ABS Ownership Diversity and Its Association with Patenting and Venture Capital Success

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Outline

- Strategies for decreasing researcher degrees of freedom and the probability of false discovery include
  - Axiomatic selection of a single ownership diversity measure applied to 127 unique combinations of age, educational level, education specialization, sex, ethnicity, race, and foreign-born status; all 127 results reported
  - Split-sample design where specification testing was limited to the exploratory stage and was applied to all combinations (this analysis)
  - Significant results passed through for *de novo* confirmatory analysis using holdout sample, with multiple comparison correction (to be presented at the Allied Social Science Associations (ASSA) conference in January)
- Protocol is applied to testing how ownership diversity is associated with patenting and venture capital (VC) funding among R&D-performing microbusinesses in the Annual Business Survey (ABS)
- Does diversity matter for radical innovation concentrated in high-tech start-ups?

The Annual Business Survey (ABS)

- Combination of former Survey of Business Owners, innovation module from Business R&D and Innovation Survey, and R&D module for microbusinesses (< 10 employees).
- Division of innovative labor explains radical innovation concentrating in R&D-performing microbusinesses (Baumol 2010).
- In ABS, at least seven principal owner attributes (age, sex, ethnicity, educational level, education specialization, race, and foreign-born status) capture ownership diversity.

Selecting a diversity index axiomatically

Homophily Axiom: All owners belonging to the same group must result in the lowest diversity-measure value.

Fractionalization Axiom: An increase in the number of groups must increase the diversity-measure value.

Team Size Axiom: Larger ownership teams not demonstrating homophily must increase the diversity-measure value relative to smaller ownership teams.

Concentration of Ownership Axiom: Ownership concentrated in one member of the team must reduce the diversity-measure value relative to ownership that is more equally distributed among team members.

Ownership fractionalization (OF) index

Derived from the ethno-linguistic fractionalization index (ELF):

$$ELF = 1 - \sum_{i=1}^{n} p_i^2$$

where *p* is the population share of *n* groups. Invariant to population size so **violates TEAM SIZE AXIOM**.

A minor modification of the ELF **satisfies all four axioms**

$$OF = 1 - \sum_{i=1}^{o} p_i^n$$

where *p* represents the ownership share of the i^{th} owner and *o* is the number of owners.

Split sample design: Restoring transparency to specification and hypothesis testing

1. Use 35% of 2018 ABS (ref. year 2017) (Anderson and Magruder 2017) and full 2021 ABS (ref. year 2020) to discover potentially useful models
2. Document the potentially useful models in a public registered report (this analysis as Center for Economic Studies WP)
3. Use 65% of the 2018 ABS (Anderson and Magruder 2017) and the full 2022 ABS for hypothesis testing and generating valid test statistics
4. Apply false discovery rate (FDR) and family-wise error rate (FWER) correction for assessing significance across multiple comparisons (to be presented at 2025 ASSA)
5. Publish full set of hypothesis tests

Specification and passthrough criteria for exploratory results

- Estimate Pr(*Patent Pending, Patent Owned, or VC Funding)* = *f(OF, NAICS 54, Family Business, Firm Age)* for R&D. performing microbusinesses using R&D and innovation sample weights.
- Estimate 127 logistic regressions using 35% of the 2018 ABS sample for patent equations, and the full 2021 ABS for VC equations.
- Passed through for confirmation if *OF* coefficient estimate significant at 0.05 level.

Intermediate innovation outcomes as harder test of diversity-innovation association

- Strong association between diversity measures and “self-reported innovation” in earlier 2018 ABS analysis (Wojan and Lambert, under review).
- Affective conflict explanation: Incompatible attitudes or opinions on value of an innovation are launched in market to test. Possibly higher rate of unsuccessful innovations.
- Cognitive conflict explanation: Different attitudes or experiences increase combination of seemingly incongruent ideas, leading to better, more novel innovation.
- Diversity associated with increased probability of patenting/VC success would support latter explanation as intermediaries assess nonobviousness or potential for market/buyout success.

Descriptive statistics

	2018 ABS 35% Sample R&D-Performing Microbusinesses		2021 ABS R&D-Performing Microbusinesses	
Variable	Mean	Range	Mean	Range
Age Diversity (A)	0.2675	0.9837	0.2729	0.9837
Educational Level Diversity (E)	0.2939	0.9844	0.2929	0.9844
Sex Diversity (G)	0.2898	0.75	0.2485	0.75
Ethnic Diversity (H)	0.0297	**0.75**	0.03038	***0.75***
Education Specialization Diversity (M)	0.1886	***0.9844***	0.3102	***0.9844***
Race Diversity (R)	0.05444	0.9375	0.06994	0.9375
Foreign-born Status Diversity (U)	0.08683	0.75	0.1129	0.75
Composite Diversity (AEGHMRU)	0.1729	***0.83***	0.2119	***0.83***
NAICS 54 (0/1)	0.322		0.4926	
Family/Jointly Owned (0/1)	0.5486		0.3458	
Firm Age	8.866		10.38	
Patent Owned (0/1)	***0.09009***			
Patent Pending (0/1)	***0.1041***			
Venture/Angel Capital (0/1)			***0.06994***	

Sources: 2018 ABS 35% exploratory sample and full 2021 ABS.

Selected patent pending exploratory estimates

Diversity Measure	Diversity Estimate	Diversity Standard Error	Diversity Odds Ratio	NAICS 54	Family Business	Firm Age
AEGHMRU	3.731	0.2087	***41.7***	0.784	-0.7086	-0.0564
AEHMRU	3.707	0.1891	***40.73***	0.7414	-0.5471	-0.0546
EHMRU	3.678	0.1965	***39.58***	0.7388	-0.5653	-0.0536
AHMRU	3.666	0.1922	***39.08***	0.7283	-0.5264	-0.055
AEHRU	3.663	0.1948	***38.98***	0.7989	-0.5459	-0.0565
GU	1.006	0.171	***2.734***	0.9534	-0.7771	-0.0613
H	0.6822	0.206	***1.978***	0.9583	-0.6752	-0.0619
GH	-0.2673	0.2233	***0.765***	0.9622	-0.6398	-0.0624
G	-0.4249	0.1304	***0.654***	0.9516	-0.5656	-0.0622

Notes: A = age, E = educational level, G = sex, H = ethnicity, M = education specialization, R = race, U = foreign-born status. Shaded estimates not passed through. Total of 126 of 127 equations passed through for confirmation.

Source: 2018 ABS 35% exploratory sample.

Selected patent owned exploratory estimates

Diversity Measure	Diversity Estimate	Diversity Standard Error	Diversity Odds Ratio	NAICS 54	Family Business	Firm Age
EHMRU	3.288	0.2073	***26.79***	0.6391	-0.6149	0.0294
AEHMRU	3.241	0.1993	***25.57***	0.6402	-0.6005	0.0285
EHMR	3.216	0.2015	***24.92***	0.6434	-0.6398	0.0284
AEHMR	3.116	0.1917	***22.56***	0.6483	-0.6184	0.0275
AHMRU	3.094	0.2034	***22.07***	0.6368	-0.5841	0.0274
GU	-0.00089	0.1905	***0.999***	0.8604	-0.6959	0.0189
GR	-0.1061	0.2099	***0.899***	0.8618	-0.685	0.0188
GHR	-0.1268	0.2826	***0.881***	0.862	-0.687	0.0188
G	-1.137	0.1436	***0.321***	0.8367	-0.3989	0.0199
GH	-1.719	0.2529	***0.179***	0.8482	-0.4684	0.019

Notes: A = age, E = educational level, G = sex, H = ethnicity, M = education specialization, R = race, U = foreign-born status. Shaded estimates not passed through. Total of 122 out 127 equations passed through.

Source: 2018 ABS 35% exploratory sample.

Selected venture/angel capital exploratory estimates

Diversity Measure	Diversity Estimate	Diversity Standard Error	Diversity Odds Ratio	NAICS 54	Family Business	Firm Age
AHR	2.305	0.1765	***10.02***	0.191	-0.5474	-0.1343
AHRU	2.116	0.174	***8.301***	0.2053	-0.5481	-0.135
AH	2.014	0.1504	***7.493***	0.2082	-0.6014	-0.1367
AHU	2.012	0.1603	***7.482***	0.2172	-0.5775	-0.1364
AGHRU	1.877	0.1987	***6.536***	0.2056	-0.6659	-0.1376
EGM	-0.2468	0.143	***0.781***	0.2355	-0.6243	-0.1396
GMR	-0.287	0.1546	***0.751***	0.2381	-0.6316	-0.1398
GHM	-0.3109	0.1646	***0.733***	0.2359	-0.6249	-0.1395
GM	-0.4759	0.1137	***0.621***	0.2285	-0.6001	-0.139
G	-0.4937	0.1206	***0.61***	0.2547	-0.5222	-0.1382

Notes: A = age, E = educational level, G = sex, H = ethnicity, M = education specialization, R = race, U = foreign-born status. Shaded estimates not passed through. Total of 107 of 127 equations passed through for confirmation.

Source: 2021 ABS.

Regression decomposition of log odds by diversity dimension

	Patent Pending		Patent Owned		Venture/Angel Capital Funding	
Diversity Dimension	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
Age	0.5356	0.0552	0.4875	0.06482	***0.7126***	0.03437
Educational Level	0.4625	0.0552	0.6601	0.06482	0.04	0.03437
Sex	-0.1401	0.0552	***-0.5885***	0.06482	***-0.3389***	0.03437
Ethnicity	0.5902	0.0552	0.3391	0.06482	0.5044	0.03437
Education Specialization	0.4933	0.0552	***0.8541***	0.06482	***-0.4923***	0.03437
Race	***0.8539***	0.0552	0.6315	0.06482	0.2861	0.03437
Foreign-born Status	0.5451	0.0552	0.4404	0.06482	0.2729	0.03437
Intercept	0.9116	0.08152	0.556	0.09572	0.4031	0.05076

Notes: All coefficient estimates significant at <0.0001 level except for Sex in Patent Pending equation (0.05 level) and Educational Level in Venture Capital equation (not significant).

Sources: 2018 ABS 35% exploratory sample, and full 2021 ABS.

Does diversity matter for radical innovation concentrated in high-tech start-ups?

- Yes, it appears to matter a lot.
  - Maximally diverse ownership teams up to 20 times more likely to own a patent and 8 times more likely to get VC funding than homophilic teams.
  - Education specialization strongly associated with increased likelihood of patent ownership but decreased likelihood of VC funding.
  - Age diversity is most strongly associated with increased likelihood of VC funding, suggesting that the combination of experience and the latest training in cutting-edge skills is valued by investors.
- Sex diversity is negatively associated with intermediate innovation outcomes, which is consistent with lower patenting and VC funding rates of female-owned businesses (Cook and Kongcharoen 2010; Gompers et al. 2022).
- Caveat: Correlation is not causation. Could ownership diversity just be a reliable indicator of places that are diverse, fast-growing, and dynamic?

Thank you!

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