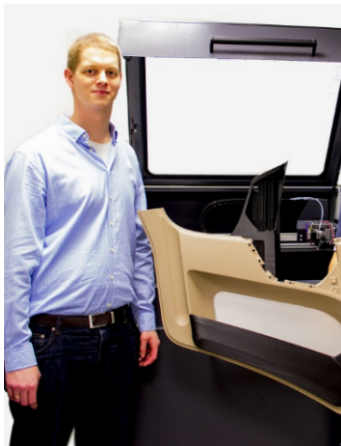
Florian Bautz, CEO, German RepRap

Ind. Mgr. Exp. (At entry): 0 years
Ind. Mgr. Exp. (Accrued): 1 year
Outside Experience: 7 years

Source: 10-Ks, LinkedIn profiles, Bloomberg, ThomsonONE.

Key study measures

Each measure is consolidated to the firm-year or industry-year level of analysis.

Variable	Operationalization	Mean	SD
TMT industry experience	Total number of years TMT has worked in focal industry in management capacity	14.9 yrs	14.3 yrs
TMT outside experience	Average number of years current TMT has worked in any company outside the focal industry in management capacity	21.3 yrs	6.2 yrs
Industry life-cycle stage	Current age of the industry (measured in number of years from 2007, situated within the second lifecycle stage)	-1.4yrs (2005)	6.8 yrs
Repertoire complexity	Entropy index of repertoire components based on a portfolio of five action types (price, product, marketing, capacity, and service related)	.59	.35
Competitive volume	Count of all actions taken by set of firms in sample frame less actions of focal firm	487 acts	602 acts
Repertoire consistency	Magnitude and direction of change in action space (five dimensions)	.56	.34
Performance	Return on assets in the following year	-2%	23%
Repertoire volume	Count of all actions taken by a firm in a one year period	52 acts	116 acts

Notes: TMTs include all reported persons with titles of Executive VP or higher; firms selling at least one unit are included in industry life cycle computations. Industry age is appropriate as an alternative measure of the life cycle since predictions were monotonic.
Sources: Hambrick, Cho, & Chen, 1996; Agarawal et al., 2002; Ferrier & Lyon, 2004; Young et al., 1996; Lamberg et al., 2009
Data from "meantable" based on all available observations.

Details

Analysis methods – consistency and complexity models

- **Main analyses**
  - Pooled GLS panel model
- **Control variables**
  - Team size, average TMT age, age diversity
  - Prior repertoire volume, prior market share
  - Prior industry wide competitive activity, firm age, public status
- **Variance structure**
  - Heteroscedasticity robust standard errors (similar results with Gaussian)

# The relationship between experience depth and repertoire consistency is influenced by the life cycle.
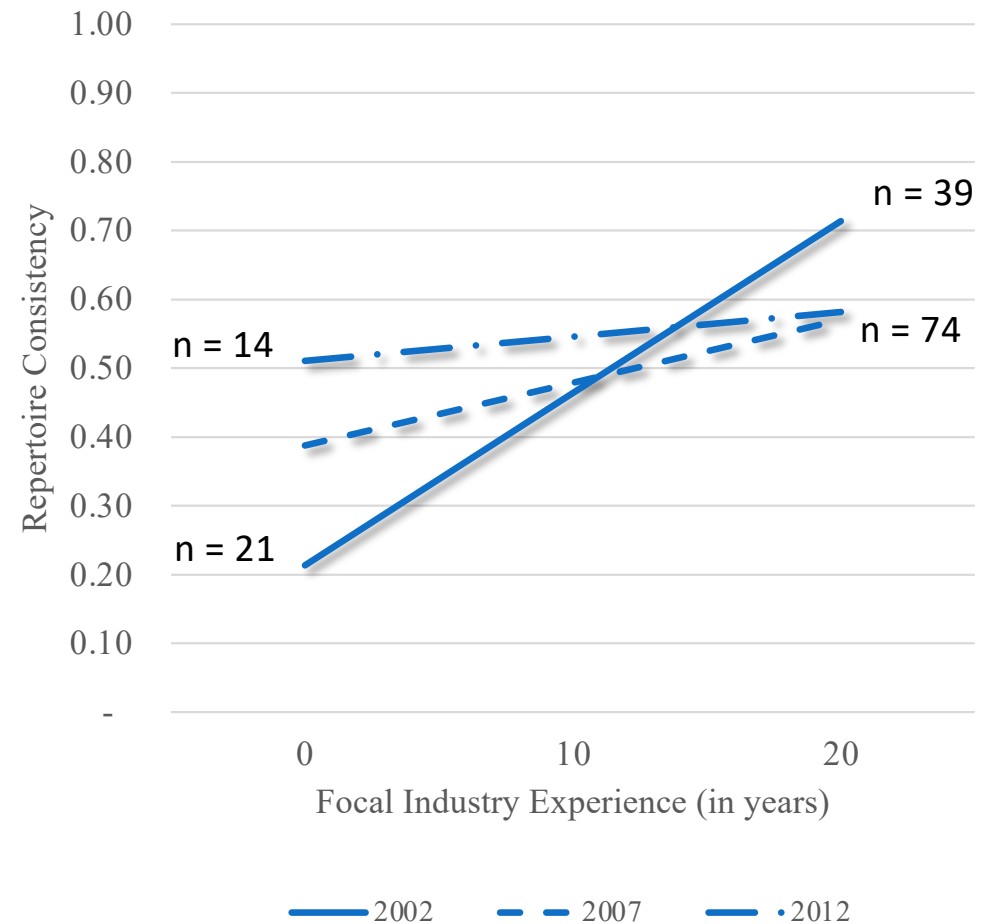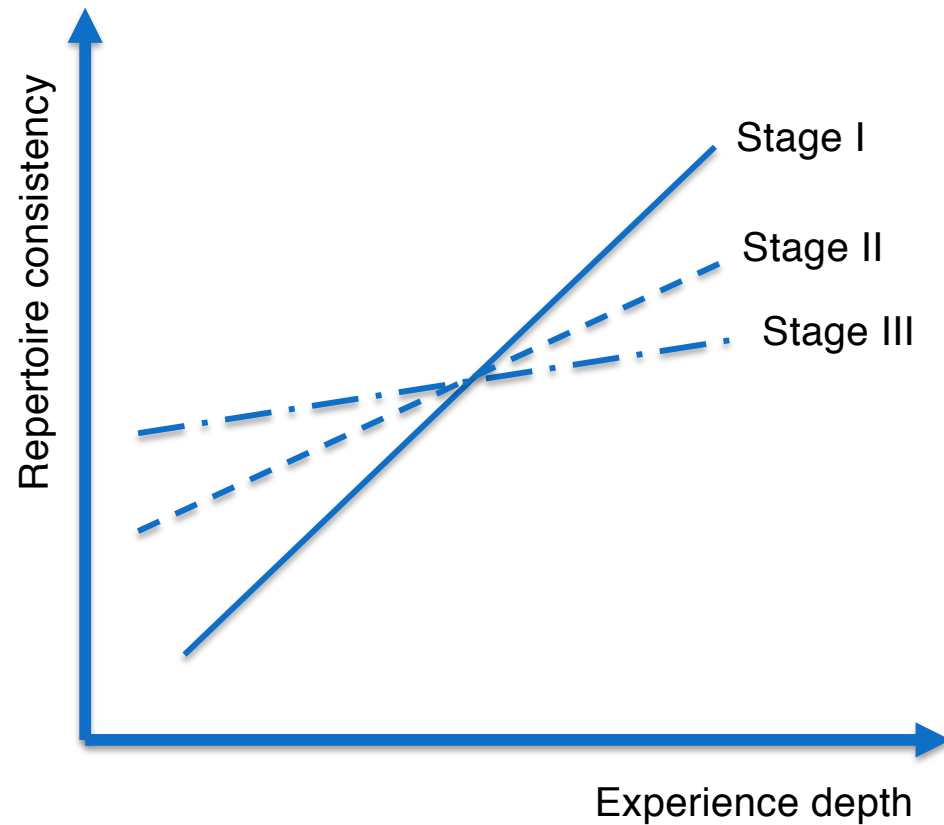
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Model 1c: Adjusted R^2 for full model = .39; ΔR^2 = .10. Plots are based on approx. +/- 1 sd from the mean, and within 10 yrs of 2007, during Phase II. N = 148.

The effect of the life cycle stage on the experience breadth to repertoire complexity relationship was opposite expectations.
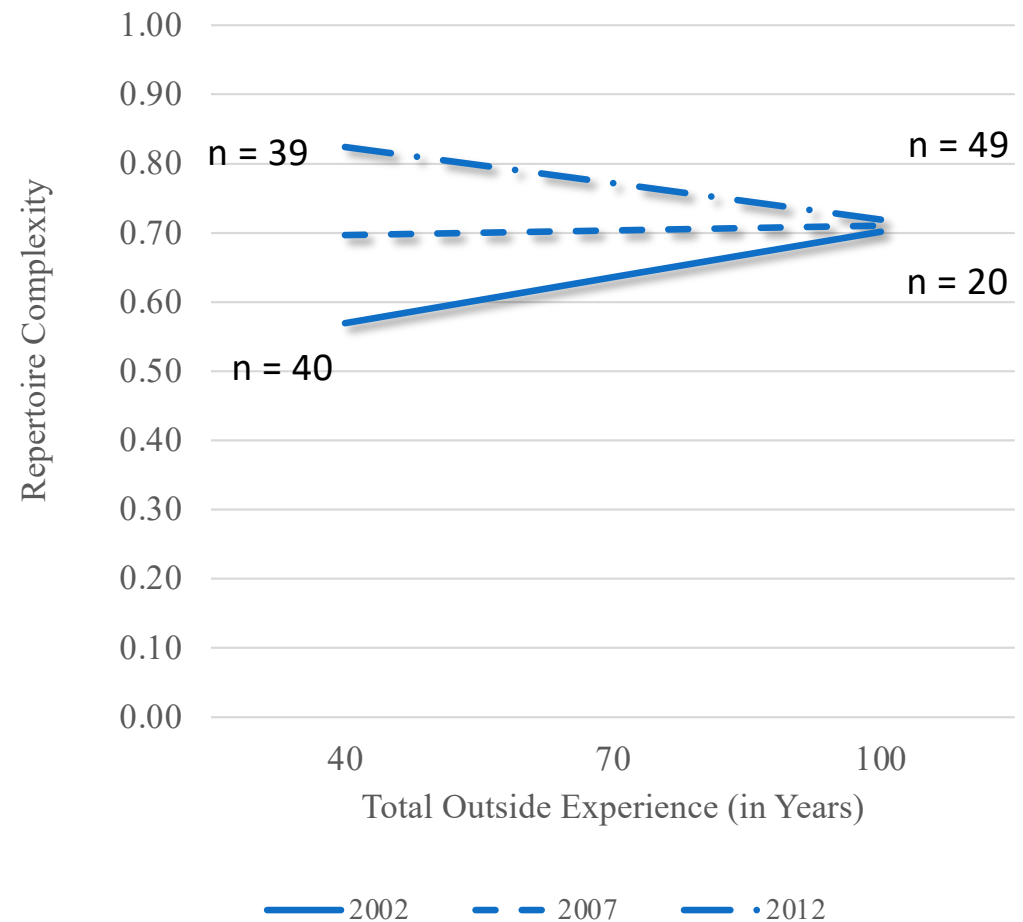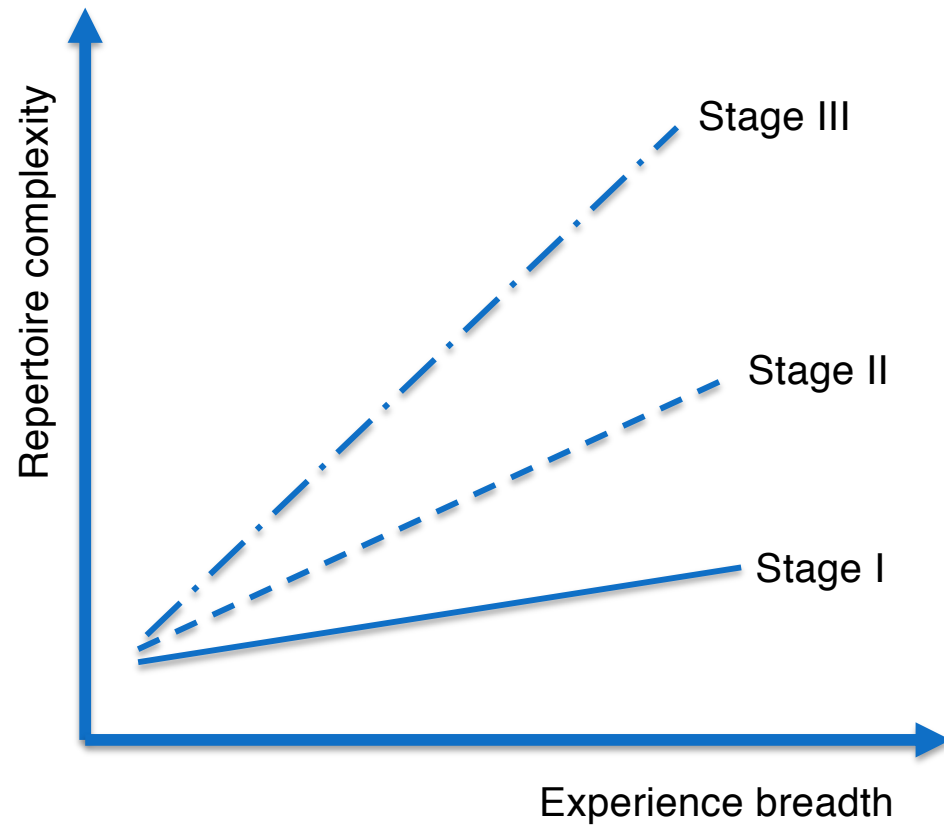
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Model 2b: Adjusted R^2 for full model = .24, ΔR^2 = .08. Plots are based on approx. +/- 1 sd from the mean, and within 10 yrs of 2007, during Phase II. N = 148.

Analysis methods – performance models

- **Main analyses**
  - Pooled GLS panel model
  - Dynamic panel model (ROA: $\hat{\rho}$ = .42***)
  - Fixed effects model (Hausman ROA: χ^2_9 = 61***; F-test ROA: $F_{(9,70)}$=10.1***)
- **Control variables**
  - Industry level: Concentration, growth rate, industry age
  - Firm level time varying: Firm size (log of assets), Number of actions taken
  - Firm level time invariant: Publicly traded, year of market entry
- **Variance structure**
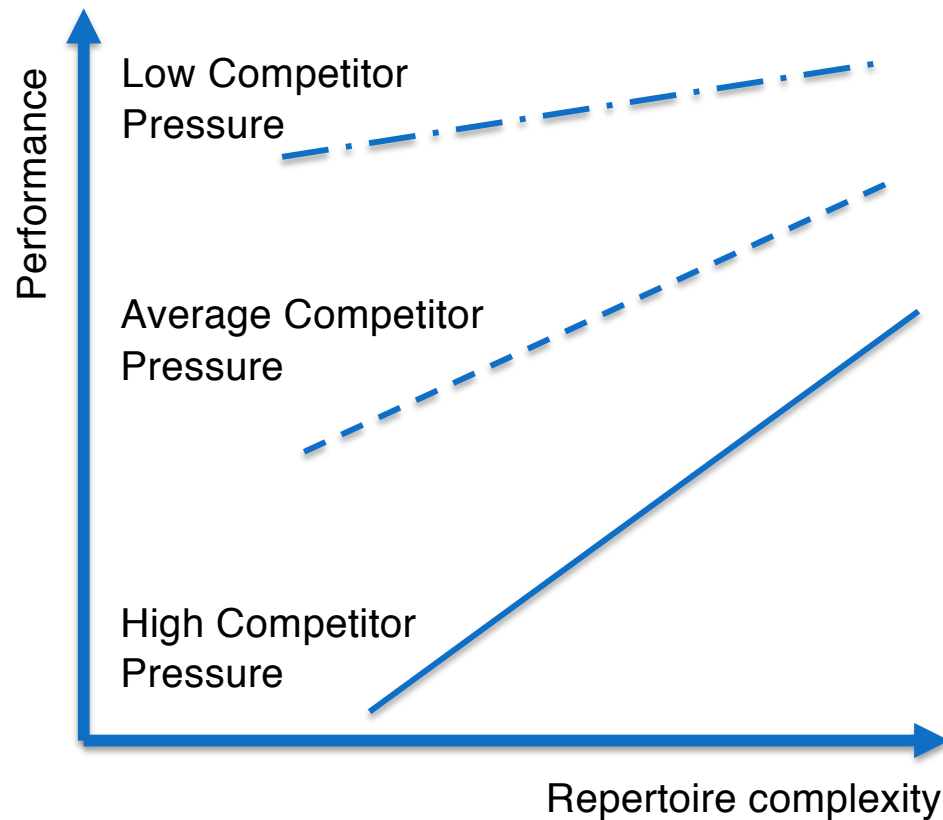 - Heteroscedasticity robust standard errors
- **Alternative specifications / post-hoc analyses**
  - Tobit-2 selection models to account for action reporting biases

The pattern for return on assets is consistent with the hypothesized model, but the results are non-significant.

(Results for the dynamic panel model shown)
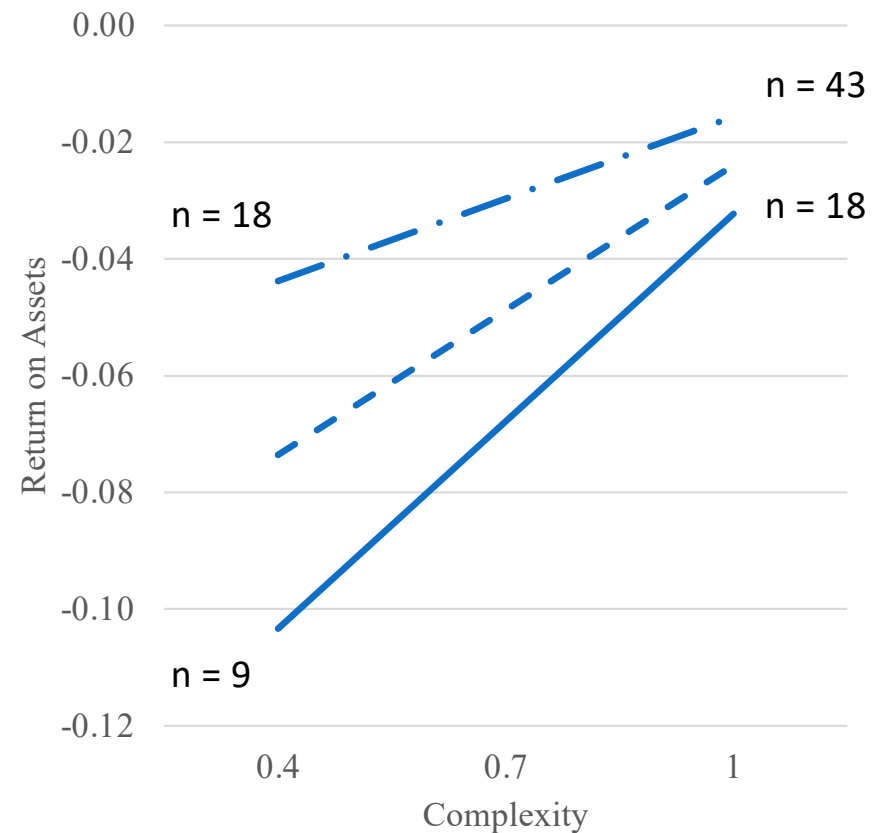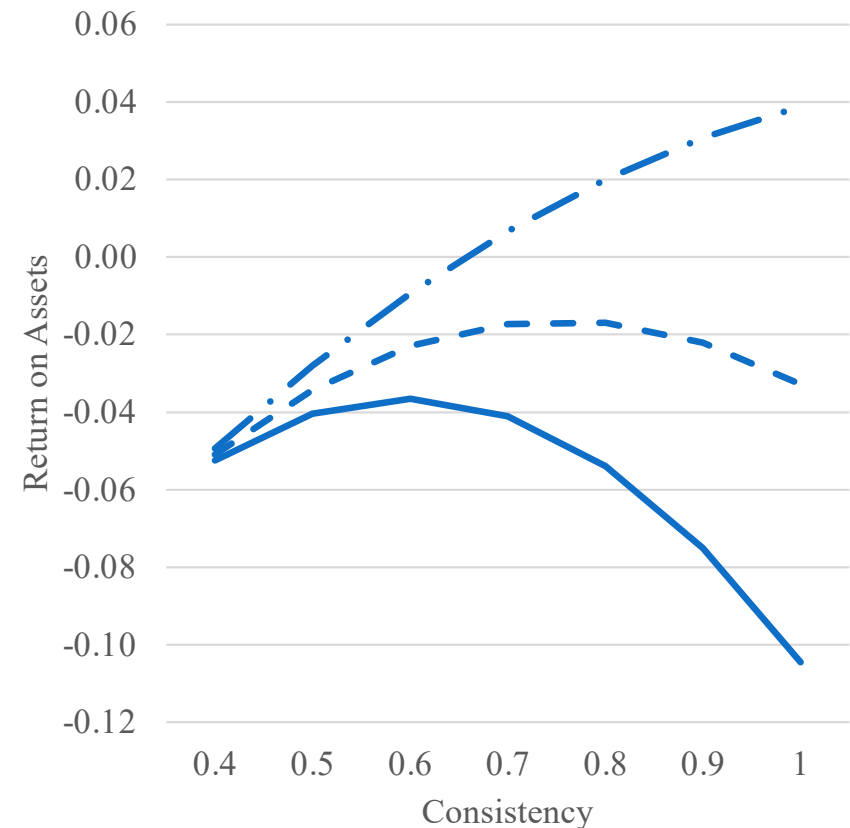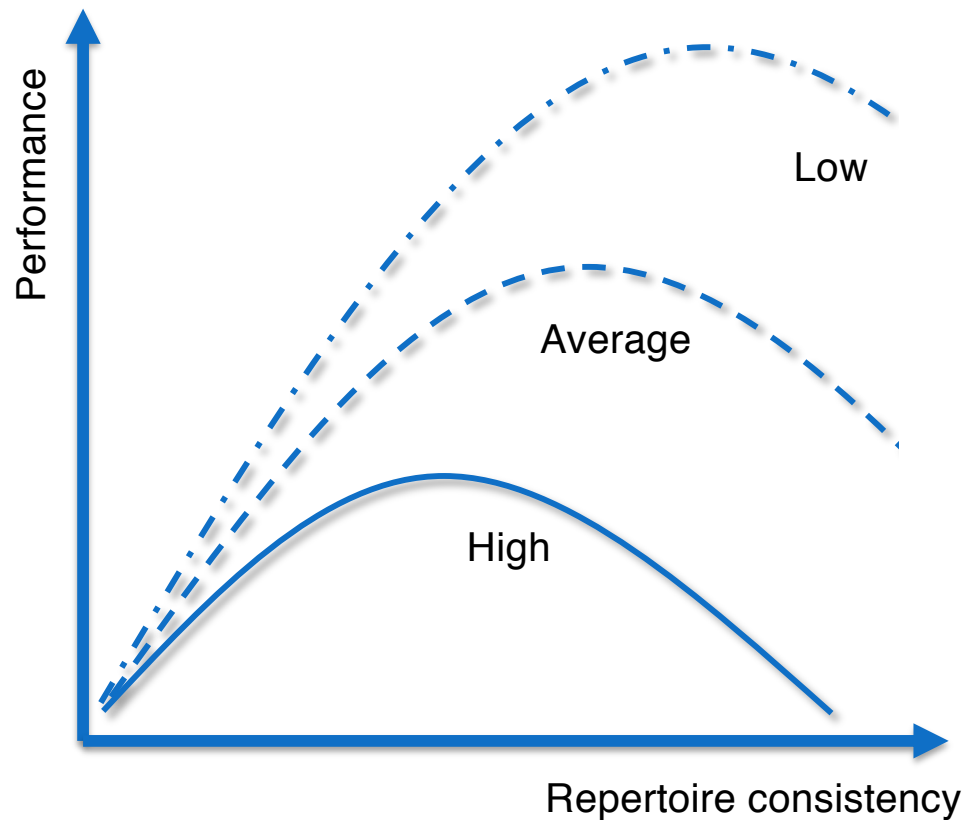

Details

Model 4d: Adjusted R^2 for full model = .40; ΔR^2 = .002. Plots are based on + / - 1 standard deviation for independent and moderating variables. N = 92.

The curvilinear effect is present for ROA but is not significant except at higher than average levels of competition.

(The moderating effect is marginally significant in the pooled model)

Details

Model 5d: Adjusted R^2 for full model = .40; ΔR^2 = .005. Plots are based on approx. +/- 1 SD for independent and moderating variables. N = 87.

However, the curvilinear effect is particularly pronounced when controlling for unobserved firm effects.

The interaction effect is not interpretable in the fixed effects model due to the moderator's construction.
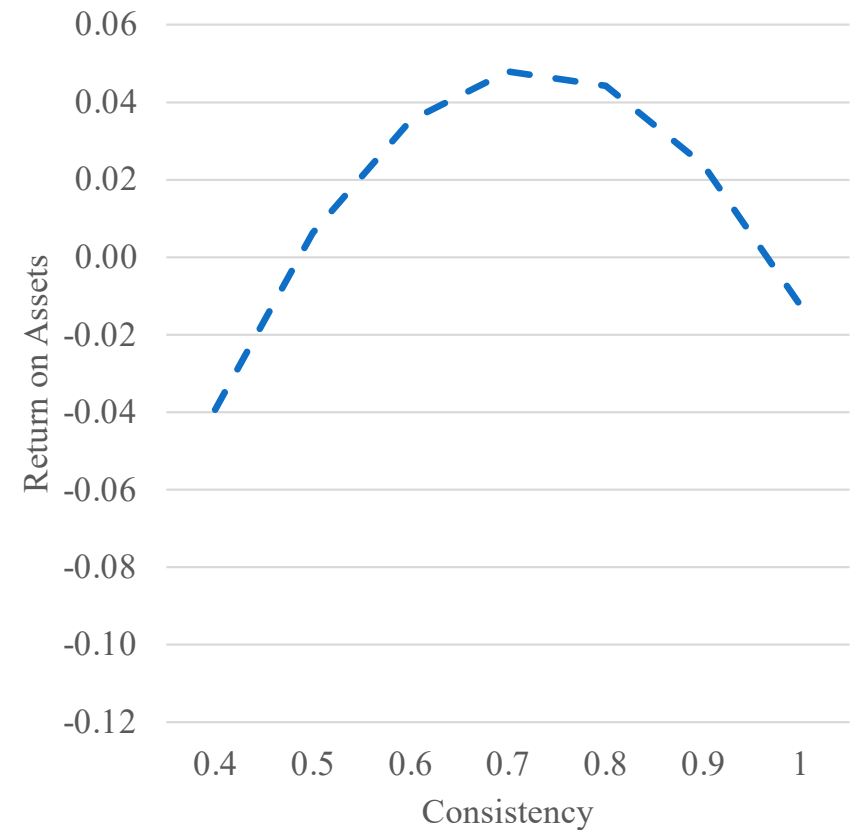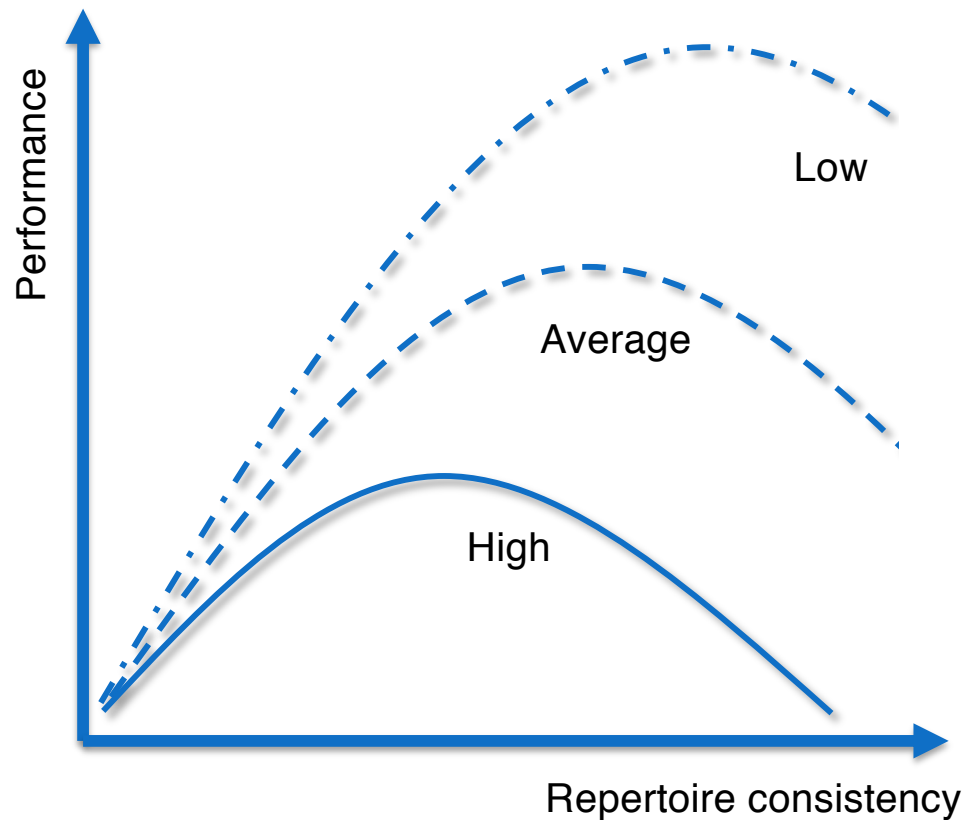
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Model 3f: Adjusted R^2 for full model = .66. Plot based on approx. +/- 1 SD. N = 91.

Intended contributions and limitations

Potential contributions

- Demonstrates that industry life cycle conditions both repertoire formation and repertoire manifestations

- First large scale empirical investigation of consistency

- Creation of dynamic indices of within/outside experience

- Extending competitive dynamics constructs to an early stage industry

Study limitations / next steps

- Understanding the quality versus quantity of actions performed

- Enhanced repertoire measure

- Competition from outside of the focal industry sector

- Alternative definitions of the dominant coalition

- Examine the "double-edged sword" of competition in the early industries