

Innovation Pipeline Progression and Venture Outcomes from Concept to Commercialization among Women Co-Founded Startups in Tamil Nadu under the Startup India Seed Fund Scheme

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Abstract: This paper examines the innovation-to-impact pathway among 175 women co-founded startups funded under the Startup India Seed Fund Scheme (SISFS) in Tamil Nadu, using startup-level secondary data. The study investigates how startups progress through five innovation milestones and how cumulative milestone completion measured as pipeline depth on an ordinal scale of zero to four, which relates to employment generation, intellectual property filing, and external funding mobilisation. Kendall's tau-b, Somers' D, Goodman-Kruskal gamma, the Kruskal-Wallis H test, and Cramér's V are applied to match the ordinal and binary distributional characteristics of the data. The pipeline exhibits steep attrition between prototype development and field trials, with inter-stage dropout rates of 26.8% and 30.0% at those two transitions. Pipeline depth is a strong predictor of market launch ($\tau = 0.574$, $p < .001$), a moderate predictor of employment ($\tau = 0.299$, $p < .001$; Somers' D = 0.324), and a weak-to-moderate predictor of external funding ($\tau = 0.169$, $p = .013$; $\gamma = 0.322$), but is unrelated to IP filing ($\tau = -0.048$, $p = .491$). Industry group significantly predicts pipeline depth (Kruskal-Wallis H = 20.297, $df = 7$, $p = .005$): Agriculture/Food achieves the highest mean depth and market launch rate (50.0%), while Healthcare/Biotechnology, at 25.1% of the sample, shows the lowest market launch rate (24.3%) and the highest stall concentration. Women co-founded startups are disproportionately concentrated in care-adjacent industries at 42.3% of the sample, yet this concentration produces no statistically significant aggregate outcome penalty. The paper argues that pipeline depth, not sectoral identity or incubation structure, is the primary determinant of women-led innovation outcomes within this scheme.

Key Words: Innovation pipeline, Women entrepreneurship, Technology Commercialisation, Startup India Seed Fund Scheme, Pipeline depth, Care-adjacent industries, Ordinal association, Tamil Nadu.

1. INTRODUCTION

How early-stage ventures advance from validated concepts to commercial products is among the most consequential questions in innovation policy. For women co-founded startups operating within government-supported incubation frameworks in India, this question carries added structural significance, as women entrepreneurs face sector-specific regulatory environments, uneven access to development resources, and documented patterns of sectoral concentration that may shape not only where they start ventures but how far those ventures advance.

The Startup India Seed Fund Scheme, launched in 2021, addresses the pre-revenue financing gap by channelling seed capital through incubation centres conditional on milestone completion. Tamil Nadu hosts 175 women co-founded SISFS-registered startups spanning 24 districts, 67 incubators, and 36 distinct industries. The present study uses this population to answer three questions: at which points in the five-stage innovation pipeline does attrition concentrate most severely; which industry, organisational, and incubation characteristics predict how deeply a startup advances through that pipeline; and how pipeline depth relates to employment creation, intellectual property generation, and

external funding mobilisation. A gender structural dimension underlies all three questions: the dataset provides an opportunity to examine whether the disproportionate representation of women co-founded startups in care-adjacent industries is associated with observable outcome differences not as a study of individual attitudes, but as an analysis of patterns observable in aggregate secondary data.

The paper is structured as follows: the Literature Review situates the study within Innovation Ecosystem Theory, Technology Commercialisation Literature, and Entrepreneurial Development Theory; the Research Gap identifies what prior scholarship has not addressed; the Objectives and Methodology sections describe the analytical strategy; and the Results and Discussion section presents and interprets the empirical findings, followed by Conclusion, Policy Implications, and Limitations.

2. LITERATURE REVIEW

Innovation Ecosystem Theory

Innovation Ecosystem Theory, developed from Moore's (1993) biological analogy and extended to venture contexts by Adner (2006) and Autio et al. (2014), frames the conditions for startup progression as a set of interdependent actors whose interaction rather than any single element determines commercialisation outcomes. Applied to government-mediated incubation, the theory predicts that institutional scaffolding such as SISFS can partially substitute for organic ecosystem density by providing milestone-linked resources that support sequential stage completion (Acs et al., 2014). Nair et al. (2022) demonstrated in the Indian context that ecosystem support mechanisms operate unevenly across startup populations, with industry type and organisational context shaping how effectively incubation translates into venture advancement.

Technology Commercialisation Literature

The technology commercialisation literature consistently identifies the gap between prototype validation and commercial market entry as the most attrition-intensive segment of the innovation pathway. Auerswald and Branscomb (2003) termed this the valley of death, characterised by simultaneous demands for product finalisation, regulatory navigation, manufacturing scale-up, and market development that typically exceed the resource base of seed-stage ventures. Markham (2002) showed empirically that completion rates decline most steeply at the product development and field trial transitions. Teece's (1986) framework further predicts that intellectual property generation should accompany pipeline progression as a mechanism for appropriating returns from innovation, a prediction this dataset allows to be tested directly.

Entrepreneurial Development Theory and Gender

Entrepreneurial Development Theory, synthesised by Bruton et al. (2010), treats venture progression as context-dependent: industry regulatory environment, product tangibility, and market channel access shape the rate and pattern of milestone completion in ways that are specific to each sector. Feminist entrepreneurship scholarship adds a structural layer to this framework. Brush et al. (2019) and Marlow and McAdam (2013) documented a systematic pattern of sectoral channelling in which women entrepreneurs are disproportionately represented in industries associated with care, service provision, and social purpose. This channelling has been theorised to produce outcome disadvantages through investor undervaluation, reduced access to technical mentorship, and the devaluation of care-sector knowledge relative to technology-sector knowledge (Marini & Hamilton, 1996). Whether these predicted disadvantages appear in the present dataset is an empirical question the analysis addresses.

3. RESEARCH GAP

Existing studies of Indian government startup schemes have examined aggregate success rates and geographic distribution of venture activity (Dutta, 2021; Nair et al., 2022) without conducting stage-resolved pipeline analysis that locates attrition precisely within the milestone sequence. The question of which stage transition produces the most attrition in the SISFS pipeline has not been answered empirically. The relationship between pipeline depth and concurrent venture outcomes which are examined using ordinal association methods matched to the non-normal and binary nature of startup-level secondary data that has similarly not been addressed for this population. Within the women entrepreneurship literature, the structural consequences of care-sector concentration for pipeline progression and employment outcomes have not been examined quantitatively for Indian women co-founded startups. This study addresses all three gaps.

4. RESEARCH OBJECTIVES

This study pursues four objectives: first, to construct a stage-wise completion profile identifying where inter-stage attrition is most concentrated; second, to examine whether industry group, organisational form, and incubator sector alignment predict pipeline depth; third, to assess the associations between pipeline depth and employment creation, IP generation, and external funding using ordinal methods appropriate to the variable distributions; and fourth, to examine whether women co-founders' structural concentration in care-adjacent industries is associated with observable differences in pipeline progression and venture impact outcomes.

5. METHODOLOGY

The dataset contains 175 startup records from the SISFS beneficiary database, covering variables including company type, industry, sector, associated incubator, five stage-wise innovation milestone statuses, external funding status (binary), number of employees, and IP registration requests filed. Geography is treated as background context only, as a prior study examined district-level spatial patterns using this dataset.

The five stage variables were originally coded with up to five values. Completed and Completed Pre-SISFS were merged to a binary completion indicator of one; In-Progress and Not Started were coded zero; Not Applicable and Information Not Shared were excluded from stage-specific denominators, yielding valid n values of 145 to 149 per stage. Pipeline depth is the ordinal sum of binary completions across the four pre-launch stages, ranging from zero to four. External funding is binary. IP registration was treated as a count for ordinal association analysis and as a binary indicator (any filing versus none) for cross-tabulation. Employment is continuous but heavily right-skewed, with a mean of 5.78, a median of 3.0, and a Gini coefficient of 0.615. Industry categories were consolidated from 36 raw labels into eight analytical groups.

Because pipeline depth is ordinal, employment is non-normal, and most outcomes are binary, parametric methods were not appropriate. Kendall's tau-b is the primary association measure for ordinal-continuous and ordinal-binary pairs, chosen over Spearman's rho because it handles ties in variables with few distinct values more accurately. Somers' D is reported alongside tau-b when a directional hypothesis is stated, treating pipeline depth as independent. Goodman-Kruskal gamma is reported for binary outcome associations, as it excludes tied pairs and provides a cleaner directional signal. The Kruskal-Wallis H test compares pipeline depth across nominal categorical groups. Cramér's V is the effect size measure for chi-square tests of categorical association. A sector alignment indicator was constructed by matching incubator name keywords to industry keywords, yielding a binary aligned/non-aligned classification. Care-adjacent industries comprising Healthcare/Biotechnology, Agriculture/Food, and Social/Education were identified based on their alignment with socially assigned care roles, following Brush et al. (2019).

6. RESULTS AND DISCUSSION

Stage Completion Profile and the Valley of Death

Table 1 presents the stage-wise completion profile. All rates are calculated on valid n, excluding withheld and inapplicable records.

Table 1. Innovation pipeline stage completion and inter-stage attrition

Stage	Completion %	Completed n	Valid n	Prior-stage attrition %
Proof of Concept	91.2	134	147	—
Prototype Development	82.6	123	149	8.2
Product Development	60.8	90	148	26.8
Field Trials	43.2	63	146	30.0
Market Launch	35.9	52	145	17.5

Note. Valid n excludes records coded as Information Not Shared or Not Applicable. Prior-stage attrition is the percentage of startups completing the preceding stage that did not complete the current stage.

The pipeline exhibits a pronounced funnel structure. Proof-of-concept completion is near-universal at 91.2%, consistent with the SISFS entry requirement that beneficiaries demonstrate at minimum a conceptual proof before

receiving incubation support. The two steepest inter-stage attrition transitions are the shift from Prototype Development to Product Development at 26.8% and from Product Development to Field Trials at 30.0%. These two transitions account for the loss of 60 startups that had successfully validated a concept and built a prototype but could not progress to completed product development or field testing. This pattern corresponds precisely to the technology commercialisation valley of death identified by Auerswald and Branscomb (2003) and empirically located at those exact transitions by Markham (2002). The lower attrition at the Field Trials to Market Launch transition at 17.5% suggests a survivor effect: startups reaching field completion have accumulated sufficient technical and financial capacity to proceed to commercial launch.

Pipeline Depth: Distribution and Outcome Associations

Table 2 shows the distribution of pipeline depth scores and associated outcome rates. Table 3 presents the full inferential results.

Table 2. Pipeline depth distribution and venture outcome rates by depth level

Depth	n	%	Market launch %	Mean employment	IP filing rate %
0	37	21.1	0.0	1.9	8.7
1	14	8.0	0.0	4.6	57.1
2	34	19.4	6.2	2.9	32.4
3	32	18.3	25.0	5.1	6.2
4	58	33.1	72.4	9.7	20.7

Note. Market launch rate, mean employment, and IP filing rate are calculated among startups at each pipeline depth level with valid data for the respective outcome variable.

Table 3. Summary of inferential statistics

Test / measure	Statistic	df	p	Direction / interpretation
Kendall tau-b: pipeline depth ↔ market launch	$\tau = 0.574$	—	< .001	Strong positive
Kendall tau-b: pipeline depth ↔ employment	$\tau = 0.299$	—	.000	Moderate positive
Somers' D: pipeline depth → employment	$D = 0.324$	—	—	Directional confirmed
Kendall tau-b: pipeline depth ↔ ext. funding	$\tau = 0.169$	—	.013	Weak–moderate positive
Goodman–Kruskal gamma: depth ↔ funding	$\gamma = 0.322$	—	—	Moderate ordinal signal
Kendall tau-b: pipeline depth ↔ IP count	$\tau = -0.048$	—	.491	No association
Kruskal–Wallis: pipeline depth by industry	$H = 20.297$	df = 7	.005	Significant variation
Kruskal–Wallis: pipeline depth by company type	$H = 2.165$	df = 2	.339	Not significant
Cramér's V: industry group ↔ field trial completion	$V = 0.318$ ($\chi^2 = 14.727$)	df = 7	.040	Medium–large effect

Note. Kendall's tau-b and Somers' D are calculated for pipeline depth as the independent variable. Goodman-Kruskal gamma excludes tied pairs. Kruskal-Wallis tests use pipeline depth as the dependent variable. Cramér's V accompanies chi-square for stage completion by industry group.

The relationship between pipeline depth and market launch is strongly monotonic. No startup with a depth of zero or one has achieved market launch; the rate rises from 6.2% at depth two to 25.0% at depth three and 72.4% at depth four. Kendall's tau-b = 0.574 ($p < .001$, $n = 145$) and Somers' D = 0.456 confirm a strong directional ordinal association. Each additional milestone completion compound-effects the probability of commercial launch.

The relationship between pipeline depth and employment follows a similar gradient: mean employment rises from 1.9 at depth zero to 9.7 at depth four. Kendall's tau-b = 0.299 ($p < .001$, $n = 161$) and Somers' D = 0.324 confirm a moderate directional association. Startups at the deepest pipeline level generate on average more than five times the employment of those at the shallowest level, establishing pipeline depth as not only a commercialisation predictor but a job creation mechanism.

External funding shows a weaker but statistically significant association with pipeline depth (tau-b = 0.169, $p = .013$; gamma = 0.322). Funding rates rise from 8% at depth zero to 31% at depth four, but the large proportion of unfunded startups at every level means pipeline advancement is necessary but not sufficient for capital acquisition.

The most analytically unexpected result is the complete absence of a significant association between pipeline depth and IP filing. Kendall's tau-b = -0.048 ($p = .491$) and gamma = -0.117 confirm that intellectual property activity is decoupled from innovation progression. The IP filing rate peaks at depth one at 57.1% driven by 8 of the 14 startups at that level having filed at least one request and then drops sharply to 6.2% at depth three before partially recovering to 20.7% at depth four. This non-monotonic pattern is inconsistent with Teece's (1986) prediction that IP generation accompanies and reinforces commercialisation pathway progression. The elevated depth-one rate is more consistent with defensive early patenting, in which ventures protect intellectual assets before product development is complete, independent of subsequent pipeline advancement. IP strategy in this population appears to follow a logic that is orthogonal to innovation stage.

Industry Group as a Pipeline Predictor

Industry group is a statistically significant predictor of pipeline depth (Kruskal-Wallis $H = 20.297$, $df = 7$, $p = .005$). Mean depth ranges from 1.24 for Green/Sustainability to 2.91 for Agriculture/Food. The Cramér's V for industry group versus field trial completion is 0.318 ($\chi^2 = 14.727$, $df = 7$, $p = .040$), a medium-to-large effect, confirming that industry differences are most pronounced at the field trial transition, exactly where Entrepreneurial Development Theory would predict them to be, given that this stage is where sector-specific regulatory and validation requirements diverge most sharply (Bruton et al., 2010).

Agriculture/Food's position as the highest-depth industry group with the highest market launch rate of 50.0% and the highest mean employment of 9.6 persons per startup is the most counterintuitive finding in the dataset. Standard innovation frameworks privilege technology-intensive industries as innovation leaders; the data does not support this for the SISFS population. Agricultural startups benefit from structural advantages that commercialisation theory has not adequately theorised for emerging economy contexts: proximity to established supply chains, tangible products that can be field-validated without regulatory gatekeepers, access to rural distribution networks, and co-founder domain expertise that directly reduces the resource intensity of the product development and field trial stages.

Healthcare/Biotechnology presents the most structurally concerning profile. It is simultaneously the largest industry group at 25.1% of the sample, carries the lowest market launch rate at 24.3%, and concentrates stalled startups disproportionately: of the 54 startups that have completed two or three pre-launch milestones but have not launched, 19 or 35.2% are healthcare or biotechnology ventures, compared to their 25.1% share of the full sample. The healthcare stall reflects requirements external to the SISFS framework, including clinical trials, medical device certification, and institutional review processes that extend development timelines beyond the scheme's seed-funding horizon. Green/Sustainability shows the lowest mean depth at 1.24, with particularly steep attrition at the prototype stage at 50.0% completion versus the full-sample rate of 82.6%, suggesting that the capital intensity of clean technology prototyping exceeds what seed funding can support.

Organisational form, by contrast, does not significantly predict pipeline depth (Kruskal-Wallis $H = 2.165$, $df = 2$, $p = .339$), nor does incubator sector alignment predict depth or market launch. Of the 175 startups, 67 (38.3%) are hosted by sector-aligned incubators, but alignment produces no significant difference in pipeline depth (Mann-Whitney

$U = 3687.0$, $p = .828$). These findings suggest that structural incubation characteristics are not the mechanism connecting startups to milestone progression: industry context, not incubation configuration, determines how far a startup advances.

Gender Structural Analysis: Sectoral Concentration and Its Consequences

Healthcare/Biotechnology (25.1%), Agriculture/Food (13.1%), and Social/Education (4.0%) together account for 42.3% of the sample which is a care-adjacent concentration consistent with the structural channelling thesis in feminist entrepreneurship research, which argues that women entrepreneurs are systematically directed toward industries aligned with socially assigned caregiving roles (Marlow & McAdam, 2013; Brush et al., 2019). In the broader Indian startup ecosystem, technology sectors dominate new venture formation, making the care-adjacent overrepresentation in this SISFS cohort analytically significant.

Comparing care-adjacent startups with non-care startups across all four outcome measures produces no statistically significant differences: funding rates of 20.3% versus 25.7% ($\chi^2 = 0.441$, $p = .507$), IP filing rates of 17.6% versus 24.7% ($\chi^2 = 0.780$, $p = .377$), pipeline depth means of 2.36 versus 2.33, and employment medians of four versus three (Mann-Whitney $U = 3155.0$, $p = .982$). The absence of an aggregate outcome penalty for care-adjacent concentration is an important finding: within the SISFS framework, structural sectoral channelling does not produce measurable performance disadvantages at the population level.

This aggregate result conceals, however, a consequential within-category divergence. Agriculture/Food substantially outperforms Healthcare/Biotechnology on every measured dimension. Market launch rate (50.0% versus 24.3%), pipeline depth (2.91 versus 2.20), and mean employment (9.6 versus 3.9). Pooling these two groups into a single care-adjacent category suppresses the divergence and makes the composite group appear average. The theoretical implication is that care-adjacent sector is a heterogeneous category, and that the mechanisms disadvantaging women entrepreneurs in healthcare, principally regulatory burden and long clinical validation timelines do not operate in agriculture, where physical product tangibility and established supply chains instead accelerate commercialisation.

Employment concentration is the dimension where the gender development implications are most visible. Total employment across 161 startups with valid records amounts to 930 jobs. Agriculture/Food accounts for 212 jobs. 22.8% of total employment from only 13.1% of startups, at a mean of 9.6 employees per startup that exceeds twice the full-sample mean of 5.78. The employment Gini coefficient of 0.615 indicates that job creation within this cohort is highly concentrated; Agriculture/Food is among the key concentrators. This finding revalues women co-founded agrarian entrepreneurship as a high-impact employment pathway that standard innovation policy frameworks, which privilege technology-intensity as the primary metric of venture value, tend to render invisible.

7. CONCLUSION

Three conclusions emerge from this analysis. First, the SISFS innovation pipeline exhibits a valley of death concentrated between prototype development and field trials, with cumulative inter-stage attrition of 56.8% across those two transitions. Pipeline depth is the dominant predictor of market launch, employment, and funding, while IP activity is strategically decoupled from pipeline progression in a manner that challenges technology commercialisation theory. Second, industry group is the most consequential predictor of pipeline advancement: Agriculture/Food achieves the highest pipeline maturity and employment generation in the sample, while Healthcare/Biotechnology concentrates stalled startups despite being the largest single industry group. These patterns locate the structural barriers to commercialisation in sector-specific regulatory and validation environments rather than in incubation configuration or organisational form. Third, 42.3% of women co-founded startups are concentrated in care-adjacent industries, consistent with structural channelling in feminist entrepreneurship theory, but this concentration produces no aggregate outcome penalty. Within-category divergence the Agriculture/Food is outperforming Healthcare/Biotechnology on every measure. Which reveals that care-sector identity is heterogeneous and that agrarian innovation by women co-founders is generating employment impact at a rate that far exceeds its apparent policy visibility.

8. POLICY IMPLICATIONS

The stage-resolved attrition analysis identifies the product development and field trial transitions as the priority intervention zones. Stage-differentiated mentorship, matching product development specialists to startups at depth two and supplementary financing tranches specifically for the field trial transition would target the resource gap that the attrition data reveals. Healthcare/Biotechnology requires policy coordination beyond the SISFS: regulatory pre-submission support and extended funding timelines calibrated to clinical validation cycles would address the stall that results from a mismatch between the scheme's seed-funding horizon and the medical device regulatory timeline.

Agriculture/Food's superior pipeline and employment performance argues for an explicit recalibration of programme selection criteria away from technology-intensity proxies toward pipeline depth and employment generation measures that capture the breadth of innovation value this population produces. The decoupling of IP activity from pipeline progression suggests that IP support should be provided on a need-assessed and stage-targeted basis, aligned with each startup's commercialisation roadmap rather than offered as a uniform benefit.

9. LIMITATIONS

The cross-sectional design means that all associations are correlational rather than causal, and pipeline depth may function as a proxy for underlying founder capability rather than as a mechanism generating employment. The external funding variable captures only whether funding was raised, not amounts or sources, which is insufficient to detect bidirectional relationships between capital acquisition and pipeline advancement. Approximately 14 records per variable were withheld as Information Not Shared, introducing uncertainty about the representativeness of valid-n subsamples if non-disclosure is associated with performance. The gender structural analysis is constrained to patterns observable in aggregate secondary data and cannot distinguish structural channelling from self-selection or distinguish the relative roles of founder choice, incubation specialisation, and investor direction in producing the observed sectoral concentration.

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