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From Lab to Market: A Conceptual Taxonomy of Technology Commercialization Pathways in Startup Ecosystems

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Abstract

There has been a rich, but disjointed, research output on technology commercialization that has resulted in a variety of classifications for how entrepreneurs interact with the incumbent, the type of spin-off, the transfer vehicles, and the environments where ventures are born. The need of the moment is to have a taxonomy of the pathway itself, that is, the end-to-end journey from a laboratory technology to a market presence that incorporates these levels. This conceptual paper lays out such a classification. The interaction of two theoretically derived dimensions, the appropriability of the focal technology and the accessibility of complementary assets in the ecosystem, results in four pathway families: the venture pathway (build and scale a firm), the license pathway (sell into the market for ideas), the service pathway (commercialize tacit knowledge directly), and the platform pathway (open the technology and monetize on the position). The revenue logic, archetypal vehicle, dependency on ecosystem, and failure mode of each family will be different, and each will cross two discontinuities: the funding valley of death, and the adoption chasm, at different points and at different severity. Pathways are not selected but afforded by the central claim of the taxonomy, as pathways depend on what technology is and what the ecosystem contains: a significant percentage of commercialization failures is due to technology-pathway ecosystem misfit, rather than to technology quality. Seven propositions formalise the claims. Consequences for the founders (diagnose before going down the venture pathway), for the technology transfer office (portfolio logic across families) and for policy (the cost of pathway monoculture). The paper is conceptual, not empirical data are reported.

Keywords: technology commercialization; startup ecosystems; taxonomy; academic entrepreneurship; technology transfer; appropriability

1. Introduction

The distance between an innovation working laboratory and a revenue generating market position in innovation studies is the least theorized. The starting and ending points are well covered: A good

literature exists on the nature of invention in research, and the other on the nature of competition between established firms and technology. The crossing from one to the other is the point of commercialization, and the integration comes to an end. The entrepreneur's decision on the competitive strategy between product-market entry and the market for ideas (Gans & Stern, 2003). Transfer vehicles and spin-off types are types of academic-entrepreneurship research (Mustar et al., 2006; Rothaermel et al., 2007). The environments actors, institutions, cultures or resource endowments in which ventures are formed and develop are seen as part of the ecosystem (Isenberg, 2010; Stam, 2015; Spigel, 2017). Each classification is helpful; none is a classification of the thing practitioners must navigate, namely the pathway: the end-to-end road from lab to market, the vehicle, the revenue logic, the resource dependencies, and the characteristic ways of dying.

The fact that he wasn't there has real-world consequences. Founders—especially academic founders—take the most popular route up the startup ladder built by venture-capital-backed startups without considering whether their tech and their ecosystem support it (Shane, 2004). Technology transfer offices adopt the same traditional approach of counting spin-offs and license revenue, viewing them as part of the same product stream rather as final destinations of different product streams (Siegel et al., 2003; Markman et al., 2008). And policy, after having invested in ecosystem features appropriate for one pathway family, looks for the next Silicon Valley, while the local technology base enables another one (Autio et al., 2014).So, the next Silicon Valley is on the horizon for policy to invest in, while another may be on the local technology base.

The theoretical ingredients of a pathway taxonomy are present and are, individually, canonical. Teece (1986) has shown that returns on innovation are related to the appropriability regime of the technology and the access to complementary assets needed for commercialization, such as manufacturing, distribution, brand, and regulatory capability. Gans & Stern (2003) have presented the notion of appropriability and incumbent asset control as a strategic choice model for start-ups. The ecosystem literature has already defined complementary assets as not being floating but rather as placed and associated with specific networks (Spigel, 2017). What is yet to be done is the synthesis, that is, the treatment of appropriability and asset accessibility as the generative dimensions of a taxonomy of qualitatively different commercialization routes, each with its own anatomy and conditions of its ecosystem.

This paper undertakes that synthesis, guided by three questions:

RQ1. What dimensions generate a theoretically grounded and practically discriminating taxonomy of commercialization pathways?

RQ2. What are the resulting pathway families, and how do they differ in vehicle, revenue logic, discontinuities, and failure modes?

RQ3. How does the surrounding startup ecosystem condition which pathways are feasible and what follows for founders, transfer offices, and policy?

The contributions are a two-dimensional generating framework and four-family taxonomy (Section 4.1–4.2), a pathway anatomy locating the funding and adoption discontinuities within each family (Section 4.3), an ecosystem-contingency analysis with seven propositions (Section 4.4–4.5), and implications for practice and policy (Section 5). The paper is conceptual and reports no empirical data.

2. Literature Review

2.1 Commercialization Strategy: The Competitive Choice

The strategy stream starts with Teece's (1986) question of who benefits from innovation? and the answer by identifying appropriability (how well the innovation can be protected, by patents or secrecy or tacitness) and ownership of complementary assets. The transfer of the value of the innovation to the asset owners is facilitated in the case of weak appropriability, while in the case of strong appropriability, the bargaining position of the innovator is altered. On this basis, Gans and Stern (2003)

developed a framework for how to calculate the costs and benefits of starting a business: ideas that can be appropriated, where incumbent assets count, the business rests in the hands of the cooperating market; product-market competition takes over. Through open-innovation research, Chesbrough (2002, 2003) introduced the business model choice as a new variable in the process of commercializing technologies, between technical potential and economic value, and he took the firm boundary itself as the variable. This stream is a classification of strategies but does not follow the stream of vehicle dependency, staging and ecosystem dependency as it moves downstream.

2.2 Academic Entrepreneurship: The Vehicle View

A second classifies the vehicles of transfer in the form of organisations. The phenomenon of university patenting and licensing, along with the measurement infrastructure, emerged as a result of the post-Bayh–Dole institutionalisation (Mowery et al., 2001; Siegel et al., 2003). Taxonomies were developed for the literature on university-entrepreneurship (Rothaermel et al., 2007), research-based spin-offs, based upon resources and business model (Mustar et al., 2006), and incubation strategies, based upon selectivity and intensity of support (Clarysse et al., 2005). Formal transfer of knowledge does not exist in isolation but is accompanied and overshadowed by informal academic engagement in the form of consulting, contract research, and collaboration, which are more effective in transferring knowledge than patents, and leave few institutional footprints (Perkmann et al., 2013). It also found that spin-off formation is not a path that is automatically taken whenever technology meets an entrepreneurial ability or institutional support, but is a unique and resource-intensive pathway (Shane, 2004; Markman et al., 2008). Pathway families are all along the stream: The service family is emerging in the data without a name that references them as alternatives, through common dimensions informal-engagement finding is the service family that pops up in the data without a name. This stream separates the vehicles, the origins, but mostly on the supply sides, as well as "market conditions" which constitute contextual variables that make one vehicle viable, and the other futile.

2.3 Startup Ecosystems: The Context View

Environments are classified into an Ecosystem Stream. Isenberg (2010) listed domains policy, finance, culture, supports, human capital, and markets for which the local configuration determines the success of ventures. Stam (2015) disciplined the concept, distinguishing between framework conditions and systemic conditions, and warned against 'outcome-driven policy'. Spigel (2017) demonstrated that ecosystem attributes are relational cultural, social, and material attributes that reinforce and/or undermine each other, and Autio et al. (2014) proved that entrepreneurial innovation is contextual all the way down: the same technology, the same founding team would have different feasible sets in different places. The classifications of places and configurations refer to the stream, the pathway that a given technology can follow through a given configuration is not typologised but assumed.

2.4 Process Models and the Two Discontinuities

The fourth, adjacent to the practice one, represents the stages and dangers of the journey. Technical maturation is a laddered process (Mankins, 1995) known as technology readiness levels. Funding gaps between research grants and market returns, in which no public or private funds are reliable, are called the valley of death (Auerswald & Branscomb, 2003). The discontinuity in market adoption between early and mainstream markets is referred to as diffusion research and practitioner translation (Rogers, 2003; Moore, 2014). Lean methodology redefined a commercialisation process as a search for a validated business model, not as a plan (Ries, 2011; Blank, 2013). What is being offered here are pathway-shaped, but pathway-generic models: surely a taxonomy should not take one road and put all technologies on it?

2.5 The Gap

Four streams, four classifications strategy, vehicle, context, stage and no taxonomy of the pathway that integrates them. Table 1 summarises. The integration matters because the streams' variables interact: a strategy is only executable through some vehicle, a vehicle only viable within some ecosystem, and the stage hazards fall differently on different routes. The taxonomy developed next is built from that interaction.

Table 1. *Literature streams and their classifying objects*

Stream	Classifies	Exemplar classifications	What remains unclassified
Commercialization strategy	The competitive choice	Compete vs cooperate; market for ideas (Teece, 1986; Gans & Stern, 2003)	The downstream route the choice initiates
Academic entrepreneurship	Vehicles and origins	Spin-off types; incubation strategies (Mustar et al., 2006; Clarysse et al., 2005)	Market conditions that select among vehicles
Startup ecosystems	Environments	Ecosystem domains and attributes (Isenberg, 2010; Spigel, 2017)	Pathways a given ecosystem affords
Process models	Stages and hazards	TRL; valley of death; chasm (Mankins, 1995; Auerswald & Branscomb, 2003; Moore, 2014)	Variation in the road itself

3. Research Methodology

3.1 Design

This is a conceptual paper that contributes in the form of a typology, a theoretically derived system of ideal types created by the cross product of explicit dimensions, as opposed to an empirical taxonomy, the taxonomy induced from data (Jaakkola, 2020). Typology-building is suitable in cases of a phenomenon that is heterogeneous, a mature but silo mentality of the literatures, and a contribution that is a discriminating vocabulary, rather than an effect estimate of the current situation. Adequacy is measured against generally accepted criteria for conceptual contribution (Whetten, 1989), plus the need of typology to do identifiable work here—relabel is not the problem, misfit with the pathway is (MacInnis, 2011).

3.2 Procedure

It took 4 steps to develop. First, candidate dimensions were identified in the four literature streams, and the dimensions were screened based on (1) theoretical grounding, (2) discriminating power in relation to the observed commercialization routes, and (3) independence from each other. Second, the

two surviving dimensions (Section 4.1) were crossed to create the pathway families, each of which was a construction of an ideal type across vehicle, revenue logic and staging. Third, each family was stress-tested against the process-model stream by relocating two discontinuities in this stream. Fourth, ecosystem contingencies were generated by posing, for each family, which other ecosystem attributes are load-bearing, leading to the propositions listed in Section 4.5.

3.3 Scope and Boundary Conditions

The taxonomy focuses on science and technology-based commercialization from research, such as in university laboratories, public research institutes, and corporate research organisations in market economies. Ideal types are analytical tools: actual ventures combine and alternate stategies; and the utility of the taxonomy is not that it precludes combination and alternation, but that it makes them describable. No frequencies, success rates or effect sizes are made any particular pathways are claimed.

4. Analysis: The Taxonomy

4.1 Generating Dimensions

Two dimensions survive the screening of Section 3.2; Table 2 states them with their grounding.
Table 2. *Generating dimensions of the taxonomy*

Dimension	Definition	Theoretical grounding	Why it discriminates
D1: Technology appropriability	The degree to which returns from the technology can be excluded and captured by its originator (patents, secrecy, tacitness, complexity)	Appropriability regimes (Teece, 1986); market-for-ideas viability (Gans & Stern, 2003)	Determines whether value can be sold as an idea, embodied in a firm, or only delivered as expertise
D2: Complementary-asset accessibility	The degree to which the assets commercialization requires (capital, manufacturing, distribution, regulatory capability, talent) are accessible to a new entrant within the surrounding ecosystem	Complementary assets (Teece, 1986); ecosystem attributes and resource endowments (Spigel, 2017; Stam, 2015)	Determines whether the originator can assemble the route's assets or must transact with those who hold them

D1 is a property of the technology-in-law-and-practice; D2 is a property of the ecosystem-relative-to-the-entrant. Their independence is the taxonomy's engine: appropriability without asset access and asset access without appropriability generate opposite commercial problems, and the four combinations generate qualitatively different routes.

4.2 The Four Pathway Families

Figure 1 presents the taxonomy; Table 3 specifies the families.

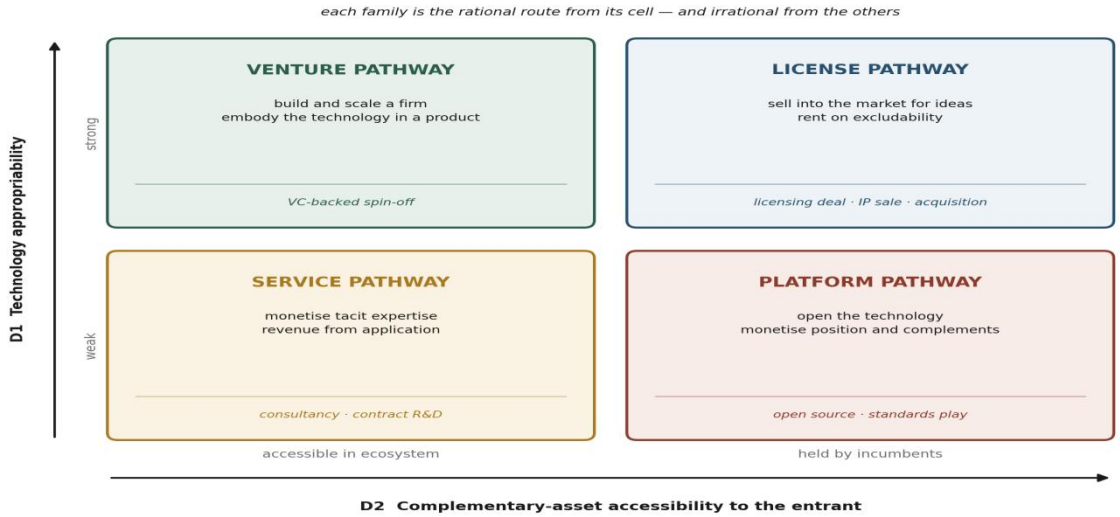


Figure 1. *The pathway taxonomy: technology appropriability crossed with complementary-asset accessibility yields four pathway families.*

Table 3. *The four pathway families*

Family	Generating cell	Archetypal vehicle	Revenue logic	Characteristic failure mode
Venture pathway	Strong appropriability × accessible assets	VC-backed spin-off scaling to product firm	Capture margin by embodying the technology in a proprietary product	Scaling collapse: assets prove less accessible than assumed mid-route
License pathway	Strong appropriability × incumbent-held assets	Licensing deal, sale of IP, or acquisition into an incumbent	Sell into the market for ideas; rent on excludability	Disclosure paradox and buyer hold-up; undervaluation of early-stage claims
Service pathway	Weak appropriability × accessible assets	Consultancy, contract R&D, boutique engineering firm	Monetise tacit expertise directly; revenue from application, not exclusion	Founder-bound scaling ceiling; imitation the moment knowledge codifies
Platform pathway	Weak appropriability × incumbent-held assets	Open-source release, standard, or platform play with position-based monetisation	Give the technology away; monetise complements, position, or services around it	Commons capture: incumbents adopt the technology and the position never materialises

The families give a closer walk-through. The technology of the venture pathway is in the firm's DNA since it can: excludability protects margin while the entrant makes the assets of the ecosystem accessible. It's logic is capture through embodiment, its tempo is staged and capital-intensive, and its characteristic self-deception is over-reading D2, treating the assets as accessible because an ecosystem narrative deems them as such (Spigel, 2017). The license pathway, on the other hand, welcomes the other verdict—the assets which are crucial for regulatory apparatus in the pharmaceutical industry and fabrication in semiconductors are behind the walls that no entrant will scale, and value is generated in the market for ideas (Gans & Stern, 2003). The core conflicts are information-based: disclosure paradox (the buyer doesn't know the value of what it hasn't seen; the seller doesn't know the value of what he or she can't show) and the lack of markets for early-stage claims. The service pathway markets what you can't exclude and you can apply: the tacit knowledge of the founder, which is the technology being sold, as engagements. It starts making money off the bat, and for this reason it prevails wherever the other routes are not viable, and it does not scale when codification would be needed, and that is precisely what weak appropriability can't stand. The platform pathway enables weakness to be a strategy: If exclusion is not possible and incumbents have assets, offer the technology for nothing, let it diffuse and make a position, monetize the position complements, services, control points, not the technology (Chesbrough, 2003). It is the family which relies most on collective adoption and the family that fails to make its failure commons visible without positioning, in which case the technology can flourish.
Families are not listed in priority order. Each is the rational route from its cell, and each is irrational from the others (which is the default, and most common, culturally, way of doing things: the venture pathway; Shane, 2004; Gans & Stern, 2003).

4.3 Pathway Anatomy: Two Discontinuities, Four Crossings

All families pass through similar gross stages disclosure, translating, vehicle formation, market entry, scaling and all experience funding discontinuity (Auerswald & Branscomb, 2003) and the adoption discontinuity (Moore, 2014; Rogers, 2003). They intersect at various places and to varying degrees, however, and Figure 2 makes the difference. The discontinuities happen at the valley before revenue and the valley after early adoption, but also at the highest variance part of the venture path (because it's the part that's left behind), and that's why it's the most visible part of the venture path. The license pathway externalises, at the deal, both crossings to the incumbent buyer thereby making them a valuation discount rather than a traversed discontinuity. The service pathway around the valley is not only a major detour from the revenue but also gets capped at a point where the chasm is, as tacit knowledge cannot be codified in the mainstream volume. On the platform pathway it does the opposite: Openness comes first in the process of engineering an adoption, and the funding problem comes last, when the challenge is to monetise a place that has been given away.

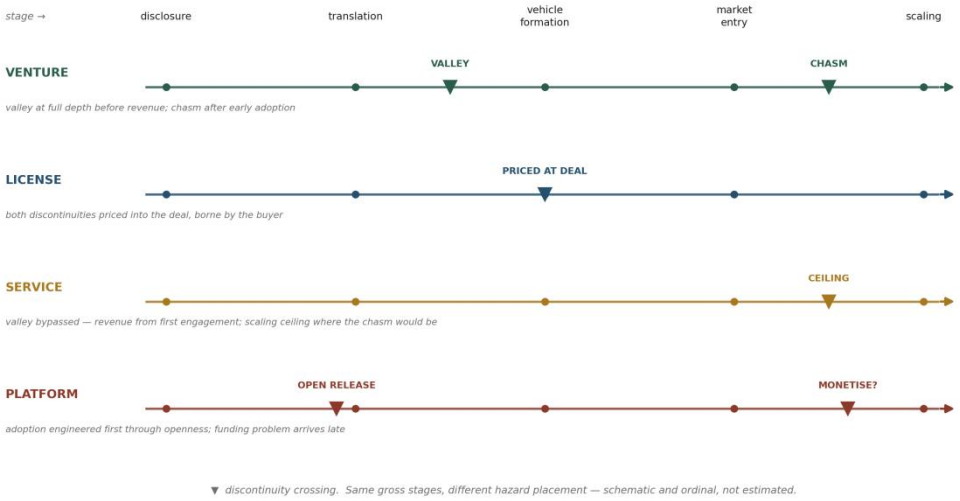


Figure 2. *Stage anatomy of the four families, with the funding discontinuity (valley of death) and adoption discontinuity (chasm) located on each. Depictions are schematic and ordinal, not estimated values.*

The anatomy reframes lean methodology's domain: build–measure–learn search (Ries, 2011; Blank, 2013) is the venture pathway's technique for approaching its first discontinuity, valuable there, and category-mismatched on the license pathway, where the search object is a buyer's private valuation, or the platform pathway, where the searched-for model must be found after diffusion.

4.4 Ecosystem Contingency: Pathways Are Afforded, Not Chosen

The situation is already a generating dimension in D2, but the contingency goes deeper, because each family pulls on a different profile of the attributes of the ecosystem, as summarised in Table 4. Venture pathways are the most ecosystem consuming, they need risk capital at depth, serial founder talent and exit markets at the same time (Stam, 2015; Spigel, 2017). For the majority of that apparatus, license pathways replace institutional capability transfer offices that are able to price, protect, and enforce claims (Siegel et al., 2003; Markman et al., 2008). Service pathways are the easiest, and thus the standard recourse: that's the path the environment provides and that is where baby eco-systems begin to flourish with consultancies. Network density and standards institutions are more crucial to platform pathways than capital.

Table 4. *What each family requires from the ecosystem*

Family	Load-bearing ecosystem attributes	Substitute if absent	Ecosystem signature when dominant
Venture	Deep risk capital; serial entrepreneurs; exit markets; dense mentorship	Corporate venture capital; cross-border capital (partial)	Celebrated scale-ups and high failure churn
License	Capable transfer offices; IP courts; incumbent absorptive capacity (Cohen & Levinthal,	Brokers and specialised IP intermediaries	Quiet deal flow; few visible startups

Family	Load-bearing ecosystem attributes	Substitute if absent	Ecosystem signature when dominant
	1990)		
Service	Skilled labour; professional norms; client base	Remote delivery to external clients	Consultancy-dense, scale-up-scarce landscape
Platform	Developer communities; standards bodies; network density	Global open-source infrastructure (substantial)	Commons contribution with delayed monetisation

The paper's thesis is called the consolidated claim and it is a pathway that is afforded, not chosen. The technology's cell fixes the rational family; the endowment of the ecosystem fixes whether the family is executable locally; bad technology/failing commercialization is very often not about the technology, but about the pathway/ecosystem, where the former is attempted when service assets exist, the latter is attempted when no absorptive incumbent exists, the latter is attempted when the density openness is missing. The affordance view in figure 3 is a different technology portfolio yielding different sets of feasible pathways as the ecosystem's endowment changes.

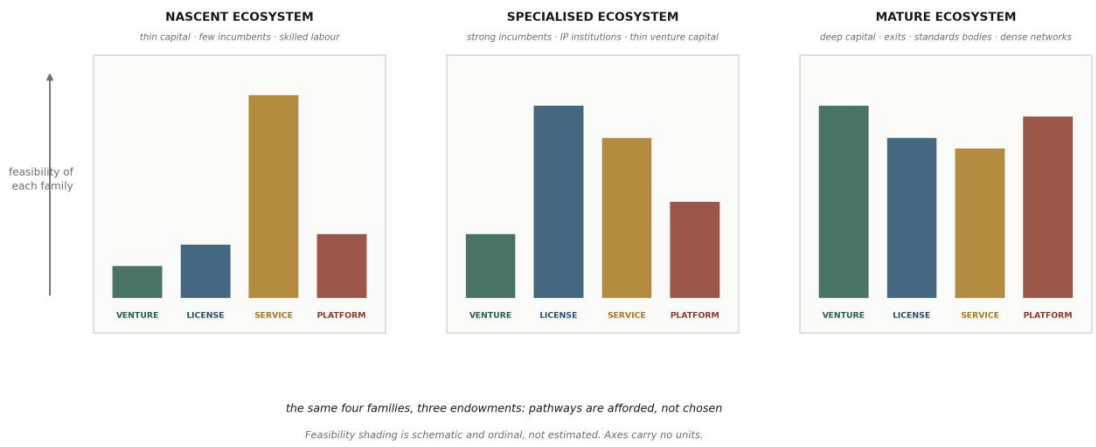


Figure 3. *Ecosystem endowment conditions the feasible pathway set: the same four families against three ecosystem profiles. Feasibility shading is schematic and ordinal, not estimated.*

Pathway migration is a final dynamic that comes from the affordance view. The misfits that cells encounter during the course of the venture turn out to be far more of a problem than they bargained for, as do the misfits that should have occurred at the point the venture should have been licensed, at the point the platform should have recruited a firm and at the point the taxonomy predicts that recognised misfit is best addressed by a change of families rather than a stay at the same family. Migration is expensive and direction: service-to-venture is the praised ascent (consulting revenues are used to productise), venture-to-license the face-saving descent (acqui-hire and the patent sale), and platform-to-venture, the rarest, because jobs lost can't be re-enclosed. The name of migration – family transition

– not the name of the transition itself – as a pivot in general, provides a codable object to process research.

4.5 Propositions

Table 5. *Propositions of the taxonomy*

ID	Proposition
P1	Commercialization routes cluster into the four families of Table 3, generated by appropriability (D1) and complementary-asset accessibility (D2).
P2	Pathway–cell misfit predicts commercialization failure independently of technology quality: technologies commercialized through a family other than their cell's fail at higher rates.
P3	The severity and sequencing of the funding and adoption discontinuities differ systematically by family, as specified in Figure 2.
P4	Ecosystem attribute profiles (Table 4) moderate family viability: the same cell yields different family success across ecosystems with different endowments.
P5	In nascent ecosystems, commercialization activity concentrates in the service family regardless of the local technology base's cell distribution.
P6	Policy that expands a single family's ecosystem attributes (pathway monoculture) increases misfit failures among technologies whose cells afford other families.
P7	Ventures that switch families mid-route (pathway migration) outperform persistence under misfit, conditional on the destination family matching the technology's cell.

5. Discussion

5.1 Theoretical Implications

The taxonomy incorporates the four streams at the intersection of their interaction. It provides the strategy stream with a downstream: Gans and Stern's (2003) choice model is the entry decision into a family, the full anatomy vehicle, staging, discontinuities, are specified by the taxonomy. It restates Mustar et al.'s (2006) stream heterogeneity by introducing a demand side, in the form of variation in family and cell, not just a supply side resource endowment. It provides an object for the ecosystem stream: ecosystems can be described by the pathway portfolio they provide, a more powerful policy variable than attribute checklists. It also disciplines the process stream: there is no one process path from lab to market; there are four, and the hazards well known on one are priced, bypassed, or inverted on the other three.

5.2 Practical Implications

To the founders, the taxonomy is a diagnostic first, it's not really a thing to be claimed. Assets are what they are here and let the cell nominate the family and let the venture default be a hypothesis, not an identity. For transfer offices, it means portfolio logic: an office with a competitive licensing metric will fail to route venture-cell or platform-cell technologies uniformly, and what's needed instead are family differentiated processes (Markman et al., 2008). For policymakers, it identifies the monoculture mistake, which is to bring in technology and skill infrastructure accelerators, seed funds, pitch culture into an ecosystem that has a technology base and an asset endowment that can support the production of ceremony without commercialization (Stam, 2015; Autio et al., 2014). The mistake is not giving more, but giving more the wrong kind: the same amounts of public spending spent on the attributes that the product that the public affairs the transfer-office cells expects the cell to have, also buy the public the public for the service cells and professional labor markets, and for the platform cells to participate in standards. Thus, the policy method of the taxonomy is a sequence-reverse approach: map the local technology base's cell distribution first, then allow the distribution to nominate the ecosystem investments, as opposed to picking a known ecosystem and hoping that the technology base fits. The second corollary is related to measurement: a pathway-diverse ecosystem will perform worse on any individual family's metrics than a venture monoculture; it will perform worse on metrics of commercialization than a commercialization machine but not worse on family-weighted metrics; and the family-weighted metrics are the ones that don't introduce the monoculture error into the evaluation.

5.3 Limitations

The taxonomy is ideal typologies and the dimensions are continuous in the real world – cells have interiors and boundaries, and real ventures are in between. It is derived, not induced its families are hypotheses about clustering (P1), not findings and its propositions await operationalisation, for which the principal difficulties are: (a) measuring appropriability as practised not patented; (b) measuring asset accessibility relative to a specific entrant. Commercialization conducted outside of research environments is excluded from the scope condition and the ecosystem analysis brings along the bias of the literature in favour of well documented and high income ecosystems.

5.4 Future Research

The priority is P2, the misfit hypothesis, as this is the explanatory claim in the taxonomy that is testable on spin-off registries where family, cell and outcome can be coded independently. Ecosystem panels will be tested in P5 and policy discontinuities in P6. Pathway migration (P7) offers longitudinal examples of ventures that relocated families, with the trigger, cost and fit of the destination family coded. Another agenda item is measurement – a practice for cell location, an appropriability instrument, and an entrant-relative asset accessibility tool would turn the taxonomy into a tool for the founders and transfer offices as well.

6. Conclusion

In most of the literature, and almost all of the culture, the road from the lab to the market has been represented as a single highway with the hallowed dangers of raising money, crossing the valley, jumping over the chasm, and scaling. This paper has made a particular and significant claim: There is no one road. Each of the families of technologies - cross with each of the families of the surroundings - gives rise to four families of routes, with a rational vehicle for each, a revenue logic for each, a sequence of hazards for each, and a failure mode for each. The families are not numbered and the most famous family is the one which is given the "afforded route" in one cell out of four. By the excludability of the technology and its legality, as well as its practicability, and by the endowment of the ecosystem as compared to the entrant. The field gets a new way to conceptualize commercialization failure, from the lack of technologies to the lack of affordances and the lack of

practices, and the field gets a new name to describe its problems, the taxonomy, which gives the question "how should this leave the lab?" more than one imaginable answer.

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Declarations

Conflict of Interest

The authors declare no conflicts of interest related to this study.

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Ethical Approval

This study did not involve any human or animal subjects and, therefore, did not require ethical approval.