TOWARD A THEORY OF THE EVOLUTION OF BUSINESS ECOSYSTEMS: Enterprise Architectures, Competitive Dynamics, Firm Performance & Industrial Co-Evolution

by

THEODORE F. PIEPENBROCK

B.S. Engineering (da Vinci program), Santa Clara University, 1987
M.Eng. Civil and Environmental Engineering, University of California at Berkeley, 1993
M.B.A./S.M. Sloan School of Management, Massachusetts Institute of Technology, 2004
S.M. Civil and Environmental Engineering, Massachusetts Institute of Technology, 2004

Submitted to the ENGINEERING SYSTEMS DIVISION
in Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY
in ENGINEERING SYSTEMS

at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

16 September 2009

Author
Theodore F. Piepenbrock
Engineering Systems Division

Certified by
Dr. Charles H. Fine (Thesis Supervisor and Committee Chair)
Chrysler LFM Professor of Management and Engineering Systems; Director, *International Motor Vehicle Program*

Certified by
Dr. Deborah J. Nightingale (Thesis Committee Member)
Professor of the Practice of Engineering Systems and Aeronautics & Astronautics; Director, *Lean Advancement Initiative*

Certified by
Dr. Yossi Sheffi (Thesis Committee Member)
Professor of Engineering Systems and Civil & Environemental Engineering; Director, *Engineering Systems Division*

Certified by
Carolyn Corvi, SM (Thesis Committee Member)
Retired Vice-President and General Manager of Airplane Programs, *Boeing Commercial Airplanes*

Approved by
Dr. Nancy Leveson
Professor of Engineering Systems and Aeronautics & Astronautics; Chair, ESD Education Committee

TOWARD A THEORY OF THE EVOLUTION OF BUSINESS ECOSYSTEMS: Enterprise Architectures, Competitive Dynamics, Firm Performance & Industrial Co-Evolution

by
THEODORE F. PIEPENBROCK

Submitted to the Engineering Systems Division on September 16, 2009 in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Engineering Systems.

Abstract

This research lies at the intersection of the intellectual domains of strategic management, organizational science and complex systems theory. It aims to contribute to fundamental debates in these fields regarding the source of long-term firm performance – namely does it reside within the firm or in the firm's environment, and what are the roles of managerial adaptation and environmental selection in its creation? Crucially, how does this shape our understanding of strategic leadership? At its most fundamental level therefore, this research addresses a question that has been posed by evolutionary theorists in the economics and sociology literatures for decades: "Why do firms in the same industry vary *systematically* in performance *over time*?" Seeking a *systematic* explanation of a *longitudinal* phenomenon inevitably requires characterizing the evolution of the ecosystem, as both the organization and its environment are co-evolving. This question is therefore explored through the lens of Engineering Systems: 1) within the *domain* of Extended Enterprises, where architectural competition is examined in three classic engineering systems: aerospace, automotive and airlines; and 2) using the *approaches* of Design and Dynamics, by analyzing enterprise architectures and their change management processes and by modeling the competitive dynamics of these complex ecosystems.

The research builds grounded theory on empirical findings which suggest that sources of firm performance appear to lie neither exclusively within the firm, nor in its environment, but in *how* the firm interacts with its environment – i.e. in the network *architecture* of the firm's extended enterprise which enables and constrains managerial agency through spatially and temporally bounded rationality. A theoretical framework is proposed which endogenously traces the co-evolution of firms and their environments using their highest-level system properties of *form, function* and *fitness* (reflected in the system sciences of *morphology, physiology* and *ecology*). The framework captures the path-dependent evolution of heterogeneous populations of extended enterprises engaged in *symbiotic inter-species competition* and posits the evolution of "dominant designs" in enterprise architectures that oscillate deterministically and chaotically between *modular* and *integral* states throughout an industry's life-cycle. Architectural innovation – at the extended enterprise level – is demonstrated to contribute to the failure of established firms, with causal mechanisms developed to explain tipping points.

The research is based primarily on a seven-year, multi-level, multi-method, longitudinal empirical case study of two firms in a global *mixed* duopoly as well as the key stakeholders in their extended enterprises. The theory is further tested and generalized across a theoretical sample of firms in manufacturing and service sectors, with both historical comparative analysis and nonlinear dynamic simulation models developed to capture the evolution of business ecosystems. The resulting framework is grounded empirically, analytically as well as theoretically by synthesizing a broad range of literatures from economics to sociology, from physics to biology.

Thesis Supervisor: Dr. Charles H. Fine, *Chrysler LFM* Professor of Management & Engineering Systems
Thesis Member: Dr. Deborah J. Nightingale, Professor of the Practice of Engineering Systems
Thesis Member: Dr. Yossi Sheffi, Professor of Engineering Systems, Director of ESD
Thesis Member: Carolyn Corvi, Vice President & General Manager, *Boeing Commercial Airplanes*

Acknowledgements

As shown in Figure 1 below, this work is the product of a series of both collaborative and competitive and yet integrative partnerships between the following world-class institutions:

- The academic institutions of MIT and The University of Oxford:
  - Within MIT:
    - *Engineering Systems Division* & the *Sloan School of Management*
  - Within Oxford:
    - *Templeton College* & the *Said Business School*

- The academic / industrial partnerships:
  - Within MIT:
    - *Leaders for Manufacturing* (LFM) program
    - *Lean Aerospace/Advancement Initiative* (LAI)
  - Within Oxford:
    - Oxford-Wharton Executive Education programme, *Gateway to Strategic Leadership*

- The industrial competitors engaged in these academic / industrial partnerships:
  - *Boeing*
  - *Airbus*

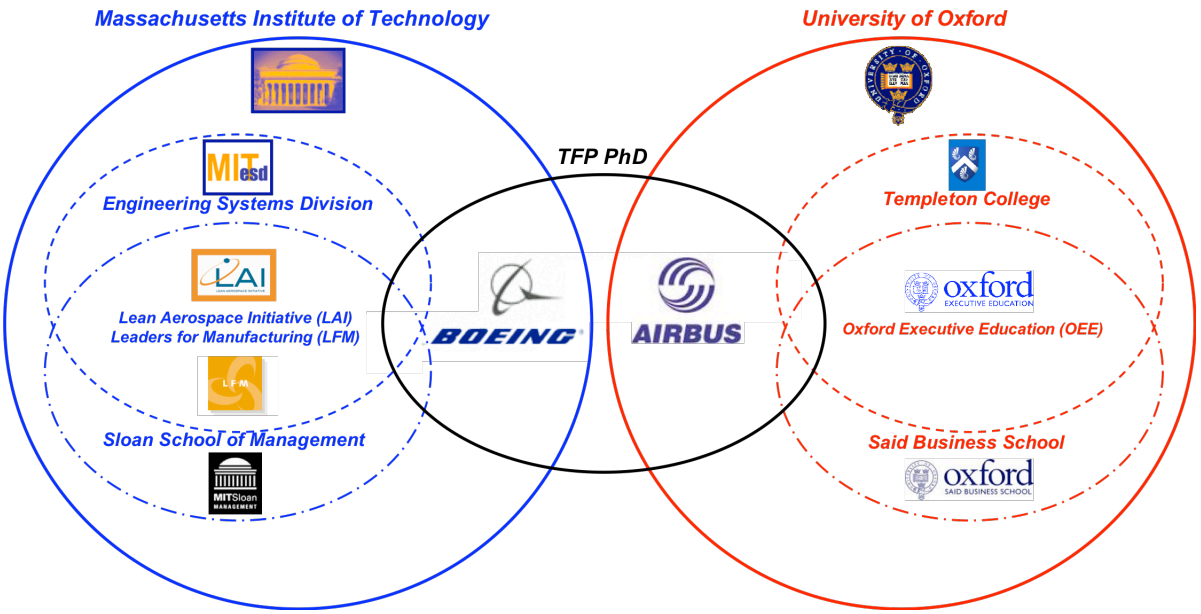


Figure 1: Integrating *Academic Collaborators* and *Industrial Competitors*

At one of the first public presentations of this research in 2003, I received a public critique from the late Dr. Michael Hammer, international author and management consultant of the Business Process Reengineering movement. He colorfully exclaimed, *"This is either the work of a madman or a genius, and at this moment I am inclined to think that it is the latter."* I would like to acknowledge at this point that if the ideas presented herein appear strange, unconvincing, illogical, or simply wrong, then I take full blame as the "madman" responsible for this work. However, if these insights while unconventional do seem to uncover some truths, then I must quickly acknowledge the true source of any "genius" that may exist.

While I have faithfully tried to acknowledge the intellectual sources of this work through the traditional and formal process of citations, footnotes and the use of (over 500) references, the following acknowledgements are equally important as they inspired and enabled this research.

As my advisor, Prof. Fine acknowledges in his book, *Clockspeed*, "if I have seen farther, it is by standing on the shoulders of giants". My giants are numerous in space and time, ranging from Sir Isaac Newton to my classmates at MIT. I have just served as a humble questioner, listener and integrator of their knowledge, mental models and points of view. I would therefore like to thank those whose inspiration and contributions made this thesis possible.

***Academic* Influences:**

As I look back over the past seven years of this project, it becomes more and more clear that this work would simply have been impossible without the continued guidance and support from the exceptional people at an exceptional institute who served as my masters and doctoral thesis supervisors, my doctoral committee members, as well as my professional and personal mentors. They are equal peers with complementary talents and are listed alphabetically at MIT: Professor Charles H. Fine, Professor Deborah J. Nightingale and Prof. Yossi Sheffi. I have become convinced that if I had selected any other world-class academics to lead me through this research, this project would simply not have been permitted to get off the ground. It is through their personal ambitions and extraordinary capabilities to solve the most complex socio-technical problems while simultaneously balancing the academic rigor – professional relevance tradeoff, that this work has been enabled.

- Professor Charles Fine, *MIT Sloan School of Management* and *Engineering Systems Division* and *Director of the International Motor Vehicle Program* taught me power of Three-Dimensional Concurrent Engineering (of products, production systems, and global extended enterprises) and encouraged me to use this to extract simple patterns amidst the dynamic complexity of value chains, industries, firms and technologies.

- Professor Deborah Nightingale, *MIT School of Engineering* and Director of the *MIT Lean Advancement Initiative (LAI),* taught me the power of enterprise thinking, the complexity of multiple stakeholder integration and gave me the tools and encouragement to understand how such enterprises are architected and to begin to participate in the process of their architecting.

- Professor Yossi Sheffi, *MIT Engineering Systems* and *Civil & Environmental Engineering* and Director of the *MIT Engineering Systems Division (ESD),* created a bold vision for an innovative and impactful academic division, which had the intellectual courage to ask the big unanswered questions, and who protected and enabled those foolish of us to give it a shot.

- Carolyn Corvi, MIT Sloan Fellow and VP and GM of Airplane Programs at *Boeing Commercial Airplanes*, taught me not only how modular and intergral enterprises work, but crucially how one might begin to transform modular to integral, a journey she began over 20 years ago, which she documented in her MIT Sloan Fellows thesis.

- Professor Sophie Marnette, University of Oxford, a specialist in linguistics and philology who greatly influenced my ability to analyze and transform qualitative discourse and textual data into quantitative data. She supported, pushed and challenged my thinking over many years over which time I have had the privilege of experiencing a truly "beautiful mind".

I am grateful for the opportunity they gave me to have presented, discussed and developed this material in academic and professional forums around the world in North America, South America and Europe, in particular:

- MIT Sloan School of Management graduate courses:
  - *15.795 Technology Roadmapping* (Fall, 2002)
  - *15.769 Operations Strategy* (Spring, 2003)
  - *15.769 Operations Strategy* (Spring, 2008)
  - *15.769 Operations Strategy* (Fall, 2008)

- MIT Engineering Systems Division graduate courses:
  - *ESD.61J Integrating the Lean Enterprise* (Fall, 2004)
  - *ESD.38J Enterprise Architecting,* 2 sessions (Spring, 2006)
  - *ESD.61J Integrating the Lean Enterprise* (Fall, 2006)
  - *ESD.38J Enterprise Architecting,* (Spring, 2007)
  - *ESD.61J Integrating the Lean Enterprise* (Fall, 2007)
  - *ESD.61J Integrating the Lean Enterprise* (Fall, 2008)
  - *ESD.38J Enterprise Architecting,* 2 sessions (Spring, 2009)
  - *ESD.940 The Auto Industry in Crisis* (Spring, 2009 - presented by Prof. Charlie Fine)

- The MIT Sloan School of Management research seminars:
  - System Dynamics doctoral seminar (Fall, 2003)
  - Operations Management research seminar (Fall, 2004)
  - Behavioral and Policy Sciences Seminar (Fall, 2006)

- The MIT Engineering Systems Division doctoral research seminars:
  - Fall, 2008

- The MIT *Lean Aerospace Initiative / Lean Advancement Initiative* (LAI):

  - Fall, 2002 – research seminar
  - Fall, 2003 – research seminar
  - Fall, 2004 – research seminar
  - Spring, 2005 – Executive Board, Dana Point, CA
  - Summer, 2005 – research meeting presentation
  - Spring, 2006 – research seminar
  - Fall, 2006 – research seminar
  - Fall, 2007 – research seminar
  - Fall, 2008 – research seminar

- The MIT *Lean Aerospace Initiative / Lean Advancement Initiative* (LAI) executive education "Knowledge Exchange Events":
  - March, 2007
  - October, 2007

- The University of Oxford's executive education programmes at the *Saïd Business School*:
  - Oxford *Strategic Renewal Research Programme*
    - Spring, 2005
  - Oxford-Wharton *Gateway to Strategic Leadership*
    - Fall, 2005
    - Spring, 2006
    - Fall, 2006
    - Fall, 2007
    - Fall, 2008

- Senior Executives at *Embraer*, and the Brazilian *Society of Automotive and Aerospace Engineers*, Sao Paulo, Brazil (Summer, 2004).

- Executives at *The Boeing Company's* Lean Enterprise Conference in Costa Mesa, California (May, 2007).

- Senior Executives at *Spirit Aerosystems* Executive Council meeting presentation, in Wichita, Kansas on 17 June 2008 and at their Board of Directors meeting in Williamsburg, Virginia on 7 September 2008.

- London Business School, *Conference on Innovation in Operations* (7-8 June 2009, London, UK), with Prof. Charlie Fine.

- *2nd International Symposium on Engineering Systems*, MIT, (17 June 2009, Cambridge, MA), with Prof. Charlie Fine, Prof. Deborah Nightingale and Prof. Yossi Sheffi.

In addition, the following individuals and groups have contributed to the development of the research:

- The MIT *Leaders for Manufacturing* (LFM) classes of 2003, 2004 and 2005; co-directors Professor Steve Graves, Professor Steve Eppinger, Professor Tom Allen, Professor Paul Lagace, Professor David Simchi-Levi, Bill Hanson and Don Rosenfield and LFM staff including Monica Nakamine, Lois Slavin, Patty Sullivan and Nancy Young.

- The MIT *Lean Aerospace Initiative / Lean Advancement Initiative* (LAI) Executive Board, directors, research staff and research assistants, including: Terry Bryan, Kirk Bozdogan, Heidi Davidz, John Dickman, Troy Downen, Blaise Durante, Gregoire Ferre, Chris Glazner, Marc Haddad, Erisa Hines, Hugh McManus, Earll Murman, Debbie Nightingale, Noel Nightingale, Eric Rebentisch, Donna Rhodes, Nirav Shah, Tom Shields, JK Srinivasan and Alexis Stanke.

- The MIT *Engineering Systems Division* (ESD) which serves as among other things the umbrella organization for the LFM and LAI programs. In particular, the leadership including Professors Yossi, Sheffi, Dan Hastings, Daniel Roos, Fred Moavenzadeh and Sheila Widnall who inspired me to stay in the field of engineering and contribute towards its evolution.

- Professor John Carroll for his insights into the lenses through which organizations and particularly leadership can be viewed, his Summer 2001 class, 15.316.
- Professors Jay Forrester, John Sterman, Nelson Repenning, Jim Hines and Dr. Bradley Morrison; doctoral candidates Gokhan Dogan, Mila Getmanski, Joe Hsueh, Dan McCarthy, Tim Quinn, Hazhir Rahmandad, and Jeroen Struben of the *MIT Sloan School of Management's* System Dynamics Group.
- Brian Bowers & Kirk Bozdogan of the *MIT Lean Aerospace Initiative* for the Fall 2002 work in Professor Fine's 15.795 *Technology Roadmapping* class.
- Dan Allison, Karen Marais and Kim Murdoch, for their work on our final project for Professor Deborah Nightingale's Fall 2002 class, ESD.61J *Integrating the Lean Enterprise*.
- Masashi Kojima, Juan Marchini, Hiroshi Taguchi and Janelle Wright, for their work on our final project for Professor Mamood Samii's Fall 2002 class, 1.45 *Construction Finance*.
- Professors Peter Belobaba, John Hansman et al. for their insights in the Fall 2002 class, 16.71J *The Airline Industry*.
- Professor Kent Hansen and his Spring 2003 class, ESD.74J *System Dynamics for Engineers* - particularly for his encouragement for my class project on "Enterprise Structural & System Dynamics".
- Brian Bowers, Lou Rassey and Eric White for their discussions in our final project for Professor Charlie Fine's Spring 2003 class, 15.769 *Operations Strategy*.
- Lou Rassey for his support and encouragement, particularly over Spring break, 2003.
- Professors Joel Cutcher-Gershenfeld, Chris Magee, and my fellow classmates of the ESD.84 *Engineering Systems Doctoral Seminar*, Fall 2003.
- Professor Deborah Nightingale, Dr. Donna Rhodes, and my fellow classmates of the ESD.935 *Enterprise Architecting Doctoral Seminar*, Spring 2004.

- Professors John Sterman & Nelson Repenning, and my fellow classmates of the 15.879 *System Dynamics Doctoral Research Seminar*, Spring 2004.
- Doctoral students of the MIT *Complex Systems Research Laboratory*, particularly Dr. Karen Marais and Nicolas Dulac.
- Professor Sarah Kaplan, *The Wharton School*, University of Pennsylvania, USA
- Professor Rafael Ramirez, *HEC*-Paris and *Templeton College*, University of Oxford, UK
- Professor Harbir Singh, *The Wharton School*, University of Pennsylvania, USA
- Dr. Felix Reed-Tsochas, Research Fellow, *Saïd Business School*, University of Oxford, UK
- Professors Wanda Orlikowski, MIT *Sloan School of Management*, and Michael Cusumano, MIT *Sloan School of Management* and *Engineering Systems Division,* while on sabbatical in Oxford on the Balliol-MIT exchange program.
- Beth Milnes, ESD Academic Administrator, for her patience and hard work in always keeping me pointed in the right direction.

Professional **Influences:**

The Boeing Company served as the most encouraging and supportive teaching & learning laboratory that one could hope for. I am indebted to those at *Boeing* with whom I have had the privilege to learn along side with. Those whose courage and intellectual and ethical leadership stand out were:

- Carolyn Corvi, VP and GM, Airplane Programs, *Boeing Commercial Airplanes*
- Sherry Carbary, VP, Business Strategy, *Boeing Commercial Airplanes*
- Tim Meskill, Director, Business Strategy, *Boeing Commercial Airplanes*
- Adam Kohorn, Director, Business Strategy, *Boeing Commercial Airplanes*
    - Rasheed El-Moslimany, Business Strategy, *Boeing Commercial Airplanes*
    - Linsey Rubenstein, Business Strategy, *Boeing Commercial Airplanes*
    - Mike Wargel, Business Strategy, *Boeing Commercial Airplanes*
    - Rachel Portillo, Business Strategy, *Boeing Commercial Airplanes*

***Financial* Support:**

Funding for the research was generously provided by the following academic-industrial partnership organizations, for which I am grateful:

- *The Boeing Company*
- MIT *Leaders for Manufacturing* (LFM) / *Leaders for Global Operations* (LGO)
- MIT *Lean Aerospace Initiative / Lean Advancement Initiative* (LAI)
- MIT *Communication Futures Program*
- University of Oxford, *Said Business School, Executive Education*

While this work has been supported and funded by the aforementioned parties, the contents of this thesis do not necessarily reflect their views, and any errors or omissions are the responsibility of the author. I also add the disclaimer that while part of this thesis was undertaken under the supervision of *The Boeing Company*, this work in no way intends to pass judgments regarding the effectiveness its management, nor to offer normative or prescriptive recommendations for its future vision and operations. Rather, the intent was merely to pose questions and suggest hypotheses and frameworks for dealing with enterprises facing dynamic complexity.

Disclaimers:

In order to preserve an impartial and unbiased standing as an objective researcher, I make the following disclosures:

- I am a dual citizen of both home nations of the primary case study upon which this research is partially based: the US (*The Boeing Company*) and the Netherlands (*EADS*, parent of *Airbus*).

- I have never in the past owned, do not currently own, nor will I own shares of either companies in the primary case study upon which this research is partially based: *The Boeing Company* and *EADS (*parent of *Airbus)*.

***Personal* Influences:**

Finally, I would like to acknowledge the sources of personal inspiration and strength: my precious wife, Sophie, our extraordinary son, Garry Georges, and our wonderful parents, Garry & Janice and Georges & Micheline.

Biographical Note

Ted Piepenbrock is an international lecturer in executive education and consultant in strategic leadership and macro-organizational change to corporate leaders in global *Fortune 100* companies. Throughout his career, he has traveled over one million miles, worked in over twenty countries, lectured on management and engineering in many of the world's leading universities (e.g. MIT, Harvard, Berkeley, Stanford, Princeton, Oxford, Cambridge, Imperial College, UCL, Tokyo Institute of Technology) and has appeared in various international news media (e.g. *CNN-TV, BBC-TV, ITV, SKY-TV, The Learning Channel, The Discovery Channel).*

He received a B.Sc. in engineering/humanities as a *Da Vinci scholar,* an M.Eng. in nonlinear structural dynamics from the University of California at Berkeley, and a dual M.B.A./M.Sc. from the Massachusetts Institute of Technology as a *Leaders for Manufacturing* Fellow and researcher with the *Center for Technology, Policy and Industrial Development*. He went on to pursue an interdisciplinary doctorate in strategy, organization and system architecting at MIT's *Engineering Systems Division*, where his research focuses on inter-species competition and the development of a theory of the evolution of business ecosystems.

He spent the early part of his career designing high-rise buildings and long-span bridges as a director of *Ove Arup & Partners* in London, Tokyo and San Francisco. He then moved from "the business of building" to "the building of business" where he was a strategy consultant at *McKinsey & Company.* He currently teaches strategic leadership and macro-level organizational change in executive education programs and graduate courses at MIT's *Sloan School of Management*, the *Engineering Systems Division* and at the University of Oxford's *Saïd Business School*. He is a citizen of the USA and the Netherlands and currently resides in Oxford with his wife and son.




General Outline

Executive Summary

Expanded **Executive Summary**

Main Document:

Part I: RESEARCH DESIGN
Chapter 1: Research Introduction ("what?" and "why?")
Chapter 2: Research Methodology ("how?", "where?" and "when?")

Part II: THEORETICAL CONSTRUCTS & PROPOSITIONS
Chapter 3: Understanding *Long-Term Firm Performance*
Chapter 4: Enterprise *Architectural Forms*
Chapter 5: Enterprise *Competitive Dynamics*
Chapter 6: Enterprise-Environment *Co-evolution*

Part III: INTEGRATING THE THEORY
Chapter 7: Mathematical Model
Chapter 8: Toward a Theory of the Evolution of Business Ecosystems
Chapter 9: Conclusions

Part IV: APPENDICES

This dissertation is presented three successive times in a "telescoped structure", each re-telling representing approximately one order of magnitude more detail and richness than the previous.

First, I present a very brief, *high*-level executive summary of approximately 10 pages, which is intended to rapidly familiarize the reader with the theory developed herein. This is followed by a more detailed, *mid*-level expanded executive summary of approximately 100 pages, which is intended to communicate the research in a format and length suitable for academic journal publication. Finally, I present a more detailed and less-polished, *low*-level dissertation document of approximately 1,000 pages, which summarizes the empirical data and its analysis as well as the theoretical underpinnings and basis for the theory developed herein.

Whatever stage the reader chooses to engage this work, thoughtful and critical comments continue to be welcomed, as this dissertation document does not represent the end of my research journey, but merely the end of the beginning...

Table of Contents

List of Figures

List of Tables

Executive Summary

Intelligent Design:

Architecting World-class Enterprises and *Evolving* Business Ecosystems[1]

As industries evolve, so do winning strategies,
successful organizational forms and effective leadership styles.

Having the knowledge of "what, when and how"
- coupled with the courage to act on this knowledge -
is key to generating and sustaining world-class performance.

[1] Image: "The Ancient of Days (God as an Architect)" by William Blake (1794).

Architecting World-class Enterprises

Recently, the business world has been hit by a global downturn, the likes of which hasn't been seen in nearly a century. We have witnessed some of the world's most powerful incumbents like *General Motors, United Airlines* and even *Boeing* struggle to successfully launch new products and services, access capital reliably, manage global supply chains, avoid damaging labor strikes, maintain strong balance sheets and in some instances avoid bankruptcy.

In understanding these complex times, while the *devil* undoubtedly lies in the details, it is often enlightening to take a 100,000 ft. "*god's*-eye" view of our business ecosystems and how they are evolving. We propose an architectural view.

*Share*holder vs. *Stake*holder Focus

One common view of the objective of business firms is the maximization of shareholder value, where the residual cash flow is returned to the shareholders. This can be seen in many famous incumbent firms, who have built their respective industries, *General Motors* and *Ford* in the automotive industry, and *United Airlines* and *American Airlines* in the US Airline industry.

Toyota Motors and *Southwest Airlines* however appear to be maximizing a very different objective function, that of "stakeholder surplus", where the residual cash flows are shared among the firm's key stakeholders, and in the process, the firm's investors fare better than if their interests were pursued at the expense of the other stakeholders.

The extraordinarily high performance of these firms has been sustained for so long, that perhaps we are looking at a fundamentally different *organizational species*...

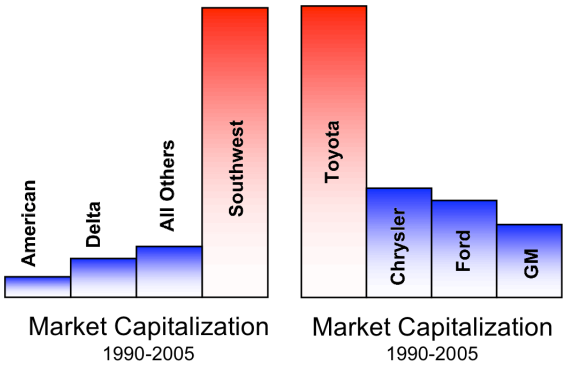
In diverse industries representing both manufacturing and services, two world-class companies in recent decades have held numerous lessons learned for senior managers: *Toyota Motors* in manufacturing, and *Southwest Airways* in services. This article explores what if anything the two have in common – what DNA are shared by this "species"?

First and foremost, is how the "architects" of these world-class enterprises manage their environments, i.e. the things outside of their direct control or responsibility - how to design the objective function, or rather how wealth is created and shared. Examples are shown below:

> *"Under Japanese company law, shareholders are the owners of the corporation. But if corporations are run exclusively in the interests of shareholders, the business will be driven to pursue short-term profit at the expense of employment and spending on research and development. To be sustainable, corporations must nurture relationships with stakeholders such as suppliers, employees and the local community. So whatever the legal position, the corporation does not belong to its owners. It's not enough to serve shareholders."* (Source: Mr. Okuda, Chairman, *Toyota Motors*; *Financial Times*, 1 August 2001).

> *"We can't let investors guide the company. That's not to say that investors aren't smart and don't have good ideas, because they do. They just have different motives. We've got to say true to who we are as a company and build for the long term."* (Source: Gary Kelly, CEO, *Southwest Airlines; The Dallas Morning News*, 20 December 2007).

As seen in the figure below, if those companies designed to maximize shareholder value are in fact delivering significantly less than those who are not trying to maximize that metric, then the question becomes, What on earth is going on here?



Such significant variance in the dependent variable would suggest that significant variance should reside in the explanation or the independent variable. In other words, the extraordinarily high performance of these firms has been sustained for so long, that perhaps we are looking at a fundamentally different organizational species - a fundamentally different enterprise architecture, which is better-suited to significantly different environmental conditions.

Theodore F. Piepenbrock, researches and teaches at MIT's Engineering Systems Division & Sloan School of Management and at the University of Oxford's Saïd Business School.[i]
Charles H. Fine is a Professor at MIT's Sloan School of Management & Engineering Systems Division.

On the Origin of *Corporate* Species

Darwin's work has stirred controversy 150 years ago that, surprisingly is alive today: the confrontation between God and Science...

Within businesses, a "generation" can be thought of as a firm's product or service offering, each new launch, a birth whereby some of the "genes" of the family are carried forward. In this way, the lifecycle of the organization may represent many generations, and a collection of such similar organizations represent a "species".

Modular & Integral Enterprise Architectures

As summarized in the diagram below, a typology of enterprise architectures – a continuum spanning two polar opposites – can be developed which form the basis the DNA of each species.

Objective functions range from the modular enterprise architecture's narrow maximization of shareholder value (competition between stakeholders) to the integral enterprise architecture's broader maximization of stakeholder surplus (cooperation among stakeholders).

In biology and business, morphology trumps physiology – i.e. species type is more important than health of the beast. **A weak cactus will outlive a strong oak... *in a desert*.**

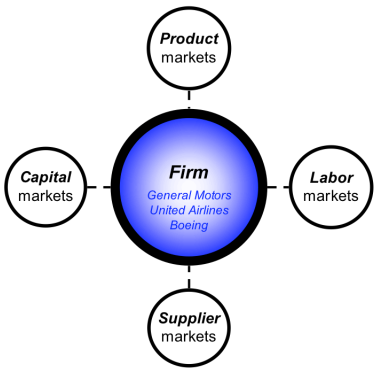
Organizational theorists, called ecologists define "species" as the goals, boundaries and activities of an organization. Similarly architectural theorists define "forms" as objective functions, boundaries, and interfaces. The form or species provides a first-order explanation of performance. In biology and business, whether in organisms or organizations, morphology trumps physiology – i.e. species type trumps the health of the beast. A weak cactus will typically outlive a strong oak... in a desert.

Architectures define how functions decomposed and divided among stakeholders. For simplicity we consider customers and suppliers (the value chain) and capital and labor (the factors of production).[ii]

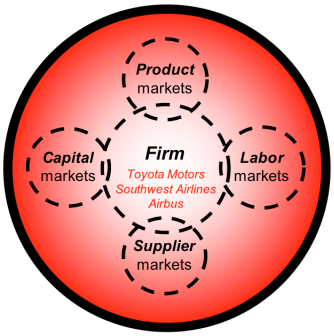
Boundaries define the extent of the stakeholders space and time horizon to be lead by the enterprise architect. Modular EAs have relatively narrow stakeholder interest and shorter time horizons. Integral EAs have relatively broad enterprise boundaries and longer time horizons.

Interfaces define the quantity and quality of the stakeholder relationships. Modular EAs have a large number of competing stakeholders in each class managed with short-term, arm's length contracts, while integral EAs have a small number of cooperating stakeholders in each class managed by long-term trust-based relationships. Modular EAs are therefore "positionally' strong, while integral EAs are positionally weak.[iii]

Modular
enterprise architecture



Integral
enterprise architecture



Singular (Maximization of *Shareholder Value*)	**Objective Function**	***Plural*** (Maximization of *Stakeholder Surplus*)
Narrow (*narrow* spatial, *short* temporal)	Enterprise **Boundaries**	***Broad*** (*broad* spatial, *long* temporal)
Simple (*High* quantity of participants in a stakeholder class, *Low* quality of stakeholder relationships)	Stakeholder **Interfaces**	***Complex*** (*Low* quantity of participants in a stakeholder class, *High* quality of stakeholder relationships)

The Evolution of Business Ecosystems

Having defined the typology of enterprise architectural forms, we can now assemble a theory of how, why and when these forms grow and die. For this, we must describe the changing conditions of the environment, which put pressure on enterprise architectures to either change and adapt to it, or to die under competitive pressures from new enterprise architectural forms – survival of the fittest, with "fit" crucially meaning in synch with what the environment demands, as opposed to "fit" meaning in good shape.

Inter-species Competition

But these two principles raise a perplexing puzzle for corporate leaders. If the ecosystem financially rewards dis-integration of the enterprise architecture in early part of an industry's evolution, but then rewards reintegration as the industry matures, is it easier for the incumbent to do this, or is it easier for a new integral enterprise architecture to be born? This is the crux of architectural leadership: the ability to adapt the boundaries of the enterprise architecture in stakeholder space and time horizons.

While **enterprises seem to naturally disintegrate** over time, reversing this process appears to require extraordinary (and extraordinarily rare) *architectural leadership*.

The environment and firm growth trajectories are characterized on two classical managerial dimensions: market growth rates (i.e. how much) and technology growth rates (i.e. what type). Many industries (e.g. durable goods manufacturers) exhibit a classical S-shaped growth over time, with the annual rates of output therefore following a bell-shaped curve as shown below.[iv]

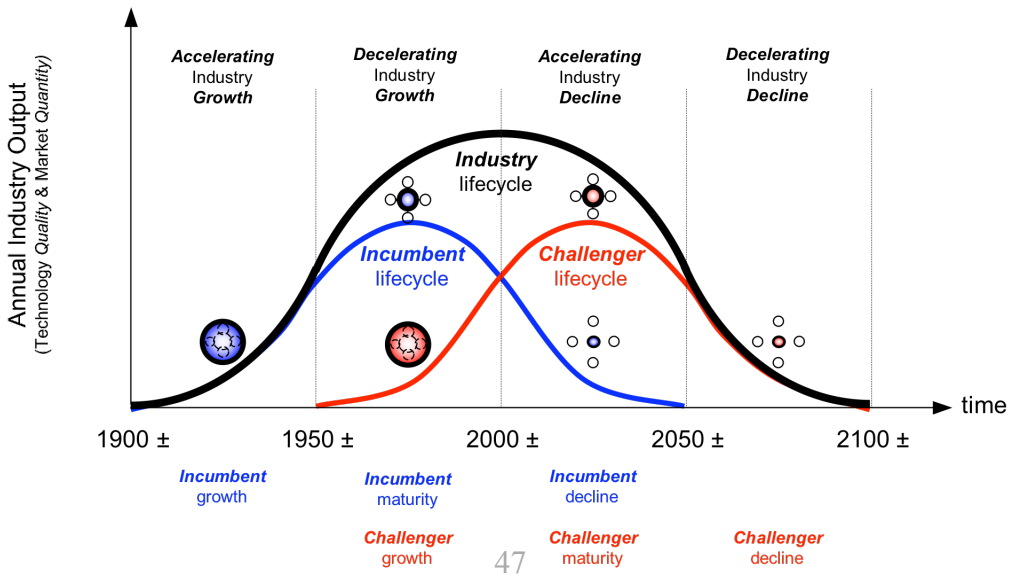
Enterprise architectures early in the industry's evolution are integral, for radical *product* innovation. They then dis-integrate for speed to build a fast-growing market, and for greater cost-leadership and more modest product innovation. As the ecosystem begins to mature, integral enterprise architectures are required for radical *process* innovation.

The principle of *enterprise entropy* states that enterprise architectures tend to dis-integrate over time. The principle of *ecosystem dominance*, however states that winning enterprise architectures oscillate over the life-cycle of their industries from integral to modular and back to integral states.

If such architectural leadership is in fact extraordinarily rare, then this raises the possibility for multiple species to occupy the same niche, incumbent firms having modular enterprise architectures, and late entrant challengers having integral enterprise architectures. Such competition between species is symbiotic, that is one species needs the other.

The market-making "r-strategists" are opportunists that attack markets with unlimited apparent growth potential. One the underlying growth opportunities begin to slow down, they are designed to exit that niche, leaving it to the market-taking "K-strategists", which are designed to thrive in environments with low resource availabilities. In the automotive and airline industries, *GM & Ford*, and *American & United* are market makers, while *Toyota* and *Southwest* are late entrant market makers.

Ironically, what works against competitors in one's own species, is precisely what doesn't work when competing against another species.



Evolution in the *Airplane* Ecosystem

Having described a theory of how business ecosystems evolve, we can now look at the empirical evidence in the ecosystem of commercial airplane design and manufacture – a rich dataset spanning 100 years of evolutionary data thus far, and including such famous r-strategists like *Douglas, Lockheed* and *Boeing*, who created and dominated the ecosystem for some half-century, before the emergence and eventual dominance over the subsequent half-century by the K-strategist, *Airbus* with its renewed integral form of enterprise architecture.

The Fossil Record

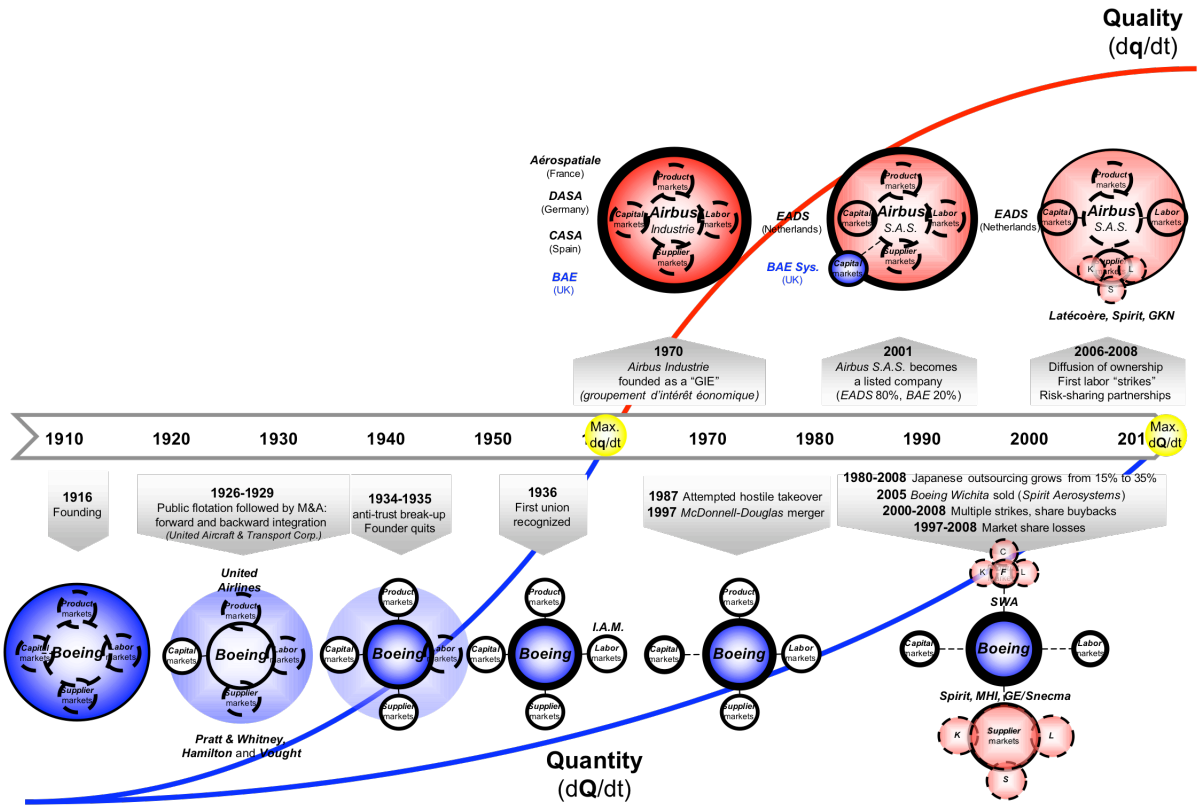
As can be seen in the diagram at the bottom, *Boeing* began its life, early in the industry's evolution as integral enterprise architecture – integral for radical product innovation. It then dis-integrated for speed to build a fast-growing market, and for greater cost-leadership and more modest product innovation. *Airbus* began its life late in the industry's evolution as an integral enterprise architecture – integral for radical process innovation. Both *Boeing* and *Airbus* are on similar trajectories, but *Airbus* is in a much less advanced state of dis-integration.

Boeing, the powerful racehorse, finds itself in ***a desert*** against *Airbus,* a fragile, young camel – but ***a camel*** nonetheless.

The ecosystem is now locked in a unique and epic evolutionary battle between the strongest remaining survivor of the r-strategists (created from the merger of *Boeing* and *McDonnell Douglas*) and the only K-strategist, *Airbus*. This rare inter-species competition – a mixed duopoly – is one of the most fascinating and famous competitions in international business today. We will next examine the "fossil record" of each species to determine who was/is winning, how, when and why.

Boeing, the powerful racehorse, finds itself in a desert against *Airbus,* a weak young camel – but a camel nonetheless. Recalling Collins' famous book, *Boeing* is evolving from "Good to Great"... to Gone.

Let us now turn our attention as business ecologists to the environment to see what types of forces have created and are destroying these enterprise architectural forms – these species.



Ecosystem Maturity: *Quality*

We characterize the maturity of the ecosystem using two broad dimensions: the rate of change in of technology and the rate of change in market size. In other words we are interested in exploring, what is being demanded – the type or *quality* of goods and services and how much is being demanded – the *quantity* of goods and services. Both these dimensions have limits to growth in both supply and demand. We begin by briefly exploring the maturity of the ecosystem in terms of technology demanded and supplied.

Airplane Ecosystem Maturity: *Quality*

In order to illustrate ecosystem maturity in quality space, we turn briefly to the large commercial airplane industry.

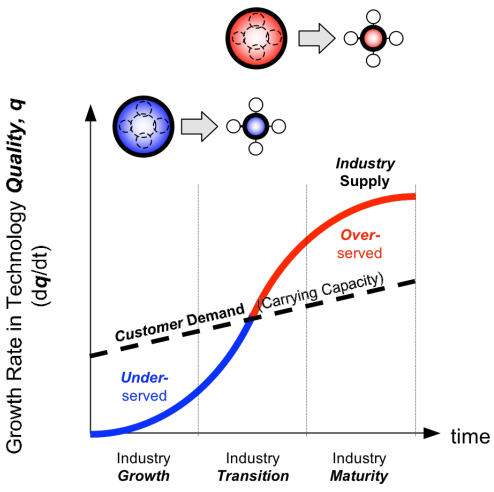
As can be seen in the figures below, the number of major companies competing in this space appears to have risen gradually over the first fifty years of evolution, followed by a gradual fall of companies from this space either through exit or consolidation.[vi]

"Once the dominant design emerges, the basis of *competition changes radically,* and firms are put to the test that very few will pass."

Researchers of the evolution of technological innovation have noted that significant technological events – called "dominant designs" can mark significant transformation of the competitive environment. James Utterback noted, "once the dominant design emerges, the basis of competition changes radically, and firms are put to the test that very few will pass."[v]

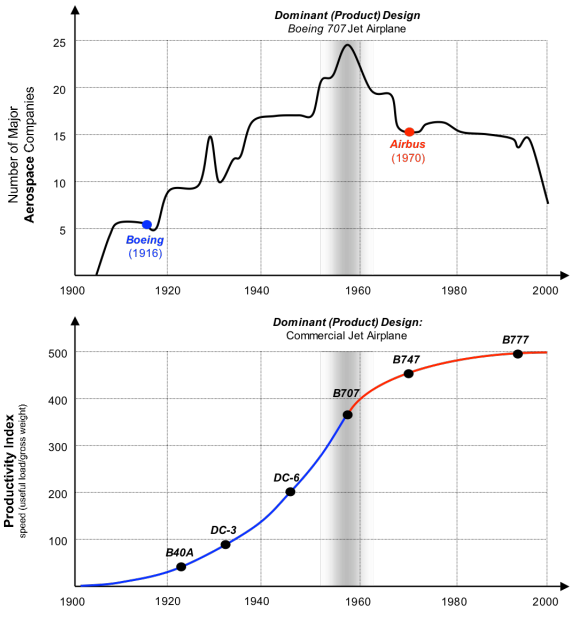
Prior to the dominant product design, the environment is characterized by radical product innovation, with firms competing to establish a standard product, and for customers to accept this as the benchmark. Christensen referred to this as "under-served" markets.

After the establishment of the dominant product design, the environment is characterized by incremental product innovation and the opportunity for radical process innovation, with firms competing to win customers on a quality, cost and delivery basis, as opposed to increasing product performance. Christensen referred to this as "over-served" markets with the conditions ripe for the emergence of a disruptive innovation.



As can also be seen in the figure at the bottom, the transition from firm proliferation towards consolidation occurred in the late 1950s at the emergence of the dominant design: the jet airplane.[vii] Prior to its arrival marked a period of significant uncertainty, experimentation and radical product innovation. After its arrival marked a period of diminishing returns from radical product innovation as technological saturation began to occur in terms of *higher* (40,000 ft cruising altitude), *faster* (just below the sound barrier) and *farther* (half-way around the world).

The basis of competition gradually switched from "higher, faster, farther" to "better, faster, cheaper" which is dominated by radical process innovation, best enabled by integral enterprise architectures – the same which launched the industry 50 years earlier, but this time focused on a radically different objective.



Ecosystem Maturity: *Quantity*

Having defined the first dimension of an ecosystem's maturity, the rate of change of technological growth – *quantity* space, we now turn to the complementary dimension of the rate of change of market growth – *quality* space.

Airplane Ecosystem Maturity: *Quantity*

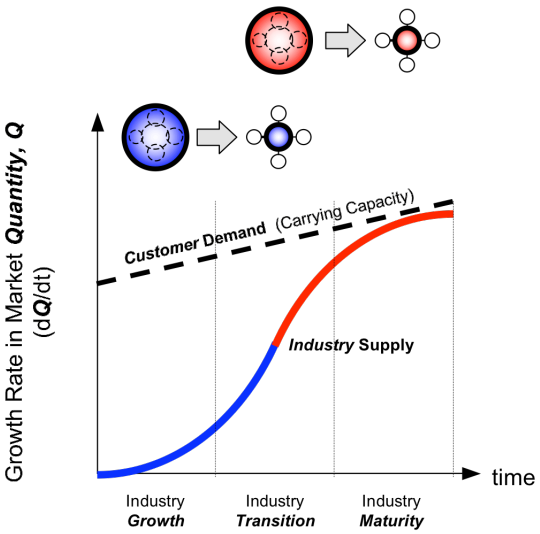
One measure of the maturity of the global commercial airplane industry is to observe the maturity of its customers, the annual global airline industry's available seat kilometers (ASKs).

"Perhaps **the most *ubiquitous force*** leading to structural change **is a change in the *long-run industry growth rate.*"**

In Michael Porter's seminal book, *Competitive Strategy*, he noted: "Perhaps the most ubiquitous force leading to structural change is a change in the long-run industry growth rate."[viii]

As all ecosystems have limits to growth or "carrying capacities", one would expect the rates of change of growth to begin to diminish. The carrying capacities could be defined by the penetration of an innovation into a constant population, or in addition it could capture the slowing of the growth of the population size representing the total market.

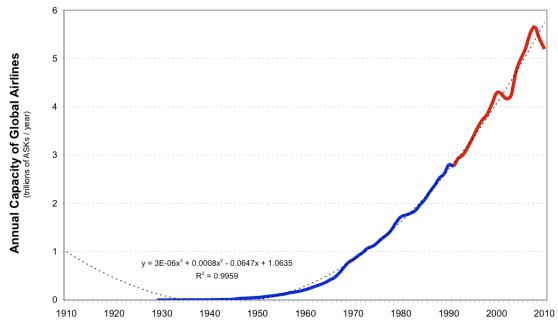
As can be seen in the figure below, the rates of change of environmental growth can impact the types of enterprise architectures which thrive in environments of rapid or slow growth.

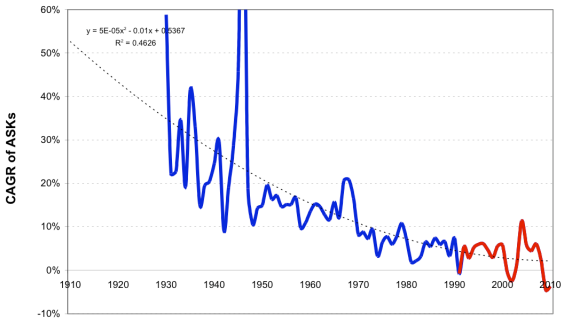


As can be seen in the figure below, global annual ASKs have grown exponentially since the industry began in the 1920's.

As the world's population is beginning to saturate, with ultimate size of around 10 billion people occurring between 2050 and 2100, one would expect this to impact the amount of air travel. Early indications are that this long-term rate of growth has started to inflect and will continue to grow, but at increasingly slower rates.

The implication of this slowing underlying growth rates is to continue to favor those enterprise architectures which are built to grow in environments that aren't. This will be discussed in the following sections.





Firm Strategies: *Quality*

While the "ecosystem" defines the broad industry where competition is taking place (e.g. automobiles, airlines, airplanes), "niches" define where these species chose to live and compete. In market strategy space this can be thought of as Michael Porter's *generic strategies* of *differentiation* and *cost-leadership*. We refer to these distinctions as either "Higher, Faster, Farther" (which refer to competition based on product performance) and "Better, Faster, Cheaper" (which refer to competition on the basis of quality, delivery and cost).

Differentiation vs. Cost-Leadership

We now briefly look at the long-term trajectories of market strategies of each pair of species in our three ecosystems.

As shown in the figure below, the respective incumbents *General Motors, United Airlines* and *Boeing* initially gained their dominance via *product* innovation which moved them initially from differentiation (enabled by an integral enterprise architecture) towards cost-leadership strategies (enabled and constrained by a modular enterprise architecture).

Enterprise architectures enable and constrain strategy. *Integral* EAs confer *exploration* advantages, while *Modular* EAs confer *exploitation* advantages.

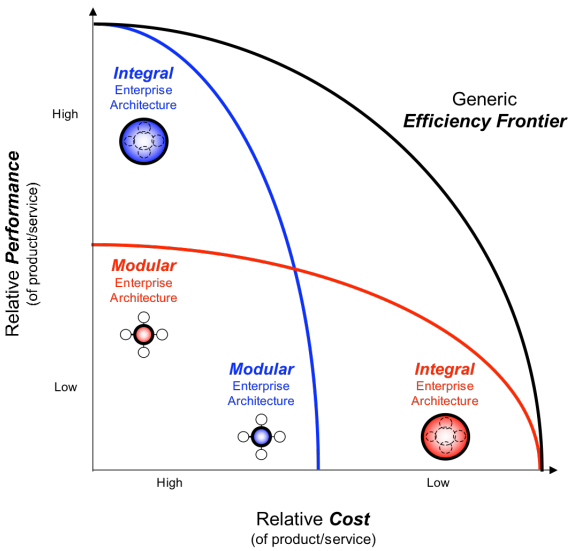
As Porter popularized in his 1996 HBR article, firms have an *efficiency frontier* which conceptually demonstrates a tradeoff between the generic strategies of differentiation and cost-leadership.[ix] What our research demonstrates is that a) enterprise architectures both enable and constrain choice of generic strategies, and b) each enterprise architecture has a skewed efficiency frontier which can bias its strategic choice.

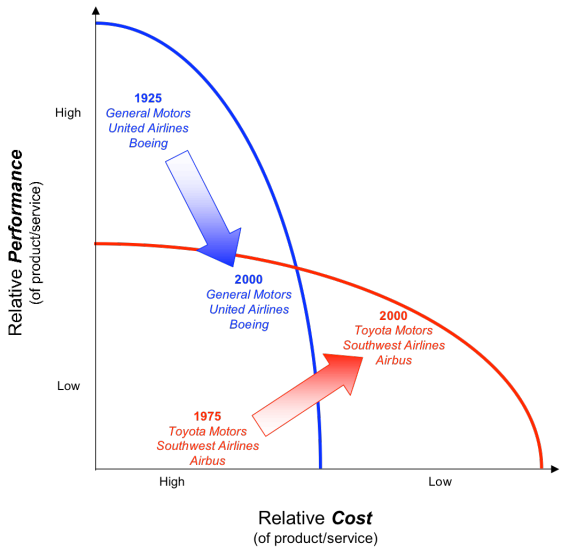
As shown in the figure below, integral enterprise architectures confer *exploration* advantages in radical innovation of both products and processes, via patient capital investing in long-term physical or human capital, with rapid and frequent feedback between customers and suppliers. Modular enterprise architectures on the other hand confer *exploitation* advantages via impatient capital driving faster short-term decisions, functional-specialization and market-based competition between and among stakeholders.

Conversely, the late-entrant challengers *Toyota Motors, Southwest Airlines*, and *Airbus* initiated their dominance competing in mass markets as cost-leaders via *process* innovation enabled by integral enterprise architectures. Examples from the early decades of each late-entrant include *Toyota's* cheap cars, *Southwest's* cheap seats, and *Airbus'* short-haul, high-volume airplanes.

Over time, their enterprise architectures are disintegrating, enabling them to move from mass markets of cost-leadership into fragmented niches of differentiation. Examples of these new niches might include *Toyota's* Lexus, and *Airbus'* long-haul, low-volume A380 superjumbo.

Today, all the companies in our sample find themselves in maturing, commoditizing mass markets, and with the late entrants out-competing their powerful incumbents in the cost-leadership space, as their architectures enable them to do so.





Firm Strategies: *Quantity*

The level of vision or myopia appears to be a function of the enterprise architecture. That is, the more patient the capital, the more long-term the trust-based partnerships, the more complex the stakeholder tradeoffs, the slower the short-term speed, but the faster the long-term speed of integral enterprise architectures, like *Toyota, Southwest* and *Airbus*. Conversely, the less patient the capital, the more short-term and contractual the relationships, the more simple the inter-stakeholder objective function, the faster the short-term speed, but the slower the long-term speed of the modular enterprise architectures, like *GM, United* and *Boeing*. This is a classic "tortoise-hare" story, where the race does not always go to the swiftest.

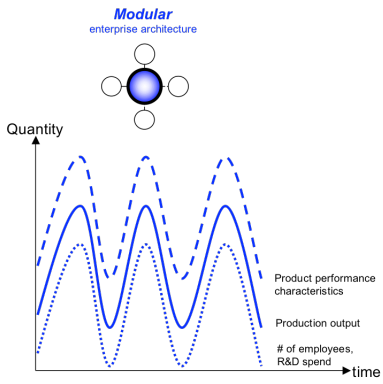
The Tortoise and The Hare

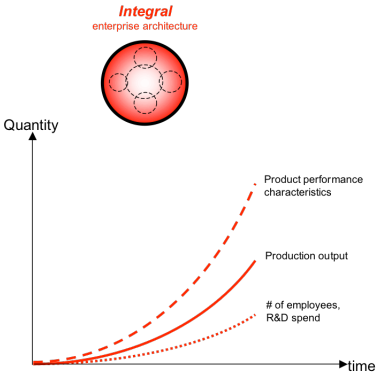
"Boeing quickly moved last week to cut commercial transport delivery in an announcement that surprised even some veteran Boeing-watchers by its swiftness and scope. At a hastily arranged news conference Sept. 18, one week after the terrorist attacks in the U.S., the company said it could also lay off up to nearly one-third of its commercial aircraft workforce. Alan R. Mulally, Boeing president and CEO of Boeing Commercial Airplanes, said 'When you order airplanes today, the lead time is anywhere from 10-14 months, so we need to make these decisions for production next year as soon as possible.'" (Source: Alan Mulally, President & CEO, *Boeing Commercial Airplanes*; *Aviation Week*, 24 Sept. 2001).

"History tells us that the quicker a company acts to counter adverse economic conditions, the better able it will be to work its way through a downturn and emerge stronger when the economy recovers." (Source: Jim McNerney, Chairman, President & CEO, *The Boeing Company*; memo to employees, 17 Feb. 2009)

Modular enterprise architectures are built for *short-term* speed, while integral enterprise architectures are built for *long-term* speed. ***This is a classic tortoise-hare story.***

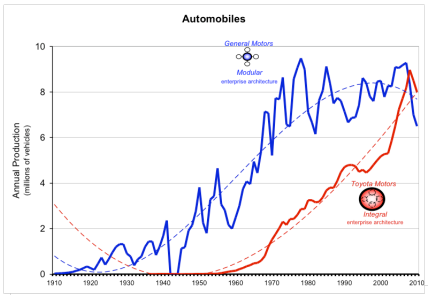
Modular enterprise architectures, therefore create or amplify the instabilities that they are designed to serve – i.e. the boom-and-bust "business cycle". Integral enterprise architectures, on the other hand create or dampen the stabilities that they are designed to serve – i.e. *Toyota, Southwest* and *Airbus* do not see such a severe cycle. The principle of *optimum speed* states that in maturing environments, the optimum rate of growth is much slower than the maximum possible. The behaviors of these architectures are summarized below.

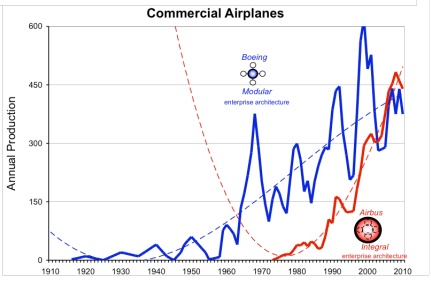


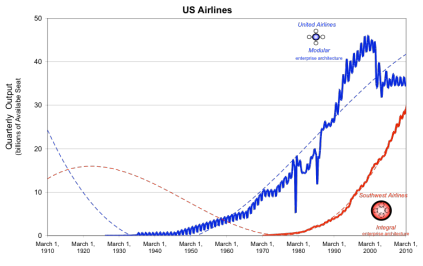


"I am always a bit surprised by the speed with which Americans take decisions: that in three days (after 9-11) they announce 25,000 lay-offs at Boeing seems to me totally stupefying," (Source: Noel Forgeard, CEO, *Airbus*; AFX, 21 Sept. 2001).

"We've always been much more careful about production rates. We do see peaks and troughs but we've always managed to limit the highs and lows better than they do in the USA." (Source: Philippe Camus, *EADS* Co-Chairman; *ATI*, 20 Sept. 2001).







Financial Performance: *Revenues*

Corporate value – or at least expected value – comes from a company's ability to grow its top-line revenues, and ultimately convert this into bottom-line profits. The data seem to suggest that early entrant modular and late entrant integral enterprise architectures grow in different ways in different stages of an industry's life-cycle and therefore focus on different sides of this income statement equation.

Modular enterprise architectures, those which launch and exploit industries, attract investors who value top-line revenue growth potential. The conversion of this into bottom-line profits is taken as an article of faith.

Financial Performance: *Profits*

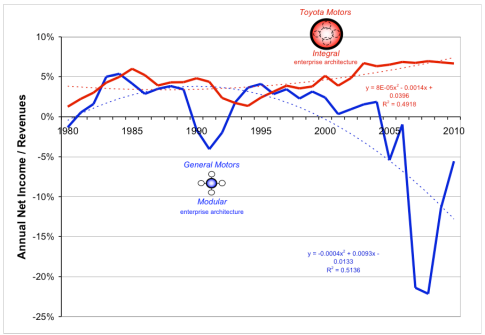
Conversely, where *growth* investors favor industries with inherently rapid top-line revenue growth, *value* investors tend to be more impressed with the conversion of top-line growth into bottom-line profits. This emphasis tends to be more prevalent in industries where inherent top-line growth has diminished and focus has shifted towards companies that can grow profits in environments that aren't growing.

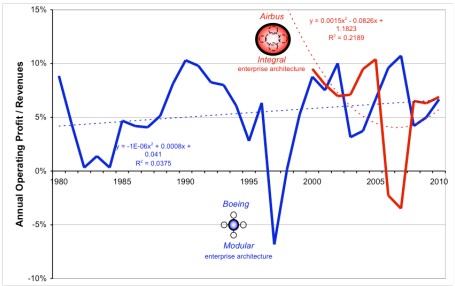
Integral enterprise architectures, those which overtake incumbents, attract investors who value bottom-line profit growth. Top line growth occurs inadvertently, as these companies take market share from incumbent modular enterprise architectures

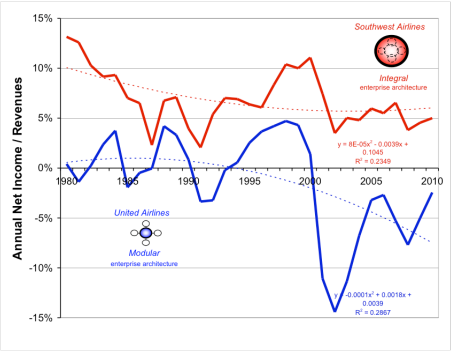
Modular enterprise architectures are focused on ***top-line revenue growth,*** while integral enterprise architectures are focused on ***bottom-line profit growth.***

Agency Theory posits that the separation of ownership from management creates the principal-agent problem, in which the managerial agents are incentivized to grow the top-line revenues, while the investors would prefer the growth of bottom-line profits.

As seen in the figures to the right, we combine the top –line and bottom-line revenues into a profitability or return on sales metric. Over the last 30 years, in industries that are in a maturing state, it appears that late entrant integral enterprise architectures are exhibiting profit margins that are not only higher than those in incumbent modular enterprise architectures, but their trajectories are increasing over time, while those of the modular enterprise architectures are falling.







The Power of Architecture

Let us now summarize the journey that we have been on. In order to explain the sources of long-term firm performance, we traced two concurrent causal loops in technology (quality) and market (quantity) space, through the architectural processes macro-organizational form, function and fit with the environment. These processes arise in the study of organisms as well as organizations: morphology and physiology and ecology – the definitions of species. The power of architecture is summarized in the figure below.

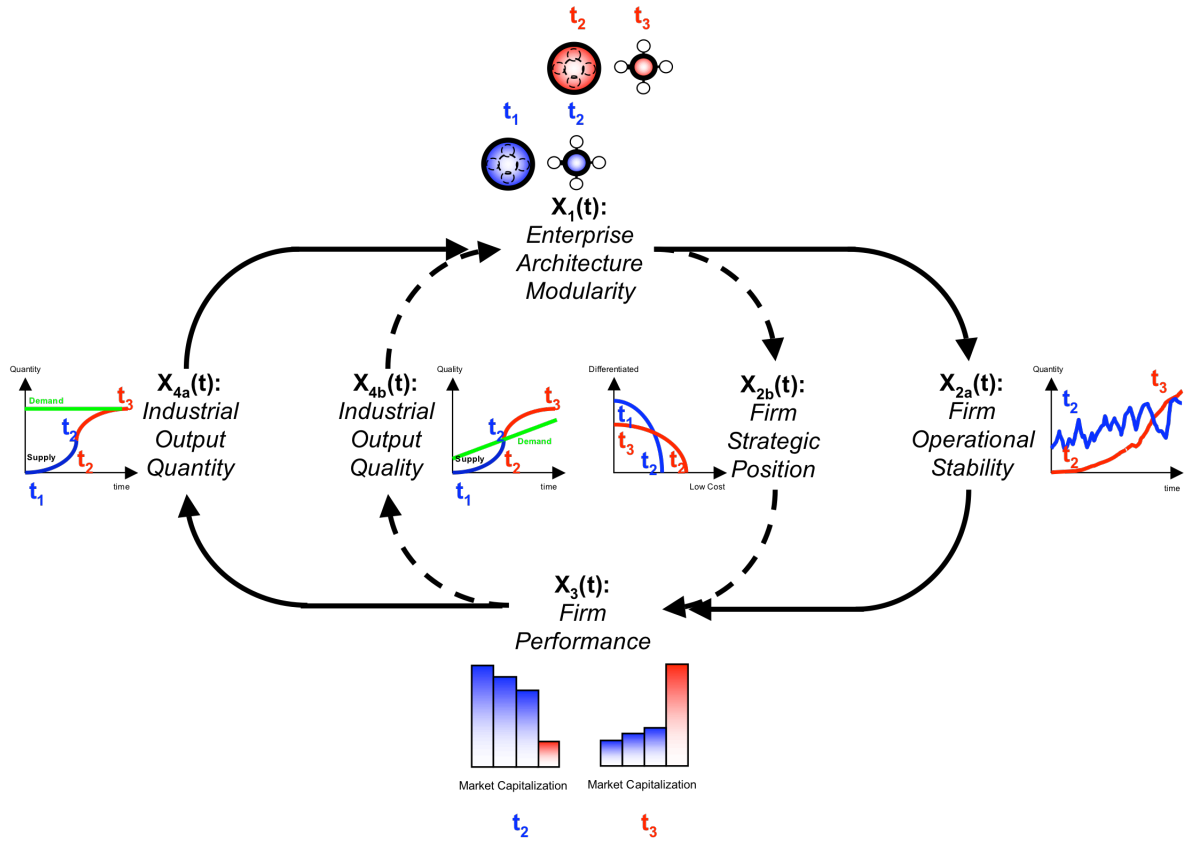
The Architecture of Power

What makes the design, operation and evolution of organizations many of orders of magnitude more complex than that of organisms, is that the functional "modules" of organisms (e.g. heart, brain, etc.) tend not to have different goals and objectives from the whole organism. The same is not necessarily true with macro-organizations or extended enterprises, where investors, unions, customers and suppliers can and often do have conflicting goals and objectives from that of the enterprise.

The business firm is a *political coalition* and the executive is a *political broker*. The composition and goals are not given, they are negotiated and bargained.

The architecture of the extended enterprise is one of the most powerful concepts in determining long-term firm performance as it both enables and constrains choice of strategic position as well as operational growth rates. The entrepreneurial architect can seek to radically transform the environment by launching the next discontinuous innovations via integrality. S/he can dis-integrate the architecture to exploit the market growth, or s/he can either attempt to re-integrate the architecture to fit with the demands of a maturing ecosystem, or establish a new integral architecture.

Many years ago, organizational theorist James March developed a theory of the firm as a political coalition, in which "The business firm is a political coalition, and the executive is a political broker. The composition of the firm is not given; it is negotiated. The goals of the firm is not given; they are bargained. Political scientist Robert Dahl defined "power" as "the ability to get things done when goals conflict". From these power and political perspectives, we begin to see the secrets of successful enterprise architecting, which we will summarize next.



Design Intelligence: Knowledge & Courage

The nervous system of the organization appears to be distributed vertically throughout the hierarchy as well horizontally throughout the extended enterprise like the nervous system of an organism. Within the macro-organizational "brain" lies the development and dissemination of system-level *knowledge* and *courage* – design intelligence – which too is a distributed activity.

Evolution by Intelligent Design

So which is it that drives the evolution of business ecosystems - Intelligent Design or Evolution by natural selection? Visionary and courageous architects create both the enterprises and the environment that their business will operate in. Both these will enable and later constrain what future leaders can do. After creating the environment, subsequent architects can match the environment's demands by disintegrating their enterprises. Further reintegration of the incumbents has (thus far) proven elusive, providing a new opportunity for new visionary and courageous architects to re-set the evolutionary clock back to integrality.

In the *Intelligent Design* vs. *Evolution* debate,
dominant organizational species *evolve* through the *intelligent design* of their extended enterprises.

System-level *knowledge,* what do each set of stakeholders want? What is the optimum balanced tradeoff to maximize the enterprise's value over the time horizon that I am interested in. This is a raw intelligence exercise, both at the top and distributed vertically and horizontally.

System-level *courage*, how do I enact this decision? This is an emotional intelligence exercise, both at the top and distributed vertically and horizontally.

For *Southwest Airlines*, the source of integrality may be/have been it pull from the center by CEO Herb Kelleher. For *Airbus*, it may be pushed together from the outside social forces. For *Toyota*, it might be both push and pull.

Architectural Leadership Lessons:

From this research, we have seen that architectural leadership has the following characteristics:

- Architectural Leadership is a political process of making complex trade-offs with "external" stakeholders.
- It requires extremely high levels of intelligence or personal knowledge of the ecosystem and emotional intelligence to develop long-term, trust-based relationships, and the courage to enact complex decisions.
- This knowledge and courage, while often developed at an early age, is in fact strengthened via enterprise crucibles, in which key leaders of one's enterprise develop shared knowledge and courage together over time.

It appears therefore, that in the Intelligent Design vs. Evolution debate, dominant organizational species evolve through the intelligent design of their extended enterprises. *Variation* is not entirely random, and the *selection* forces directing such evolution are not supernatural. Instead such architectural direction is often superhuman, notwithstanding the fact that even the most powerful business "gods" appear to have their limits.

This research is "agnostic" over which enterprise architecture is better – there is no one best way that excels in all situations. Like evolution, it merely states that the state of the environment defines which "leadership genes" will be selected and which "organizational species" will dominate.

---

[i] This article is based primarily on the finding s of a seven year international research project. See Theodore F. Piepenbrock, "*Toward a Theory of the Evolution of Business Ecosystems: Enterprise Architectures, Competitive Dynamics, Firm Performance and Industry Co-Evolution*", MIT PhD Dissertation, 2009.

[ii] This is a development of the theory presented in Charlie H. Fine's *Clockspeed: Winning Industry Control in the Age of Temporary Advantage,* 1998, Perseus Books.

[iii] This is according to classic organizational economic theory, like Porter's Five Forces framework.

[iv] Michael Porter noted: "The grandfather of concepts for predicting the probable course of industry evolution is the familiar life-cycle." See Michael E. Porter, *Competitive Strategy*, 1980 The Free Press: New York, pg. 157.

[v] James M. Utterback, *Mastering the Dynamics of Innovation*,1994, HBS Press, pg. 24.

[vi] See Murman et al. Lean Enterprise Value, 2002.

[vii] See McMasters and Cummings, "Airplane Design - Past, Present and Future." *Journal of Aircraft*, Vol. 39. 2002

[viii] See Michael E. Porter, *Competitive Strategy*, 1980, The Free Press: New York, pg. 164.

[ix] See Michael E. Porter, "What is Strategy?" *Harvard Business Review*, November-December, 1996, pp. 61-78.

Expanded Executive Summary

ABSTRACT

At its most fundamental level, this paper addresses the following question that has been posed by evolutionary theorists in the economics and sociology literatures for decades:

"Why do firms in the same industry vary *systematically* in performance *over time*?"

Seeking a *systematic* explanation of a *longitudinal* phenomenon inevitably requires characterizing the evolution of the ecosystem as both the organization and its environment are co-evolving. We therefore explore this question through the lens of Engineering Systems: 1) within the *domain* of Extended Enterprises, where we examine architectural competition in three classic engineering systems: aerospace, automotive and airlines; and 2) using the *approaches* of Design and Dynamics, by analyzing enterprise architectures and their change management processes and by modeling the competitive dynamics of these complex ecosystems.

This research lies at the intersection of the intellectual domains of strategic management, organizational science and complex systems theory. It aims to contribute to fundamental debates in these fields regarding the source of long-term firm performance – namely does it reside within the firm or in the firm's environment, and what are the roles of managerial adaptation and environmental selection in its creation? Crucially, how does this shape our understanding of strategic leadership?

We build grounded theory based on empirical findings which suggest that sources of firm performance appear to lie neither exclusively within the firm, nor in its environment, but in *how* the firm interacts with its environment – i.e. in the network *architecture* of the firm's extended enterprise which enables and constrains managerial agency through spatially and temporally bounded rationality. A theoretical framework is proposed which endogenously traces the co-evolution of firms and their environments using their highest-level system properties of *form, function* and *fitness* (reflected in the system sciences of *morphology, physiology* and *ecology*). The framework captures the path-dependent evolution of heterogeneous populations of extended enterprises engaged in *symbiotic inter-species competition* and posits the evolution of "dominant designs" in enterprise architectures that oscillate deterministically and chaotically between *modular* and *integral* states throughout an industry's life-cycle. Architectural innovation – at the extended enterprise level – is demonstrated to contribute to the failure of established firms, with causal mechanisms developed to explain tipping points.

The research is based primarily on a seven-year, multi-level, multi-method, longitudinal empirical case study of two firms in a global *mixed* duopoly as well as the key stakeholders in their extended enterprises. The theory is further tested and generalized across a theoretical sample of firms in manufacturing and service sectors, with both historical comparative analysis and nonlinear dynamic simulation models developed to capture the evolution of business ecosystems. The resulting framework is grounded empirically, analytically as well as theoretically by synthesizing a broad range of literatures from economics to sociology and from physics to biology.

INTRODUCTION

Research Question

At its most fundamental level, this paper addresses the following question that has been posed directly and indirectly by evolutionary theorists in both the economics (Nelson, 1991) and sociology (e.g. Hannan & Freeman, 1977; Carroll, 1993) literatures:

> "Why do firms in the same industry vary *systematically* in performance *over time*?"

Although it is typical that the unit of analysis is the firm and the dependent variable is long-term performance, addressing this question more subtly requires a *systematic* explanation of *longitudinal* phenomena, which inevitably requires characterizing the evolution of the business ecosystem, as both firm and industry are co-evolving.[2]

Early in our research, intriguing empirical data began to be revealed: as firms and industries co-evolved, the dominant form of the firm's objective function and its resulting interaction with its environment appeared to change. This manifested itself in the counter-intuitive observation that firms which were not focused on exclusively maximizing shareholder value, were in fact delivering significantly more of it than firms who focused exclusively on maximizing it. This result appeared in a variety of industries ranging from manufacturing to services. The exploration of why, when and how this phenomenon happens became a driving impetus of the research. Thus a second question emerged which appears to lie at the heart of the first question which was originally posed fifty years ago by Edith Penrose (1959):

> "How do firms that have a *stakeholder* approach differ in competitiveness from firms that maximize *stockholder* wealth?"

Proposed Theoretical Framework

Most research implicitly assumes that competing firms are of the same species, and thus focus on second-order *efficiency*-based explanations. We propose an alternative first-order *effectiveness*-based explanation, namely that where significant sustained long-term variance in performance between firms exists (e.g. *Toyota Motors* vs. *General Motors*, or *Southwest Airlines* vs. *United Airlines*) it is more productive to classify such competition as *inter-species*. We therefore characterize a late-entrant "challenger" species of organization (driven to maximize *stakeholder surplus*) which has evolved to systematically out-compete over the long term, the traditional "incumbent" species (driven to maximize *shareholder value*).[3]

We will argue that firms adopting different objective functions, will have different enterprise architectural forms (Hannan and Freeman, 1977), and will present a typology of isomorphic (DiMaggio and Powell, 1983) organizational sets ranging from integral to modular enterprise architectures, and having different levels of fit with their environment (Lawrence and Lorsch, 1967). In addition, the greater the variance in architectural forms, the greater the potential variance in long-term firm performance, contingent upon the demands and opportunities provided by the competitive environment of the enterprise's ecosystem.

---

[2] Wiggins & Ruefli (2002) empirically explore the sustainability of competitive advantage using a rare longitudinal sample comprising 6,772 firms in 40 industries over 25 years, demonstrating just how rare the phenomenon is.

[3] Note: in order to assist the reader to easily and rapidly identify the various "species" throughout this paper, we highlight in **blue**, the early-entrant incumbent species and in **red**, the late-entrant challenger species.

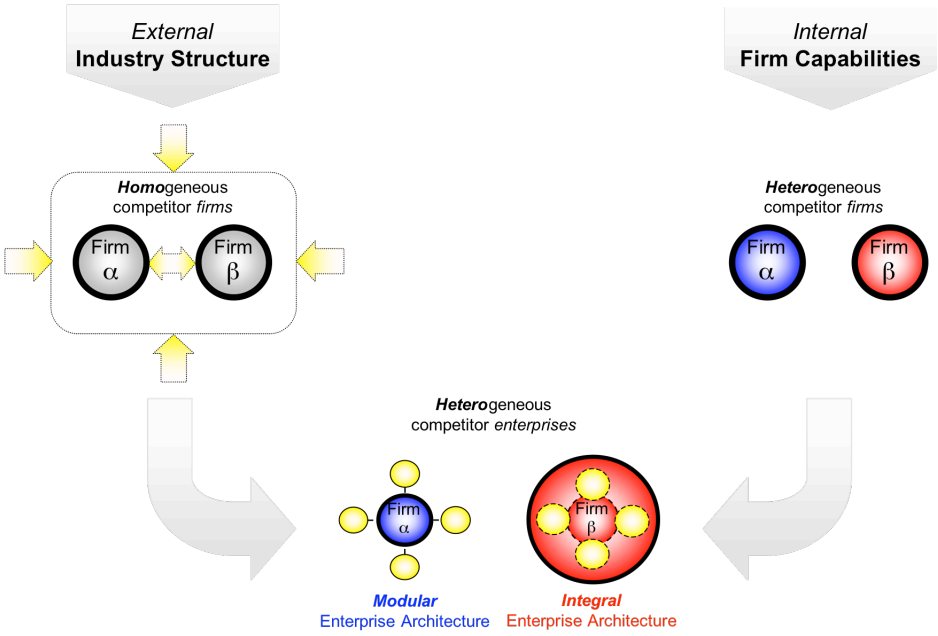
LITERATURE REVIEW

Situating within the Literatures

While significant research has been undertaken to understand how firms compete and (separately) how environments evolve, little theoretical work has been undertaken to understand how organizations and environments interact and co-evolve, and even less empirical work exists to begin to ground such theoretical studies. In the following, we briefly summarize three broad literatures, situating our potential contribution within them.

Strategic Management. Research on competition between firms is mature, and captures a rich debate which spans exogenous industry-level explanations for firm performance (Mason, 1939; Bain, 1956; Porter, 1980 and 1985), as well as endogenous firm-level explanations (Penrose, 1959, Wernerfelt, 1984) known as the resource-based view. Relatively little work has been done to begin to endogenize the environment in order to provide a higher-level of analysis – that of competition between organizational sets (i.e. extended enterprises), and the resulting evolution of organizational fields (i.e. ecosystems) as shown in Figure 2 below. Importantly, this analysis of "how" the firm engages the environment begins to re-ingtegrate strategy *process* and strategy *content* schools (Petttigrew, 1992).

Figure 2: Contributing to the Debate in Strategic Management

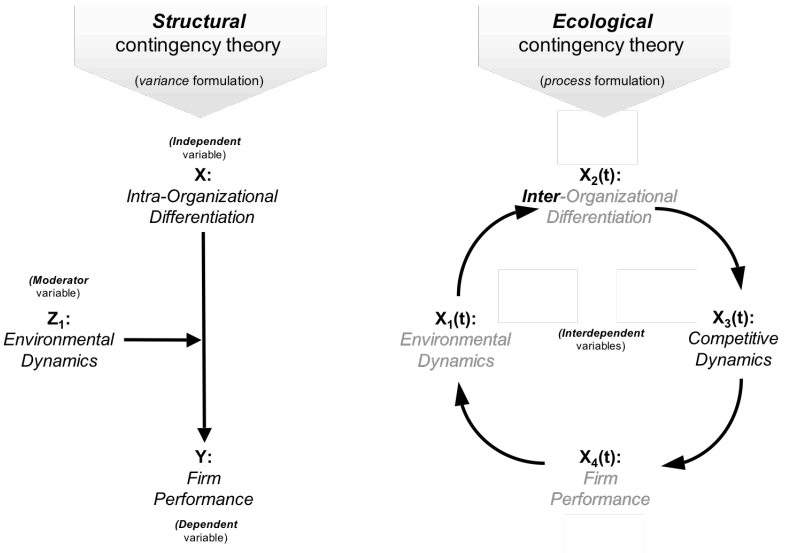


The industrial organization literature characterizes the firm's environment as a locus of competition or "extended rivalry" (Porter, 1980), with the objective function of the firm being profit-maximization, usually for maximizing the objective function of one specific stakeholder: the shareholders, resulting in a zero-sum competition within the organizational set. Conversely, relatively little work has been done to characterize other forms of organizational set, where the objective function is a more plural maximization of stakeholder surplus (Freeman, 1984) and the interaction between the two in *mixed duopoly* (e.g. Lambertini and Rossini, 1998). The *strategic complementarities* literatures in economics and political science (e.g. Milgrom and Roberts, 1990 and 1995; Hall and Soskice, 2001) have produced the basis from which to build empirically.

Organization Science. Within the broad field of open systems organization science, the past 30 years has seen the emergence and maturing of four major "schools" under the rubric of "organizations and environments" (Scott, 2003): organizational ecology (Hannan and Freeman, 1977 and 1984), neo-institutionalism (Meyer and Rowan, 1977; DiMaggio and Powell, 1983; Uzzi, 1997), resource dependence (Pfeffer and Salancik, 1978) and transaction cost economics (Williamson, 1975 and 1985). While these schools tend to address the limitations inherent in the strategic management literature – namely exogenous treatment of the environment – each has its limitations in endogenizing the environment. Organizational ecology and neo-institutionalism tend to focus on populations of isomorphic organizations; resource dependence tends to focus on static distributions of power within an organizational set; transaction cost economics tends to focus on efficiency as the primary driving mechanism defining firm boundaries. This paper attempts to address these limitations, namely: heterogeneous populations, competing dynamically, with effectiveness (not efficiency) being the governing performance mechanism (Brittain and Freeman, 1980; Brittain, 1994).

Finally, the theory that contributed significantly to the development of the aforementioned four schools over 40 years ago, *structural* contingency theory (Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Thompson, 1967) proposed a similar framework to the *ecological* contingency theory presented herein with two noteworthy differences. First, their *intra*-organizational characterization of the processes of differentiation and integration has similarities to architectural modularity and integrality presented herein, but now with *inter*-organizational focus. Second, their contingency theoretic framework was essentially expressed as *variance* theory, with the environmental variable expressed as a moderator variable, and no explicit mediator variable. This paper attempts to build from Lawrence and Lorsch's (1967) classic by 1) moving from firm to organizational set as the unit of analysis, and in doing so, 2) endogenize the environment in a process theory. The micro-mechanisms of managerial agency are captured across the macro-level of the organizational set and included as mediator variables covering strategic and operations choices. The differences between the variance-based *structural* contingency theory and the proposed process-based *ecological* contingency theory are summarized in Figure 3 below.

Figure 3: Comparing *Structural* Contingency Theory with *Ecological* Contingency Theory



Complex Systems Theory. While the two literatures mentioned above, each focus on organizational systems, the complex systems literature concentrates on the abstract principles governing general systems ranging from physical, to biological, to organizational. While general systems theory is a broad and mature literature (Von Bertalanffy, 1950 and 1962), we aim to focus this discussion on three primary threads of system science: system architecture, system dynamics, and ecosystem dynamics which theorize about complexity.

System architecture has its roots in managing *functional* complexity (Simon, 1962; Alexander 1964; Rechtin, 2000). It has impacted various socio-technical domains, including: product design (Ulrich, 1995) and more recently in *intra*-organization design (Anderson and Tushman, 1990; Henderson and Clark, 1990) and *inter*-organization design (Langlois, 1988; Sanchez and Mahoney, 1996; Fine, 1998; Schilling, 2000; Sako, 2003; Aoki and Jackson, 2008). While much of this work focuses on supply chain design, little of it focuses explicitly and more broadly on the architecture of entire organizational sets. This literature would therefore be an example of *progressive* intertextual coherence (Locke and Golden-Biddle, 1997).

System dynamics has its roots in defining and managing *dynamic* complexity in social systems (Forrester, 1961; Sterman, 2000), that is, where cause and effect are distant in space and time. Although it has been applied to various complex organizational settings (Forrester, 1958; Hall, 1976; Morecroft, 1985; Sastry, 1997; Repenning, 2002), it has only occasionally been used to explain how the competitive dynamics among firms interacts with the industry's evolution. Where such studies have been made (Paich and Sterman, 1993), inter-firm competition occurs between homogeneous enterprise architectures. System dynamics has yet to be combined with system architecture to develop a theory of how functional and dynamic complexity evolve in organizational settings. Again, this literature would be another example of *progressive* intertextual coherence.

Ecosystem dynamics has its roots in defining *competitive* complexity. While population growth models have a long history (Verhulst, 1938), and simple intra-species competition models have been proposed (Lotka, 1925; Volterra, 1931; Hannan and Freeman, 1977), only more recently have inter-species typologies been proposed in biology (MacArthur and Wilson, 1967) and subsequently in sociology (Brittain and Freeman, 1980). The science of ecosystem dynamics has yet to develop significant theoretical and empirical research on inter-species competition. Again, this literature would be another example of *progressive* intertextual coherence.

Problematizing the Literatures

Having situated this paper within the extant literatures, we would like to now note where this paper departs and where possible contributions may lie.

Incomplete. From the above discussion of a variety of literatures interested in explaining the dependent variable of organizational performance, it is clear that the literatures, while mature, are *incomplete*. A gap exists regarding how competition occurs at the organizational set level and how these co-evolve with the organizational fields within which they are embedded.

Inadequate. The extant literatures have not adequately addressed the question, by underemphasizing the role that complexity (functional, dynamic, behavioral, and competitive) plays in understanding the evolution of business ecosystems. System architecture and ecosystem dynamics serve as a set of organizing principles which characterize the evolution of a spectrum of system forms, functions and environmental fit.

Incommensurate. Finally, because these extant literatures have gaps that have not been filled, or have been filled with inadequate literatures, there are rare but noteworthy cases where the extant theories can result in misleading characterizations of competition and industry evolution. Examples of such counterintuitive insights, which go against the received conventional wisdom - discussed later in this paper - are briefly summarized.

In the strategic management literature's industry structure school (Porter, 1980), the treatment of members of one's organizational set as "extended rivals", may not under certain conditions result in maximization of profits to the focal firm. Likewise, the objective function that seeks to maximize shareholder value, may not under certain conditions achieve its aim. Conversely, the objective function that seeks to maximize stakeholder surplus, may under certain circumstances achieve more shareholder value than firms who are expressly trying to maximize this metric.

In the organizational ecology literature (Hannan and Freeman, 1977), which assumes homogenous *intra*-species competition, late entrants exhibit higher mortality rates than early entrants. However, when competition involves heterogeneous *inter*-species competition, late entrants not only survive, they can end up dominating the industry.[4]

Contribution to the Literatures

Although the fields of strategic management and organization science, with their half-century old roots in economics and sociology are considered by many to be mature, there is clearly an opportunity to integrate prior streams of research from distant disciplines to produce a new framework in order to resolve its original unsolved debates of *internal* vs. *external* sources of firm performance and *adaptation* vs. *selection* processes of organizational change. A contribution might be made in bringing for the first time, a typology or configuration from the intellectual domains of system architecting and system dynamics (i.e. complexity science) formally and systematically to the study of organizations in order to explain their evolution, structure, function and performance.

Methodological Fit with the State of Literature

From this discussion of the extant literatures, it is clear that the strategic management field exists in a general state of maturity, particularly with respect to the establishment of *variance* theories that explain sources of competitive advantage and firm performance. Strong methodological fit exists, therefore with more quantitative methods to test and validate these existing theories (Edmondson and McManus, 2007).

However, as little empirical and theoretical research exists to describe *how* business ecosystems evolve, the state of the field with respect to *process* theory can be considered nascent. In this research environment, strong methodological fit exists for a more qualitative approach to the research design.[5] In the following section, therefore we will describe the research methods that are designed to meet the challenges of this nascent literature.

[4] Under the environmental conditions of industry maturity.

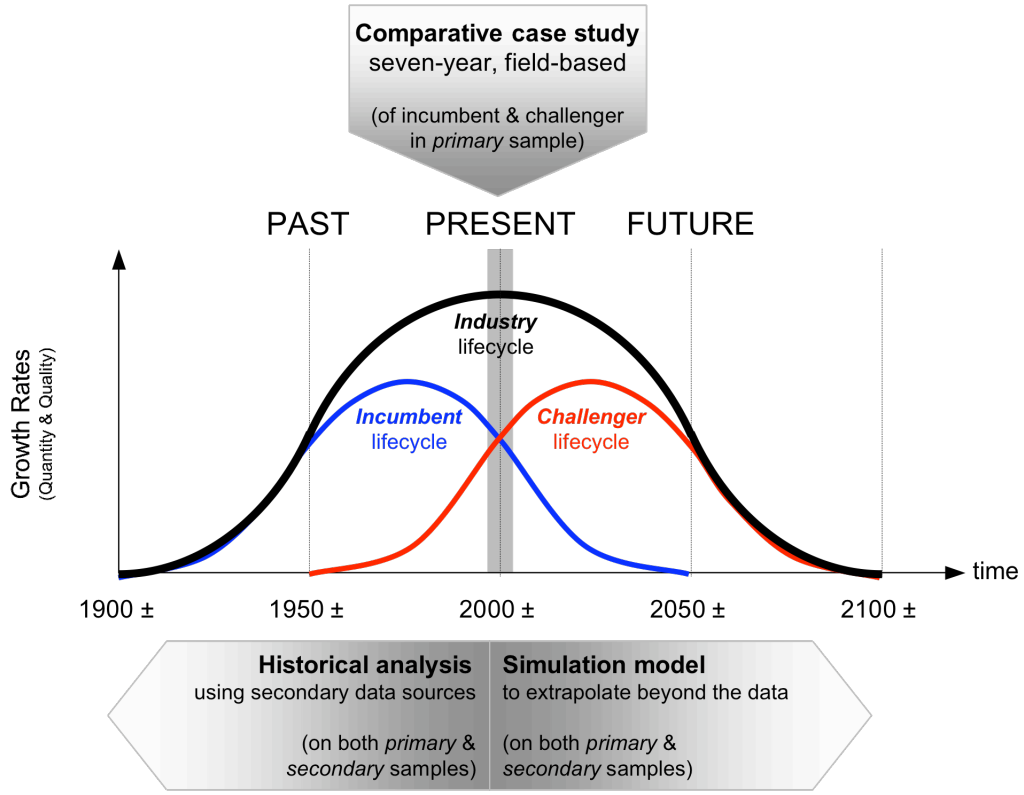
[5] Edmondson and McManus (2007) note that the use of qualitative methods in a mature field represents an "off-diagonal" methods strategy, which may generate new opportunities for insights provided that a study's focus is reframed from the broad to the narrow. In this case, we are focusing from variance to process theory.

RESEARCH METHODS

Research Design

In order to build grounded theory, data from the *past* and *present* were iteratively analyzed to develop a causal model of the *future* using three methods respectively: *historical analysis, comparative case studies* and *numerical simulation* as shown in Figure 4 below.[6] While the methods were used concurrently, the data evolved generally from more qualitative to more quantitative.

Figure 4: Summary of Research Design



Comparative Case Studies. Data analysis followed inductive grounded theory building techniques (Glaser & Strauss, 1967; Eisenhardt, 1989; Eisenhardt & Graebner, 2007), in which coding of observational, interview and archival data, generated robust sets of constructs.

Historical Analysis. In order to verify and extend the analysis of the above field-based case studies back in time, analysis of past data followed methods of business history (Chandler, 1962) using secondary data sources in both the primary and secondary samples.

Numerical Simulation. In order to verify and extend the above analyses, a simulation model was created to integrate the explicit causal structures and to explore the dynamic behavior generated by the model.[7]

[6] This combination of case-based grounded theory and numerical simulation has been recently used in the management literature (Rudolph and Repenning, 2002) to induce theory both from data and other theories.

[7] The purpose of this numerical simulation is not for quantitative calibration and prediction, but instead to gain qualitative understanding and insight into the posited governing "physics" of the underlying causal structures.

Empirical Sample

This research inductively builds grounded theory from a comparative study of six organizations – in three pairs – with each pair competing in the same industrial environment.[8] Each pair consisted of focal firms having significant variance in both the dependent variable (firm performance) and independent variable (enterprise architecture). The sample is summarized in **Error! Reference source not found.** below.

Table 1: Summary of Research Sample

Sample Type	Research Methods	Sector	Industry	Focal Firm	National Origin	Date of Birth	Current Enterprise Architecture	Firm Long-term Performance
Primary	Field-based case study	Manu-facturing & Services	Large Commer. Airplanes	*Boeing*	US	1916	Modular	Decreasing
				Airbus	EU	1970	Integral	Increasing
Second-ary	Available data analysis	Manu-facturing	Auto-motive	*GM*	US	1908	Modular	Decreasing
				Toyota	Japan	1937	Integral	Increasing
		Services	US Airlines	*United*	US	1926	Modular	Decreasing
				Southwest	US	1970	Integral	Increasing

The theoretical sample was selected for two reasons: one theoretical and the other methodological. First, the non-random theoretical sample was chosen to represent variance in organizational set[9] and environmental variables in order to assert a degree of generalizability in this exploratory stage of grounded theory building. The cases demonstrate that the theoretical framework has the possibility of applying to industries ranging from manufacturing to services, and in socio-economic environments including the US, Japan and Europe.

Second, in order to gain and sustain access to executive-level informants of the competing firms in the primary sample, we needed to mitigate conflict of interest issues and provide informants with other industry examples illustrating the theory. As a result, the secondary sample includes acknowledged world-class firms in both manufacturing e.g. *Toyota Motors* (Womack, Jones and Roos, 1990) and services e.g. *Southwest Airlines* (Hoffer Gittell, 2003). This served as the basis of discussion around which the senior decision-makers of the primary sample revealed their cognitive frames regarding themselves and those of their competitor.[10]

Potential Limitations. This non-random, small-N, theoretical sample used for theory *building* necessarily draws critiques of theory *validation* using random, large-N, statistical sample. As we aim to build *process* (not *variance*) theory which links "dependent" and "independent" variables in endogenous closed-loop feedback, capturing longitudinal switching of high and low performers, we begin to mitigate the concerns of sampling on the dependent variable[11] and survivorship bias.[12]

[8] This comparison of pairs of high- and low-performers in the same industries is similar to other theory building research in strategy *content* (e.g. Lawrence and Lorsch (1967) and strategy *process* (e.g. Pettigrew and Whipp, 1990).

[9] Each firm is posited to be representative of a population of isomorphic organizational sets, giving the theoretical sample potential for increased external validity.

[10] In order to protect the anonymity of the informants, evidence is reported based on generic enterprise architecture type, and not individual firm.

[11] Where the criterion for selecting the sample of firms is based on the "dependent variable", firm performance.

[12] Where the survivors are fallaciously compared with the historic average, despite having unusual properties.

Data Collection
The data collection strategy utilized multiple methods and multiple sources as is briefly described in the following sections.

Primary Data Sources. For the primary case study, we constructed a macro-level model of the structure, function and evolution of the organizational set from the micro-level cognitive frames of senior decision makers within each stakeholder of the organizational set. These data came from over 100 senior level informants (e.g. CEOs, presidents, vice-presidents and directors) distributed both vertically within the organizations and horizontally across both organizational sets.

The field-based data for the primary sample are largely taken from over 3,500 hours of ethnography (Van Maanen, 1988) and clinical methods participant observation (Schein, 1987) spread longitudinally over seven years from January 2002 to January 2009. Three-month field visits occurred every summer for seven years, with additional two-week trips every winter and spring. This included over 150 in-depth, semi-structured interviews and interview-based surveys, totaling over 300 hours. My relationship to the informants in both organizational sets was as a doctoral student paid to teach strategy in executive education and workshop format to senior decision-makers.

This longitudinal design allowed for intensive triangulation of the data sources across endogenous and exogenous changes. For example, during the five years of the study informants occupied multiple positions and positions (such as CEO), were occupied by multiple informants. In addition, the longitudinal design allowed for observation of how the competing organizational sets responded to changing environmental conditions including the exogenous shock of the September 11, 2001 terrorist attacks, the normal rise and fall of the business cycle, as well as the change in market leadership, which for the first time shifted from the incumbent to the challenger during the time of this study.

Secondary Data Sources. In addition, in order to ascertain the structure, function and evolution of the organizational sets beyond the temporal scope of direct observation, access was acquired to historical available data sources, including public documents and official records (e.g. annual company reports and SEC filings), private documents (e.g. internal company memos) and mass media (e.g. historical interviews of leaders in the business press and trade journals). By way of example, in order to paint a historical record of the evolutionary trajectory of the firms in the primary sample, all of the annual company reports covering nearly 100 years of history, totaling over 3,500 pages were collected for analysis.

Data Smoothing for Trends. Finally, as this research aims to explain long-term trends (i.e. a "first-mode" *signal*), the transfer of data to theory requires a smoothing of short-term *noise,* manifested as local events.[13] Such smoothing requires "empirical patience", which operationally implies a long data gestation time constant, before the stock of potential data, is drained by an outflow into the stock of theory-building data.

[13] By analogy, in a theory of annual seasonal weather change (i.e. "due to the earth's tilt and its solar orbit, winter is colder than summer in the northern hemisphere") the fact that "noisy" daily temperature measurements might reveal local "inconsistencies" with the trend does not necessarily invalidate the theory.

THEORETICAL FRAMEWORK & EMPIRICAL EVIDENCE

Overview of Theoretical Framework

Definitions. Before specifying the unit of analysis and levels of analysis, we provide four definitions along the dimensions of competition-cooperation and substitutes-complements as continuous (not binary) variables. These definitions, given in both economics and sociology terminology, are summarized in Figure 5 below.

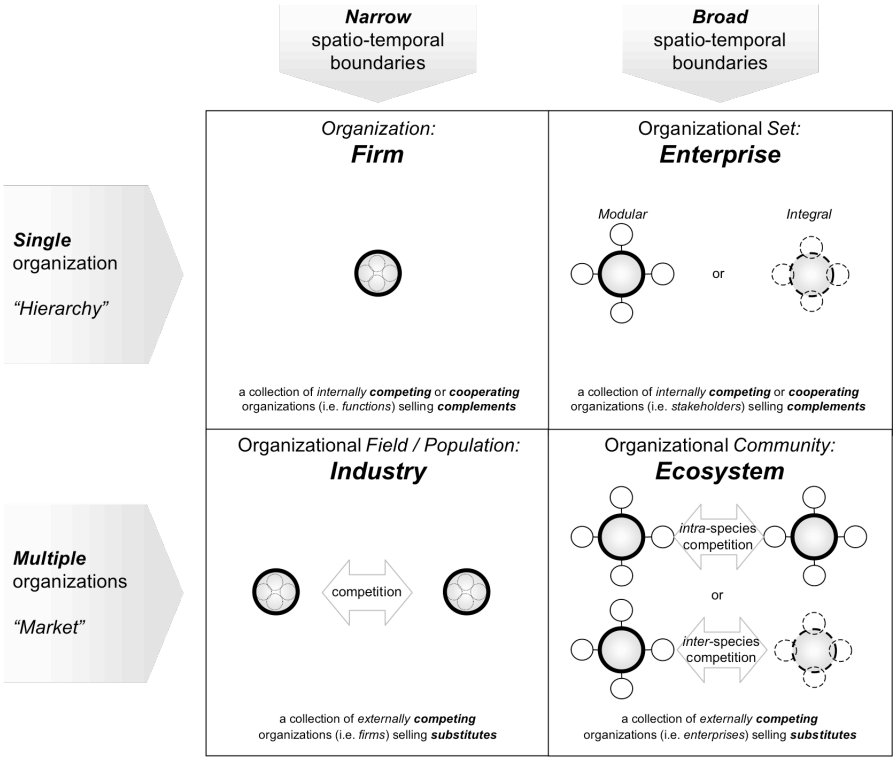
The type of *organization* under consideration is the *firm*, which is comprised of a collection of interacting internal functional organizations (e.g. marketing, R&D, manufacturing). These internal interactions tend toward the *cooperative* trading of *complementary* services.

The organizational *field* (DiMaggio and Powell, 1983) or *population* (Hannan and Freeman, 1977) or *industry* (Porter, 1980) is defined as an aggregate collection of externally interacting organizations or competing firms. These external interactions tend toward the *competitive* selling of *substitute* products and services.

The organizational *set* (Blau and Scott, 1962) or "extended *enterprise*" is defined as a focal firm and its key exchange actors (e.g. customers, suppliers, investors and employees). The set is therefore a collection of interacting internal functional organizations (or stakeholders). These internal interactions tend toward the *cooperative* selling of *complementary* products and services.

Finally, the organizational *community* (Aldrich, 1999) or *ecosystem* is defined as an aggregate collection of externally interacting heterogeneous organizations or competing enterprises. These external interactions tend toward the *competitive* selling of *substitute* products and services.

Figure 5: Summary of Primary Definitions



***Units* of Analysis.** The theoretical framework utilizes multiple units of analysis operating at different levels. The formal unit of analysis that defines the dependent variable is that of the business *firm* and specifically the performance of the single product "strategic business unit" within the more general diversified corporation (Porter, 1980).

In order to understand and explain the sources of firm performance, this framework posits the construct of an *extended enterprise*[14] that serves as the primary explanatory or independent variable of the framework.

Finally, in order to understand and explain the evolutionary forces that generate the primary explanatory variable, this framework posits the construct of an *ecosystem* of competing extended enterprises having different ecological forms or belonging to different ecological species (Hannan and Freeman, 1977).[15]

***Levels* of Analysis.** The levels of analysis occur both above and below the level of the firm. At a micro-level, the cognitive frames (Goffman, 1974) of the most senior leaders are mapped across the macro-level extended enterprise in order to determine and triangulate on the enterprise's architectural form and its function. In this dual micro- and macro-level of analysis, the enterprise architecture is analyzed as an enacted system that enables and constrains but does not determine managerial action (Giddens, 1979).

Variables. This paper however breaks with traditional strategic management research which strives to build and test *variance* theory - relating dependent and independent variables under strict necessary and sufficient conditions. Instead, this paper favors the building and testing of *process* theory, which seeks only necessary conditions plus a recipe for how they interact (Mohr, 1982; Van de Ven and Poole, 1995). In this way, the "dependent" and "independent" variables are linked via "moderating" and "mediating" variables to become a system of temporally and causally-linked "interdependent" variables. The entire system of causal relations therefore forms a closed feedback model whereby the evolution of business ecosystems is actually an endogenous theory, and the variables become antecedents (Richardson, 1991).

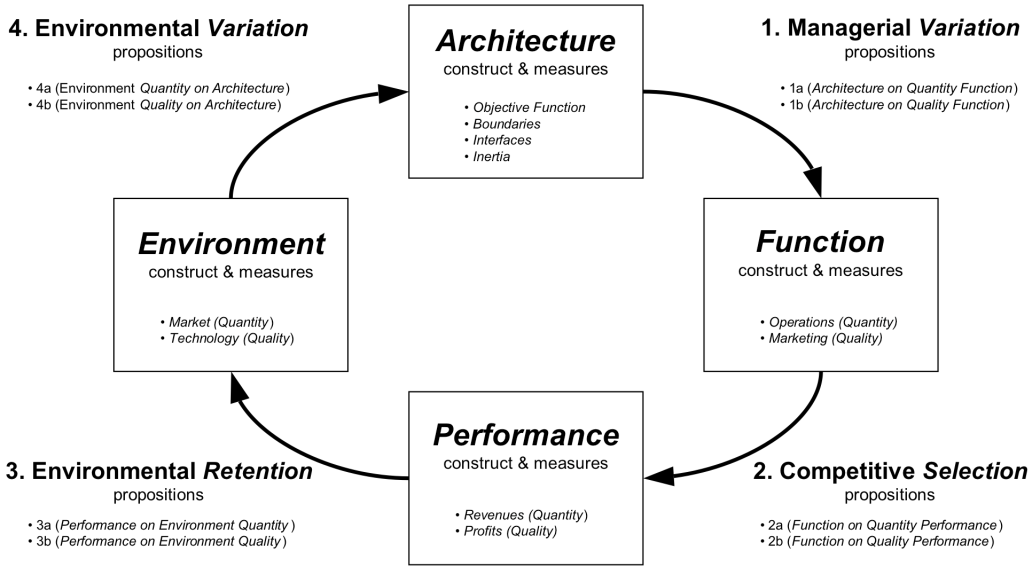
Despite this focus on process theory, we believe it useful to also characterize the four primary variables in familiar *variance* theoretic terms for illustrative purposes. In its simplest form, the dependent variable is long-term firm performance, and the independent variable is the enterprise architecture. We identify two types of intervening variables that relate the "dependent" and "independent" variables: *environmental maturity*, which describes the conditions that create and sustain different enterprise architectures, and *enterprise stability*, which describes how the enterprise functions or competes in strategic and operational terms.

[14] Researchers using the organizational set level of analysis include: resource dependence theorist (Pfeffer and Salancik, 1978), transaction cost economists (Williamson, 1975 and 1985) and industry structural analysts in strategic management (Porter, 1980).

[15] Scott (2003) notes that "organizational field" has similar definitions within organization studies: "inter-organizational community" (Hawley, 1950; Warren, 1967), "organizational community" (Aldrich, 1999), "industry system" (Hirsch, 1985), and "societal sector" (Scott and Meyer, 1991).

Framework Summary. In the following section, the framework is decomposed into its four constitutive *construct sets* of enterprise architecture, function, performance and environmental maturity[16], which are linked by *proposition sets* as shown proceeding clockwise in Figure 6 below.[17] The theoretical framework captures the essential evolutionary processes of variation, selection and retention, as first expressed for *organisms* in evolutionary biology (Darwin, 1859), and subsequently for *organizations* in evolutionary sociology (Aldrich, 1979) and evolutionary economics (Nelson & Winter, 1982).

Figure 6: Overview of Theoretical Framework



The first construct set defines the construct of enterprise architecture, which describes how the focal firm interacts with its environment. A typology of ideal enterprise architectures will be defined along a continuum ranging from modular to integral network forms. In variance theory terms, this module captures the primary *explanatory* variables.

The second construct set describes the competitive dynamics between enterprise architectures. It describes how each type of enterprise architecture functions in terms of key high-level operations and marketing variables. A typology of ideal operations and marketing strategies will be mapped to the typology of enterprise architectures. In variance theory terms, this module captures the primary *mediating* variables.

The third construct set describes how the competitive dynamics of each type of enterprise architecture impacts long-term firm performance. A typology of ideal financial strategies will be mapped to the typology of enterprise architectures. In variance theory terms, this module captures the primary *dependent* variables.

The fourth construct set describes how long-term firm performance impacts the evolution of the industry, which in turn creates the conditions for future enterprise architectural development. In variance theory terms, this module captures the primary *moderating* variables.

[16] This corresponds to the biological constructs of ecology, morphology and physiology.

[17] Each successive construct set assumes a longer time constant: the first defines the short-term static properties of enterprise architectures; the second and third define the mid-term dynamic - but non-evolutionary - process of competition, and the fourth defines the long-term co-evolutionary process of architectural change.

Primary Construct: ***Enterprise Architecture***

Theoretical Background. From the outset, we stated that seek a *systematic* explanation for long-term performance. We thus seek to characterize the firm-environment as a *system* of strategic complementarities (Milgrom and Roberts, 1990 & 1995), and as a typology of such complementarities (Hall and Soskice, 2001). The main construct of an *enterprise architecture* is introduced which originally emanates from architectural theory, which maps *form* to *function* (morphology to physiology) and specifies a typology of architectural forms ranging from *modular* to *integral*. Within design science, such an architectural typology has been developed for information (Simon, 1962), products (Ulrich, 1995; Baldwin and Clark, 2000), systems (Rechtin, 1991) and supply chains (Fine, 1998), but rarely to entire organizational sets.

Within organization science, *intra*-organizational typologies have been posited (e.g. Burns & Stalker, 1961; Lawrence & Lorsch, 1967; Miles & Snow, 1978). In addition, *inter*-organizational interactions have been proposed including: "the firm as a political coalition" (March, 1962), "theory of the firm" / "transaction cost economics" (Coase, 1937; Williamson, 1975), "resource dependence theory" (Pfeffer and Salancik, 1978), "five-forces analysis" (Porter, 1980), "stakeholder theory of the firm" (Freeman, 1984), "social network analysis" (Granovetter, 1985; Uzzi, 1997) and "varieties of capitalism" (Hall and Soskice, 2001). Finally, the evolution of isomorphic organizational forms has been posited in both neo-institutional theories (Meyer & Rowan, 1977; DiMaggio & Powell, 1983) and organizational ecology at the population- (Hannan & Freeman, 1977) and community levels (Astley, 1985). Typologies of "species" of organisms and organizations have arisen in biological ecology (MacArthur & Wilson, 1967) and organizational ecology (Brittain and Freeman, 1980) respectively. These species range from *r-strategists (opportunists)* to *K-strategists* (*equilibrium*-based) species. Table 2 below summarizes the typologies and configuration theories that have bee proposed in disciplines ranging from economics to sociology.

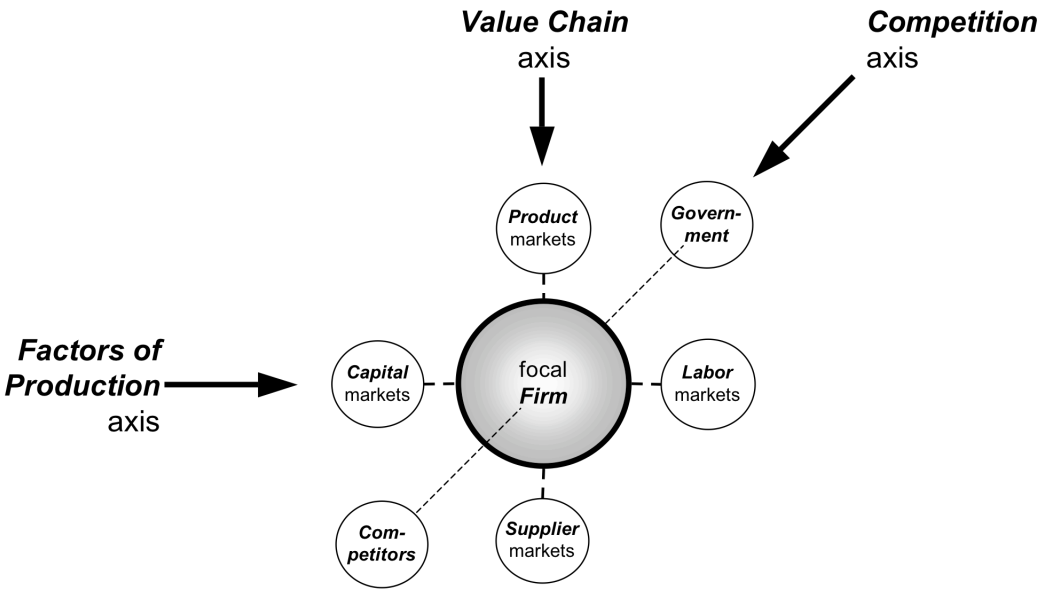
Table 2: Summary of Organizational and Economics-based Typologies

Level	**Typology** (Disciplinary Basis)	Type 1	Type 2	**Source**
Micro	Organizational Structure (Structural Contingency Theory)	Mechanistic	Organic	Burns & Stalker (1961)
	Organizational Structure (Structural Contingency Theory)	Differentiation	Integration	Lawrence & Lorsch (1967)
	"Strategic Types" (Organizational Theory)	Prospector	Defender	Miles & Snow (1978)
	Organizational "Forms" (Organizational Ecology)	r-strategist	K-strategist	Brittain & Freeman (1980)
	Organizational Learning (Organizational Theory)	Exploitation	Exploration	March (1991)
	"Generic Strategies" (Economics)	Differentiation	Cost Leadership	Porter (1980)
	"Mixed Duopoly" (Economics)	Profit Maximizer	Labor Managed	Lambertini & Rossini, (1998)
Meso	Network Theory (Economic Sociology)	Underembedded	Overembedded	Granovetter (1985), Uzzi (1997)
	Inter-organizational "Architecture" (Complex Systems Theory)	Modular	Integral	Piepenbrock, Fine & Nightingale (2009)
Macro	Varieties of Capitalism (Political Economy)	Liberal Market Economy	Coordinated Market Economy	Hall & Soskice (2001)

Enterprise Architecture as *Organizational Set*. An enterprise architecture is defined as the *form* of the organizational set.[18] An organizational set is a network comprising the firm and its key stakeholders. More specifically, the firm is seen to be the focal actor located at the center of a network of dyadic ties connecting the stakeholders to the firm. The extent of this network or enterprise is defined as including those stakeholders whose interactions with the firm significantly affect its performance (on a cost-benefit basis) over the time horizon of interest to the goals of the firm.

Before we can define an architectural typology of enterprises, we must first define the key modules or stakeholders of the organizational set, that is, we must first perform a functional decomposition or the enterprise. Each module is chosen for its relatively high internal interdependence and its relatively high external independence. For analytical simplicity, we decompose the enterprise along three dimensions or axes, with a pair of stakeholders associated with each axis: 1) the "value chain" of classical strategic management (Porter, 1985), which comprises customers and suppliers and captures classical demand and supply relationships; 2) the factors of production of classical economics which comprises providers of capital and labor; and 3) the competitive axis, i.e. those stakeholders which enable and constrain competition, (e.g. government and competitors). The primary modules of a generic enterprise architecture are summarized in Figure 7 below.[19]

Figure 7: Constituent Modules (Stakeholders) in a Generic Enterprise Architecture



[18] The architectural form of the organizational set (or morphology in organisms) represents an organization's "genotype", which may be common to both challenger (predators) and incumbent (prey). For example, the genotype of entrepreneurial radical innovators is an integral enterprise architecture – whether incumbent or late-entrant. A genotype's function and development within a specific environment, defines a richer concept of a "phenotype" or species, which is captured in the *ecology-morphology-physiology* framework.

[19] Note, for parsimony, the remainder of this paper focuses primarily on the first two dimensions of the enterprise, namely on customers, suppliers, investors and employees. For a fuller discussion of the broader organizational set, please refer to Piepenbrock (2009).

Construct Definitions & Measures. As Nohria and Gulati (1994) point out, no single unified perspective on organizations is shared between most major open systems schools of thought. For example, while contingency theorists, organizational ecologists and institutional theorists focus broadly on determinants of organizational *form*, resource dependence and transaction cost theorists focus on determinants of organizational *boundaries,* while resource dependence and network theorists focus on determinants of inter-organizational *relationships*.

The primary construct presented herein attempts to synthesize these theories, by proposing an integrated construct set which combines organizational *form, boundaries* and *relationships* in the notion of an inter-organizational or enterprise architecture.[20] These enterprise architectures are hypothesized to lie on a theoretical continuum ranging from *modular* to *integral* forms. These two extremes represent ideal types of architectures or archetypes, which can be defined in terms of three interrelated sets of properties: *objective functions,* enterprise *boundaries* and stakeholder *interfaces*.[21] Each will be briefly defined below.

Objective Functions: The objective function of the focal firm – within the classic corporate governance framework (Shleifer and Vishny, 1997) is defined by the way it appropriates residual profits to its enterprise, which ranges from maximization of *shareholder value* for the focal firm to maximization of *stakeholder surplus*. The former tends toward zero-sum *inter*-stakeholder competition, while the latter tends toward positive-sum *inter*-stakeholder cooperation. Intermediate objective functions are a weighted average of stakeholder claims.

Enterprise Boundaries. The objective function defines the spatio-temporal boundaries of the enterprise to be managed. "Spatial" refers to stakeholder space (not physical or geographic space), and "temporal" refers to the time horizon to which the enterprise is managed. For the shareholder value maximizer, the enterprise boundaries tend to be more *narrowly* defined both spatially around the firm, and temporally towards the short-term. For the stakeholder surplus maximizer, the enterprise boundaries tend to be more *broadly* defined both spatially around the entire extended enterprise, and temporally towards the long-term.[22]

Stakeholder Interfaces. The firm-stakeholder interfaces define the degree of complexity or functional in(ter)dependence. High functional *independence* is associated with narrow spatio-temporal boundaries, while high functional *interdependence* is associated with broad spatio-temporal boundaries. Interfaces can be divided into dimensions of quantity and quality of stakeholder relationships.[23] The *quantity* defines the number of providers within a stakeholder class and the *quality* defines the type of firm-stakeholder relationships, ranging from arm's-length, contract-based, market transactions to trust-based, relational coordination. The former tends toward zero-sum *intra*-stakeholder competition, while the latter tends toward positive-sum *intra*-stakeholder cooperation.

[20] This new construct redirects emphasis from *formal* aspects of the organization towards more *informal* aspects. Schilling and Steensma (2001) employ different empirical measures for modular organizations.
[21] In organizational ecology, a similar definition of a "species" or "organizational form" consists of: *goals*, *boundaries* and *activities* (Aldrich, 1979, pg. 28.)
[22] The *spatial* and *temporal* dimensions are posited to be non-orthogonal, i.e., the broader the set of stakeholders, the longer the time frame that one must consider.
[23] The *quantity* and *quality* dimensions are posited to be non-orthogonal, i.e. with high quantity being coupled with low quality and low quantity being coupled with high quality.

Architectural Typology: *Modular-Integral*. The following three axioms, summarized in Figure 8 below, define the architectures of enterprises in terms of their *objective functions,* enterprise *boundaries* and stakeholder *interfaces*.

The first axiom relates architectural form to function. The form that an enterprise architecture assumes is driven to some extent by its *objective function*, which represents the weighted average of the interests of its constituent stakeholders.

> *Axiom 1: When modular enterprise architectures are observed empirically, the focal firm's objective function will tend toward singluar maximization of shareholder value. Conversely when integral enterprise architectures are observed empirically, the focal firm's objective function will tend toward pluralistic maximization of stakeholder surplus.*

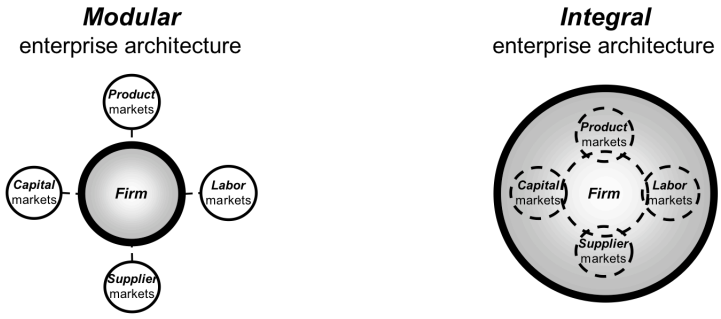
The second axiom relates architectural form to spatio-temporal boundaries. The form that an enterprise architecture assumes is driven to some extent by the boundaries within which the leader(s) of the focal firm manage(s) toward.

> *Axiom 2: When modular enterprise architectures are observed empirically, the spatio-temporal boundaries of the focal firm will be relatively narrow and coincident with the boundaries of the firm and the time expectations of its shareholders. Conversely when integral enterprise architectures are observed empirically, the spatio-temporal boundaries of the focal firm will be relatively broad and beyond the boundaries of the firm and its shareholders.*

The third axiom relates architectural form to the level of complexity of the stakeholder interfaces with the focal firm. The form that an enterprise architecture assumes is driven to some extent by the quantity and quality of stakeholder relationships with the focal firm.

> *Axiom 3: When modular enterprise architectures are observed empirically, the focal firm will tend to have a higher quantity of lower quality (i.e. contract-based) interactions within each stakeholder group. Conversely when integral enterprise architectures are observed empirically, the focal firm will tend to have a lower quantity of higher quality (i.e. relationship-based) interactions within each stakeholder group.*

Figure 8: Typology of Enterprise Architectures



Singular (Maximization of *Shareholder Value*)	**Objective Function**	***Plural*** (Maximization of *Stakeholder Surplus*)
Narrow (*narrow* spatial, *short* temporal)	Enterprise **Boundaries**	***Broad*** (*broad* spatial, *long* temporal)
Simple (*High* quantity of participants in a stakeholder class, *Low* quality of stakeholder relationships)	Stakeholder **Interfaces**	***Complex*** (*Low* quantity of participants in a stakeholder class, *High* quality of stakeholder relationships)

Empirical Data. The following representative qualitative data summarized in Table 3 below begins to support the above axioms of modular and integral enterprise architectural forms.

Table 3: Sample Qualitative Data Indicating Architectural Forms

Industry	Firm	Quotation
Com-mercial Airplanes	*Boeing* (Modular)	"[Union President] Blondin recalls asking: 'I just don't understand why you always fight us.' Blondin says [*Boeing* HR VP] Calhoun replied: 'You just don't get it. We represent Corporate America. You represent labor. We are always going to be adversaries.'" (Source: *Business Week*, 26 Sept. 2005).
	Airbus (Integral)	"I am always a bit surprised by the speed with which Americans take decisions: that in three days (after 9-11) they announce 25,000 lay-offs at *Boeing* seems to me totally stupefying," (Source: Noel Forgeard, CEO, *Airbus*; *AFX*, 21 Sept. 2001).
Auto-mobiles	*General Motors* (Modular)	"When the Japanese producers encounter these gigantic market waves, they will quickly become as mediocre as we are. They will have to start hiring and firing workers along with suppliers and will end us as mass-producers in short order." (Source: *GM* Executive; Womack, Jones & Roos, 1990).
	Toyota Motors (Integral)	"Under Japanese company law, shareholders are the owners of the corporation. But if corporations are run exclusively in the interests of shareholders, the business will be driven to pursue short-term profit at the expense of employment and spending on research and development. To be sustainable, corporations must nurture relationships with stakeholders such as suppliers, employees and the local community. So whatever the legal position, the corporation does not belong to its owners. It's not enough to serve shareholders." (Source: Mr. Okuda, Chairman, *Toyota Motor Corporation*; *Financial Times*, 1 Aug. 2001). "*Toyota's* business philosophy is to realize stable, long-term growth by working hard to strike a balance between the requirements of people and society, the global environment and the world economy. Our goal is to grow with all our stakeholders, including customers, shareholders, employees and business partners." (Source: *Toyota Motors Corporation* Annual Report, 2003).
U.S. Airlines	*United Airlines, Continental Airlines* (Modular)	"We don't want to kill the golden goose,' Dubinsky...nicknamed Mad Dog... [head of the *Airline Pilots Association*] told Goodwin [*United Airlines* CEO]. 'We just want to choke it by the neck until it gives us every last egg." (Source: Roger Lowenstien, "Into Thin Air", *New York Times,* 17 Feb. 2002). "I already hear labor leaders crying out, 'Let's go back to the old ways and let's get that again.' Do you know that a walrus isn't born fat and ugly – they become that way? So, if you want a date, you gotta kinda slim down and keep yourself in shape. So if you get fat and ugly again, someone's just going to take it away from you. Who are the big losers? The employees lost the most with pensions and incomes. Well, don't let that happen again! The guy that overeats is the one that dies. Where there's a management that says, 'Fine. We have to sign this contract, that we know that if we do will put us at a very non-competitive situation and will ultimately kill us'. Don't sign it! 'If we don't sing it they're going to strike and take the company out.' Well, take it! Shit, you're going broke anyway! It might as well be them that cause it and not you. How do you pull a band-aid off? If you do it fast, do it quick. On hair at a time or get that goddamn thing off – it's got to come off. Get it over with. *United, Delta, Northwest*, and others were a victim of compromise – another layer of fat, another deal they shouldn't have signed, another concession.." (Source: Gordon Bethune, former CEO *Continental Airlines*; *Airways*, July 2007).
	Southwest Airlines (Integral)	"We are willing to suffer some damage, even to our stock price, to protect the jobs of out people." (Source: James Parker, CEO, *Southwest Airlines*; *Business Week,* 8 Oct. 2001). "We can't let investors guide the company. That's not to say that investors aren't smart and don't have good ideas, because they do. They just have different motives. We've got to say true to who we are as a company and build for the long term." (Source: Gary Kelly, CEO, *Southwest Airlines; The Dallas Morning News*, 20 Dec. 2007).

1. Managerial *Variation*: Architecture-Function Relationship

Construct Definitions & Measures

Having defined a typology of enterprise architectures, the next step is to describe how these constructs function and interact over time in a competitive environment. Two primary variables are used which consider competition in terms of both *quality* or "what to offer?" and *quantity* or "how to offer it"? Porter (1980) frames this *quality* decision as a strategic position choice, which is broadly either *differentiation* or *cost-leadership*. Forrester (1961) frames this *quantity* decision as an operational stability choice, which is broadly either *unstable* or *stable* growth.

While organizational scholars have posited relationships between organizational form and competitive variables, for example that *intra*-organizational structure follows strategy (Chandler, 1962; Miles and Snow, 1978; Arthur, 1992; Delery and Doty, 1996), little research has shown which *inter*-organizational form delivers these strategic and operational choices the most effectively. Neither do they explain the conditions under which the converse is true, namely, when strategy follows structure.

Similarly, while organizational scholars have posited a tradeoff between the activities of exploration and exploitation (March, 1991), few have specified the *inter*-organizational forms that best deliver each activity.

Enterprise architectures can enable and constrain choice in competitive variables. The following two propositions serve to define the relationship between enterprise architectures and choices in strategic and operational variables.[24]

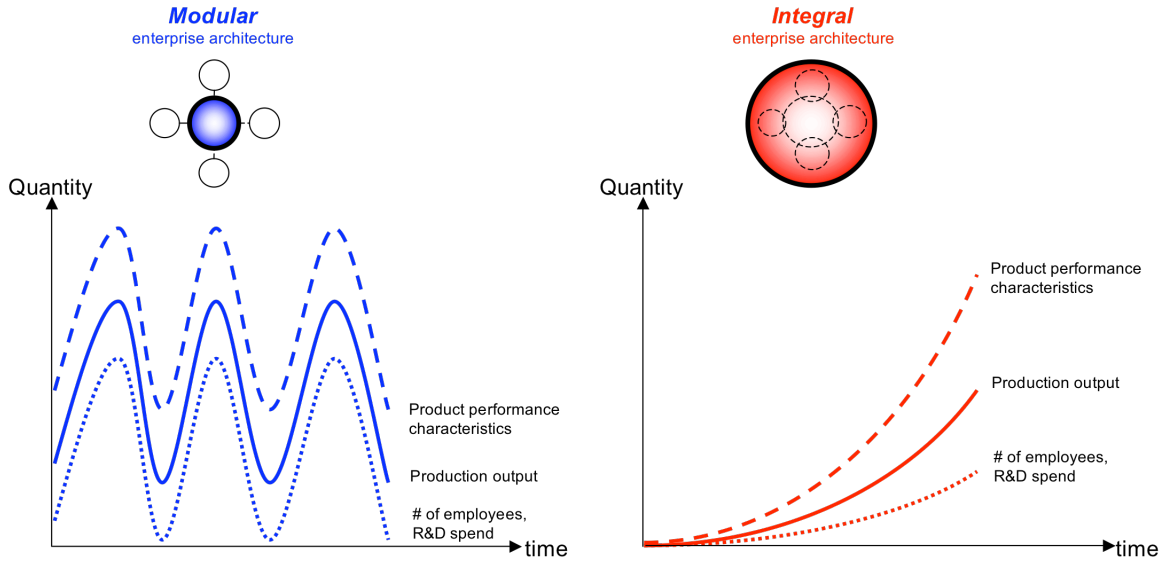
Proposition 1a: *Quantity* of Firm Growth. The first proposition relates enterprise architecture to *quantity*-type variables or operational stability choices. The choices that leaders of focal firms make are driven to some extent by their enterprise architecture.

Operations management scholars have advanced the construct of "stability" in the context of growth strategies (Forrester, 1961). The structure of growth can be characterized either as *unstable* which emphasizes reinforcing feedback and system delays, while de-emphasizing limits to growth; or as *stable* which emphasizes balancing feedback and limits to growth, while de-emphasizing system delays. As shown in Figure 9 below, the time histories of input variables (like number of employees or amount of R&D spend) and output variables (like number of units produced) reveal very different dynamic behaviors. Note that the rate of change of the inputs or outputs (i.e. the slope of the time histories) determines the "speed" of growth.

> *Proposition 1a: When modular enterprise architectures are observed empirically, the focal firm's operational strategy will tend toward unstable growth; it will have relatively high short-term speed, but relatively low long-term speed. Conversely when integral enterprise architectures are observed empirically, the focal firm's operational strategy will tend toward stable growth; it will have relatively low short-term speed, but relatively high long-term speed.*

[24] For a discussion of how strategic and operational variables interact, see Piepenbrock (2009).

Figure 9: Comparison of *Unstable* vs. *Stable* Growth



For *short* time horizons, the absolute value of the rate of change of output of the modular enterprises tends to always exceed the rate of change of output of integral enterprises. Mathematically, this can be expressed as:

$$\left| dQ_m/dt \right| > \left| dQ_i/dt \right| \qquad \text{(for small dt)}$$

For *longer* time horizons, the absolute value of the rate of change of output of the integral enterprises tends to always exceed the rate of change of output of long enterprises. Mathematically, this can be expressed as:

$$\left| dQ_m/dt \right| < \left| dQ_i/dt \right| \qquad \text{(for large dt)}$$

In addition, it appears that rate of change of output of integral enterprises tends to not go negative. In other words, integral enterprises are designed to grow at such a rate that they will not have to significantly shrink output. Mathematically, this can be expressed as:

$$dQ_i/dt < 0$$

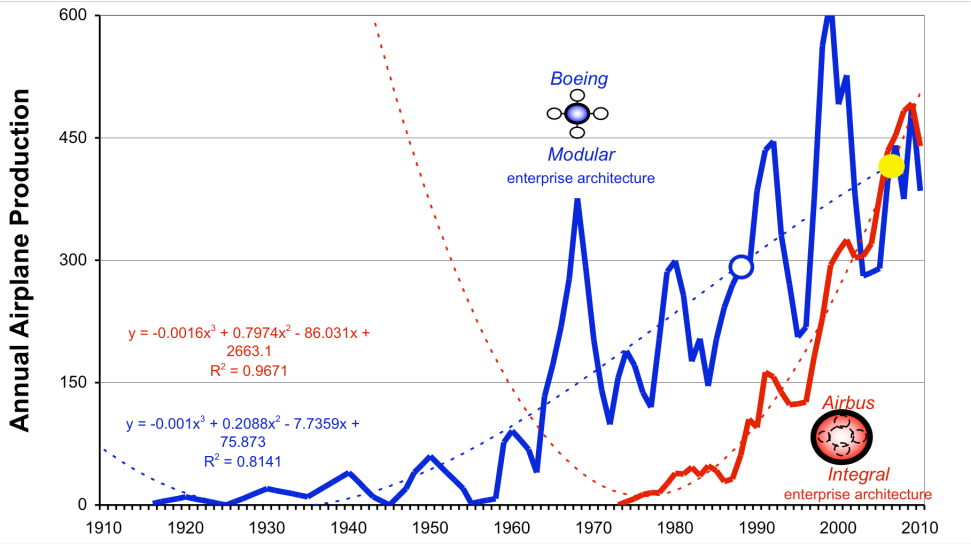
***Qualitative* Empirical Data.** Before presenting select quantitative date, we begin by reviewing select qualitative data as summarized in Table 4 below.

Table 4: Sample Qualitative Data Supporting Proposition 1a

Industry	Focal Firm (Architecture)	Quotation (Source)
Com-mercial Airplanes	*Boeing* (Modular)	"Boeing quickly moved last week to cut commercial transport delivery estimates through 2002 in an announcement that surprised even some veteran Boeing-watchers by its swiftness and scope. At a hastily arranged news conference Sept. 18, one week after the terrorist attacks in the U.S., the company said it could also lay off up to nearly one-third of its commercial aircraft workforce. Alan R. Mulally, Boeing president and CEO of *Boeing Commercial Airplanes*, said the layoffs would begin during the last quarter of this year. 'When you order airplanes today, depending on the model, the lead time is anywhere from 10-14 months, so we need to make these decisions for production next year as soon as possible.'" (Source: Alan Mulally, President & CEO, *Boeing Commercial Airplanes*; *Aviation Week*, 24 Sept. 2001). "History tells us that the quicker a company acts to counter adverse economic conditions, the better able it will be to work its way through a downturn and emerge stronger when the economy recovers." (Source: Jim McNerney, Chairman, President & CEO, *The Boeing Company*; memo to employees, 17 Feb. 2009).
	Airbus (Integral)	"We've always been much more careful about production rates. We do see peaks and troughs but we've always managed to limit the highs and lows better than they do in the USA." (Source: Philippe Camus, *EADS* Co-Chairman; *ATI*, 20 Sept. 2001).
Auto-mobiles	*General Motors* (Modular)	"When the Japanese producers encounter these gigantic market waves, they will quickly become as mediocre as we are. They will have to start hiring and firing workers along with suppliers and will end us as mass-producers in short order." (Source: *GM* Executive; Womack, Jones & Roos, 1990).
	Toyota Motors (Integral)	"In a high-growth period, productivity can be raised by anyone. But how many can attain it during the more difficult circumstances induced by low-growth rate? This is the deciding factor in the success or failure of an enterprise." (Source: Taiichi Ohno, *Toyota Motors Company* Executive Vice President; Ohno, T. 1978, pg 114). "The Toyota Production System can be realized only when all the workers become tortoises. Speed is meaningless without continuity. Just remember the tortoise and the hare." (Source: Taiichi Ohno, *Toyota Motor Company* Executive Vice President; Ohno, T. 1978, pg. 63).
U.S. Airlines	*United Airlines* (Modular)	"I don't' want to take advantage of the situation, but we have to do what is right for the company… and events of September 11 have opened certain doors for the company that were pretty much closed before." (Source: Rakesh Gangwal, *US Airways President*; Hoffer-Gittell, 2003).
	Southwest Airlines (Integral)	"The 'experts' always think we need to expand at a more rapid pace. What these so-called experts express is their desire for Southwest to jump at opportunities at a more rapid clip. Apparently growth excites investors. [But] nobody is pushing us. That could never happen." (Source: Matt Hafner, Director, *Southwest Airlines;* Jody Hoffer Gittell, (2003), pg. 246).

Quantitative **Empirical Data.** Proposition 1a describes the rates of growth and associated enterprise stability in enterprise architectures within an ecosystem. One would expect *Boeing's* more modular enterprise architecture to grow at higher short-term rates, while lower long-term rates (i.e. with less stability). Conversely, one would expect *Airbus'* more integral enterprise architecture to grow at lower short-term rates, while higher long-term rates (i.e. with greater stability). Figure 10 summarizes the output quantities for the competing focal firms in the primary sample, after the emergence of the dominant product design.

Figure 10: *Quantity* Growth of Competing Enterprise Architectures in the *Airplane* Industry



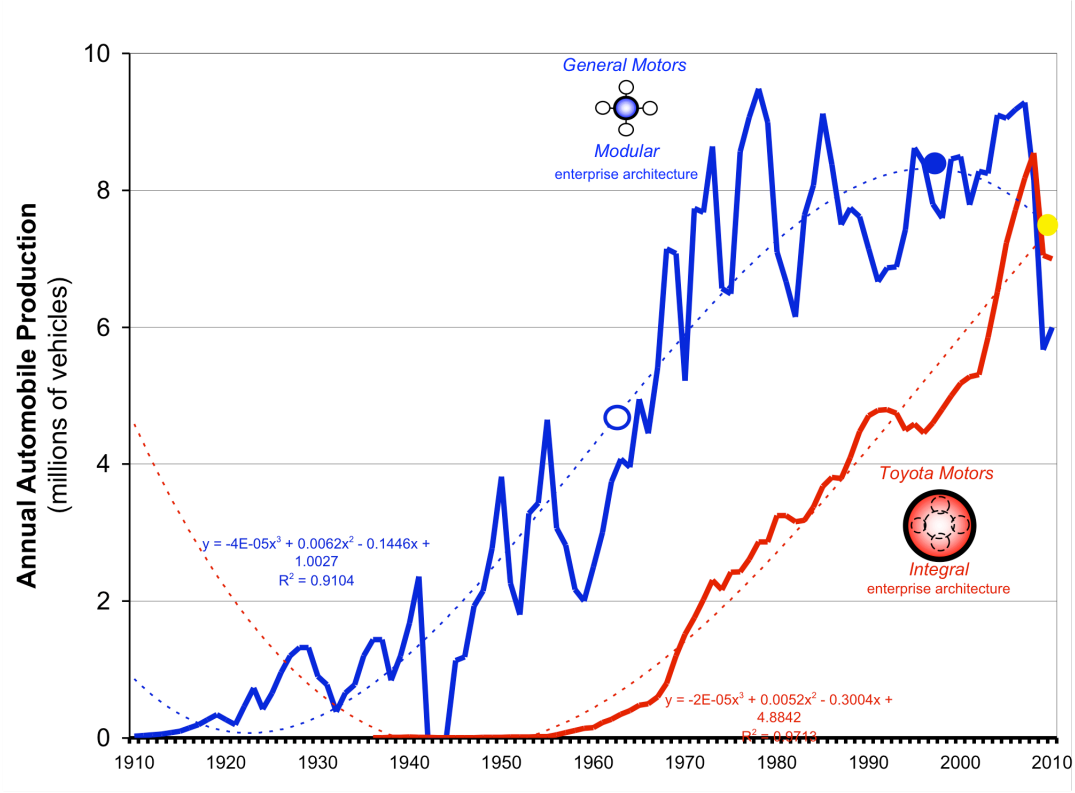
Qualitatively, after nearly 100 years of dominance, the market share-leading incumbent, *Boeing* is eventually overtaken by the late-entrant challenger, *Airbus.* Note that the late-entrant exhibits smoother growth (i.e. slow short-term growth, with fast long-term growth). Three observations can be made regarding quantity outputs: 1) during an upturn, the rate of change of output growth of a modular enterprise architecture generally exceeds that of an integral enterprise architecture; 2) during a downturn, the rate of change of output decline of a modular enterprise architecture generally exceeds that of an integral enterprise architecture; and 3) negative growth of an integral enterprise architecture is rare. These three observations combine to state that the long-term growth rates of integral enterprise architectures exceed those of modular enterprise architecture. Finally, note that the late-entrant appears to experience a prolonged incubation period of relatively low production, while capabilities are presumably built. This behavior might imply the need for patient capital.

Quantitatively, over the long-term since *Airbus* began production in 1974, its output CAGR is 12.5%, which is approximately seven times *Boeing's* output CAGR of only 1.8% over the same time period. A simple least squares fit regression analysis[25] using logistic, third order cubic polynomial trend lines, demonstrates both *Airbus'* higher long-term growth rate, as well as continued exponential growth. *Boeing* on the other hand has a lower long-term growth rate, and has begun to inflect towards downward concavity (i.e. industry exit).

[25] Note that for simplicity, the regression analyses shown use Ordinary Least Squares method. However, as the longitudinal time-series data are not independent, but autocorrelated, they require more advanced regression methods like Auto Regressive Moving Average (ARMA) models.

As illustrated in Figure 11 below, similar trajectories can be seen in the automotive industry.

Figure 11: *Quantity* Growth of Competing Enterprise Architectures in the *Automotive* Industry

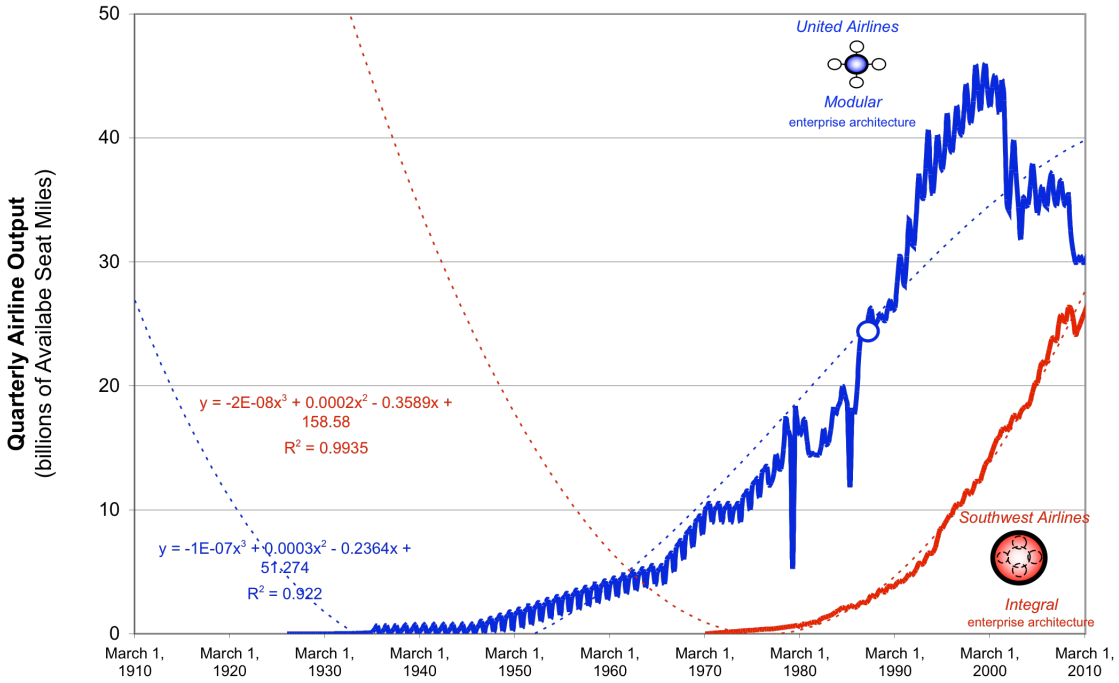


Qualitatively, after nearly 100 years of dominance, the market share-leading incumbent, *General Motors* is eventually overtaken by the late-entrant challenger, *Toyota Motors*. Note that the late-entrant exhibits smoother growth (i.e. slow short-term growth, with fast long-term growth). Note also that while *GM's* output is beginning to resemble an S-curve, with the inflection point occurring in the mid-1960s, *Toyota's* output is best described as exponential growth, with an inflection point not yet attained. Finally, again note that the late-entrant appears to experience a prolonged incubation period of relatively low production, while capabilities are presumably built. This behavior might imply the need for patient capital.

Quantitatively, over the long-term since *Toyota* began production in 1937, its output CAGR is 11.8%, which is approximately five times *GM's* output CAGR of only 2.6% over the same time period. A simple least squares fit regression analysis using logistic, third order cubic polynomial trend lines, demonstrates both *Toyota's* higher long-term growth rate, as well as continued exponential growth. *GM* on the other hand has a lower long-term growth rate, and has begun to inflect towards downward concavity (i.e. industry exit). Note also that the polynomials cross – i.e. competitive dominance switches – after the incumbent species has peaked in output growth rates, while before the challenger species has inflected.

As illustrated in Figure 12 below, similar trajectories can be seen in the airline industry.

Figure 12: *Quantity* Growth of Competing Enterprise Architectures in the *US Airline* Industry



Qualitatively, after nearly 100 years of dominance, the market share-leading incumbent, *United Airlines* is being overtaken by the late-entrant challenger, *Southwest Airlines*. Note that the late-entrant exhibits smoother growth (i.e. slow short-term growth, with fast long-term growth). The integral enterprise architecture's relative stability is evidenced by an absence of downward labor strikes, upward acquisitions and its ability general to dampen significant exogenous events like 9-11 terrorist attacks on the US, as well as the "noise" of minor seasonal fluctuation. Finally, again note that the late-entrant appears to experience a prolonged incubation period of relatively low production, while capabilities are presumably built. This behavior might imply the need for patient capital.

Quantitatively, over the long-term since *Southwest Airlines* began operation in 1970, its output CAGR is 20%, which is approximately six times *United Airline's* output CAGR of only 3% over the same time period. A simple least squares fit regression analysis using logistic, third order cubic polynomial trend lines, demonstrates both *Southwest's* higher long-term growth rate, as well as continued exponential growth. *United* on the other hand has a lower long-term growth rate, and has begun to inflect towards downward concavity (i.e. industry exit).

Table 5 below summarizes the empirical data supporting proposition 1a which captures the relationship between enterprise architectures and their function in *quantity* space.

Table 5: Summary of Data Supporting Proposition 1a

Industry	**Focal Firm**	**Enterprise Architecture**	***Quantity* Growth During *Intra*-Species Competition**	***Quantity* Growth During *Inter*-Species Competition**
Commercial Airplanes	*Boeing*	Modular	1916-1970 CAGR = **2**%	1970-2010 CAGR = **3**%
	Airbus	Integral		1970-2010 CAGR = **13**%
Auto-mobiles	*General Motors*	Modular	1908-1937 CAGR = **15**%	1937-2010 CAGR = **3**%
	Toyota Motors	Integral		1937-2010 CAGR = **12**%
Airlines	*United Airlines*	Modular	1926-1970 CAGR = **23**%	1970-2010 CAGR = **3**%
	Southwest Airlines	Integral		1970-2010 CAGR = **20**%

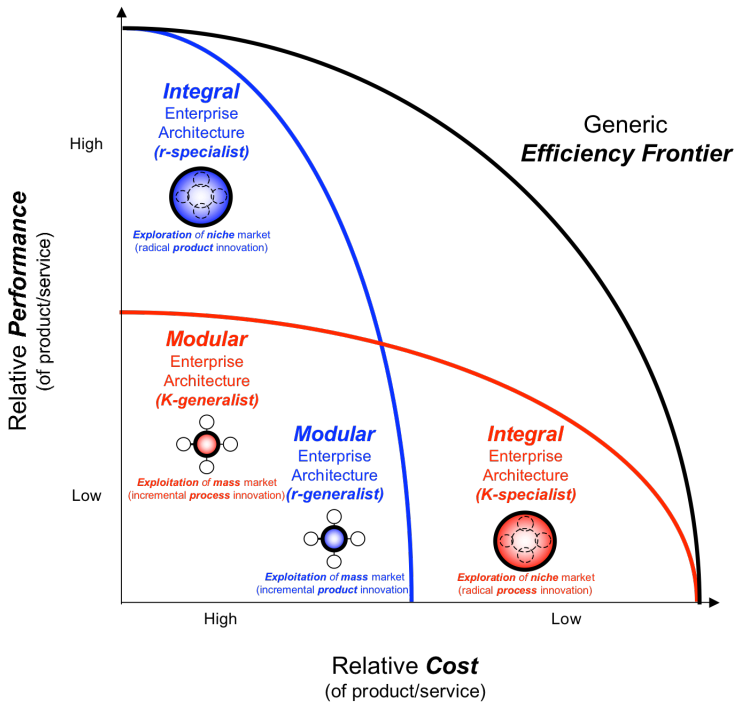
The question of how profitable this growth is will be covered in the next proposition set.

Proposition 1b: *Quality* of Firm Growth. Strategic management scholars have advanced the construct of an "efficiency frontier" in the strategic positioning space (Porter, 1996), which is defined by the orthogonal axes of differentiation and cost-leadership, or as specialist and generalists in ecological niche theory (Brittain & Freeman, 1980). As shown in Figure 13 below, a tradeoff between the two strategic positioning choices is posited to exist. *Efficiency* is defined as the distance of the firm from the frontier. Conversely, *effectiveness* is defined as the distance of the frontier from the origin. As the enterprise architecture enables and constrains performance, it defines the effectiveness potential of the enterprise (Pfeffer and Salancik, 1978). The shape of this efficiency frontier, while conceptually symmetrical at the industry level, is not symmetrical at a firm level. Firms that choose to focus on one strategy, develop capabilities and inertia around that choice, which makes switching to another strategy, while possible, lower in potential performance than a firm which chose to focus on it.

The second proposition relates enterprise architecture to *quality*-type variables or strategic positioning choices. The choices that leaders of focal firms make are driven to some extent by their enterprise architecture. When firms want to *explore* (March, 1991) or innovate radically in either products for differentiation or processes for cost-leadership, they will emphasize integration (Lawrence and Lorsch, 1967). Conversely, when firms want to *exploit* or innovate incrementally, they will emphasize differentiation as shown in Figure 13 below.

> *Proposition 1b: When integral enterprise architectures are observed empirically, the focal firm will be engaged in exploration (or radical innovation in either products or processes[26]) of niche markets. Conversely, when modular enterprise architectures are observed empirically, the focal firm will be engaged in exploitation of mass markets.*

Figure 13: *Exploration* and *Exploitation* in Strategic Position Space



[26] As will be discussed in Proposition Set 4, industries tend to evolve from product to process innovation.

***Qualitative* Empirical Data.** Before presenting select quantitative date, we begin by reviewing select qualitative data as summarized in Table 6 below.

Table 6: Sample Qualitative Data Supporting Proposition 1b

Industry	Focal Firm (Architecture)	Quotation (Source)
Commercial Airplanes	*Boeing* (Modular)	"Forever New Frontiers" (Source: Philip M. Condit, Chairman and CEO, and Harry C. Stonecipher, President and COO, *The Boeing Company;* Annual Report, Message to Shareholders 2000). "Our products bring better value to our customers, and our pricing reflects that value. We also have a responsibility to our shareholders, and that means pricing that allows us to make our financial goals. Do I think that we will ever be the lower-price option? No. Do I think that should keep us from gaining more than 50 percent market share? I answer "no" to that as well. (Source: Scott Carson, Vice President of Sales, *Boeing Commercial Airplanes*, *Boeing Frontiers*, April 2005). "Fundamental, game-changing innovation like that we're pursuing on the 787 usually has a 'bleeding-edge' quality to it – meaning it goes beyond 'leading edge' into a realm where both the risks and the potential returns are high." "We're on the bleeding edge of taking a big, big step that was just a quarter step too far." (Source: James McNerney, Chairman and CEO, *The Boeing Company; Business Week*, 23 April 2008 and *The Chicago Tribune*, 22 May 2008).
	Airbus (Integral)	"Our strategy isn't a secret...we're called, 'Airbus', not 'Airlimousine'" (Source: anonymous *Airbus* executive, 2005).
Automobiles	*General Motors* (Modular)	"Here's what's new about *GM's* strategy this year: Nothing. *GM* brought brand differentiation to the world in the 1920s. As the decades passed, and our product portfolio expanded, we slowly drifted away from that simple but effective strategy. Today the *GM* product revolution again is strengthening our brands, with more innovative marketing that better understands the customer." (Source: *General Motors* Annual Report, 2003, pp. 3 and 8).
	Toyota Motors (Integral)	"Cost Reduction is the Goal: At *Toyota*, as in all manufacturing industries, profit can be obtained only by reducing costs. Cost reduction must be the goal of consumer products manufacturers trying to survive in today's marketplace." (Source: Taiichi Ohno 1978).
U.S. Airlines	*United Airlines* (Modular)	"We have chosen to close our discount subsidiary, *Ted* in order to focus on our strengths in serving our premium customers – the historic source of our competitive advantage."
	Southwest Airlines (Integral)	"*Southwest's* business model, like that of *Toyota*, is to provide a low-cost product by utilizing its resources efficiently, while providing record levels of reliable service." (Source: Jody Hoffer Gittell, 2003 pp. 3-4.)

***Quantitative* Empirical Data.** Proposition 1b describes the strategic position taken by enterprise architectures within an ecosystem. One would expect *Boeing's* more modular enterprise architecture (as well as that of its dominant competitive predecessor) to compete via a *differentiated* product strategy that stresses product capabilities based on product innovation. Conversely, one would expect *Airbus'* more integral enterprise architecture to compete via a *cost-leadership* product strategy based on process innovation. Figure 14, Figure 15 and Figure 16 below summarizes the quality of output for the firms in the airplane, automotive and airlines industries respectively.

Figure 14: *Quality* Space of Competing Enterprise Architectures in *Airplane* Industry

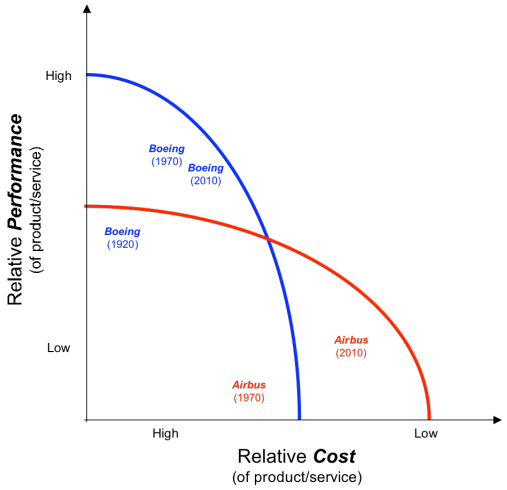


Figure 15: *Quality* Space of Competing Enterprise Architectures in *Automotive* Industry

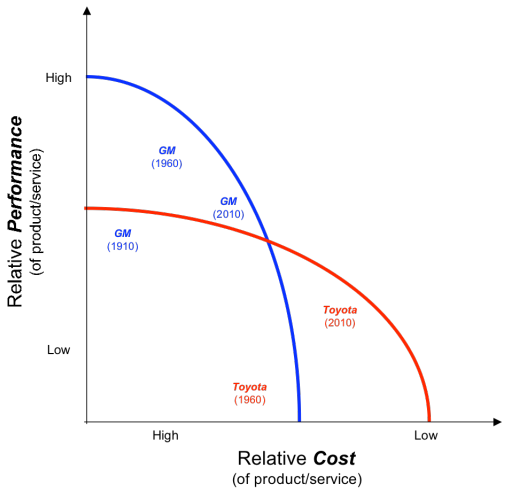
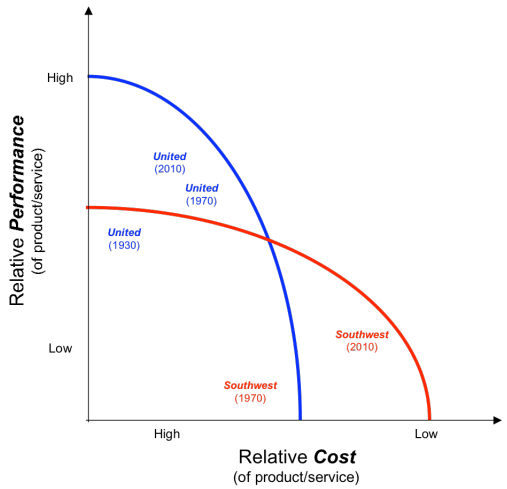


Figure 16: *Quality* Space of Competing Enterprise Architectures in *Airline* Industry



2. Competitive *Selection*: Function-Performance Relationship

Construct Definitions & Measures

The dependent variable used in this research – which is typical for most research in strategic management – is long-term firm performance, defined specifically as *economic* or *financial* performance. As such, there are a vast number of measures and metrics upon which to base the research (McGrahan and Porter, 1997). This is made even more complicated given the fact that the spectrum of enterprise architectures represents a range of performance objective functions, making a direct comparison of performance difficult.

In order to reconcile this dilemma, the common performance metric that will be used for all enterprise architectures will be maximization of shareholder value as represented by market capitalization. Although this is the explicit goal of the *shareholder*-based enterprise architecture, and only an indirect and implicit goal of the *stakeholder*-based enterprise architecture, it allows crucial comparison of zero-sum vs. positive-sum outcomes, which reveal the conditions under which an integrated approach outperforms a modular approach to enterprise architectures.

Shareholder value has been demonstrated to be dependent upon both *past* financial performance and *future* growth prospects (Dobbs and Koller, 2005). These sub-variables will be important in understanding the distinction between enterprise architectures and their underlying mechanics. Past performance is reflected on the firm's income statement, and can be decomposed into *top-line* revenues and *bottom-line* net income or profits. Longitudinal time-histories of these two variables can help explain longitudinal trajectories of shareholder value.

Modular enterprise architectures assign a functional decomposition resulting in a clear separation and of ownership (by principals, typically shareholders) and management (their agents). This "efficiency" results in the classic principal-agent problem (Jensen and Meckling, 1976). *Agency Theory* posits that managers are typically interested in maximization of top-line revenues, as their pay and influence is tied to expanding the size of the firm, while investors are typically interested in maximization of bottom-line profits. Integral enterprise architectures on the other hand assign a less clear functional separation of ownership and management, alleviating some of the problems and costs of agency. Resolution of these functional conflicts occurs above at the enterprise architectural level. Researchers have referred to this as *Stewardship Theory* (Donaldson and Davis, 1990).

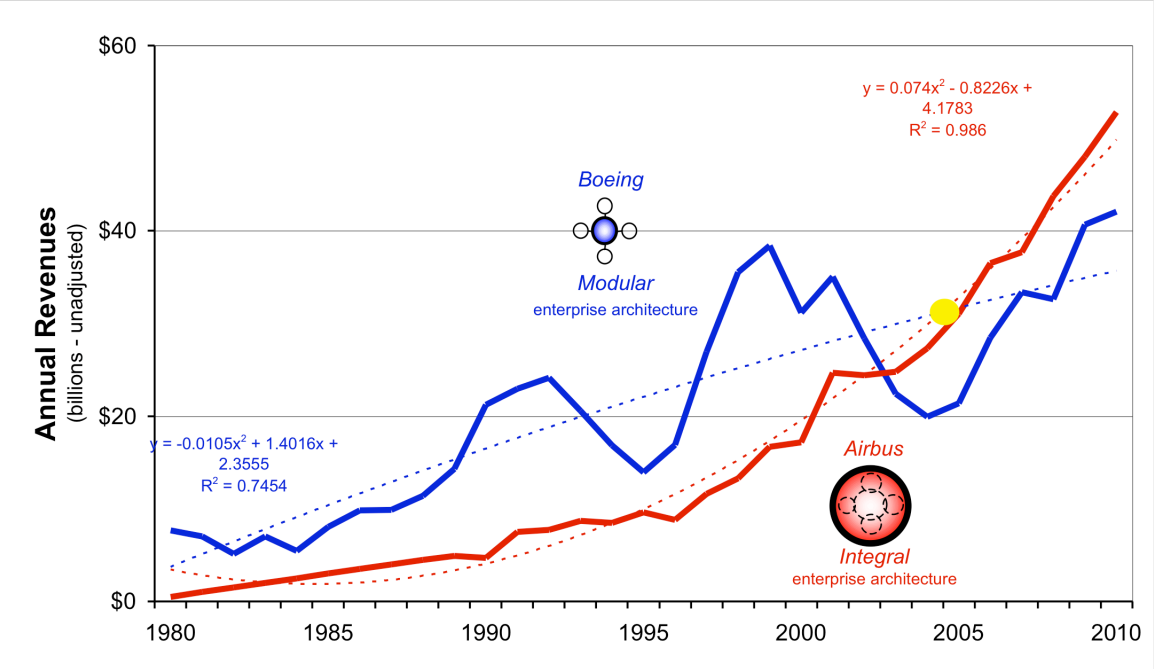
Proposition 2a: *Quantity* of Firm Performance (Revenues). Enterprise architectures, by enabling and constraining choice in key competitive variables, ultimately lead to firm performance. The following two propositions serve to define the relationship between enterprise architectures and key performance variables of growth in revenues, profits and shareholder value.

The first proposition relates enterprise function to firm performance expressed as long-term *quantity* growth or *revenues*.

> *Proposition 2a: When competing modular and integral enterprise architectures are observed empirically, the focal firm of the modular enterprise architecture will tend to have lower long-term rates of revenue growth, relative to the focal firm of the integral enterprise architecture.*

Empirical data. Proposition 2a describes the rates of growth of revenues in enterprise architectures within an ecosystem. One would expect *Boeing's* more modular enterprise architecture to grow at higher short-term rates, while lower long-term rates (i.e. with less stability). Conversely, one would expect *Airbus'* more integral enterprise architecture to grow at lower short-term rates, while higher long-term rates (i.e. with greater stability). Figure 17 summarizes the revenue quantities for the competing focal firms in the primary sample.

Figure 17: *Quantity* (Revenue) Growth in the *Commercial Airplane* Industry



Note that over the long-term since *Airbus's* founding (1974-2006), *Boeing's* revenue CAGR (unadjusted for inflation) was only 7.3%, while for *Airbus* it was more than double at 18.6%. While *Boeing* grows its revenues more quickly than *Airbus* during an upturn, it shrinks its revenues much more rapidly than *Airbus* during a downturn, with the net result being that the long-term revenue growth rates of *Airbus* are significantly higher than *Boeing*. The question of whether *Airbus'* higher long-term revenue growth is associated with higher profitability will be considered next.

As illustrated in Figure 18 and Figure 19 below, similar trajectories can be seen in both the automotive and airline industries respectively. Quantitatively, over the long-term (1980-2010), *Toyota's* revenue CAGR is 10%, which is approximately two times *GM's* revenue CAGR of only 4%. Similarly, *Southwest Airlines'* revenue CAGR is 14%, which is nearly three times *United Airlines'* revenue CAGR of only 5%.

Figure 18: *Quantity* (Revenue) Growth in the *Automotive* Industry

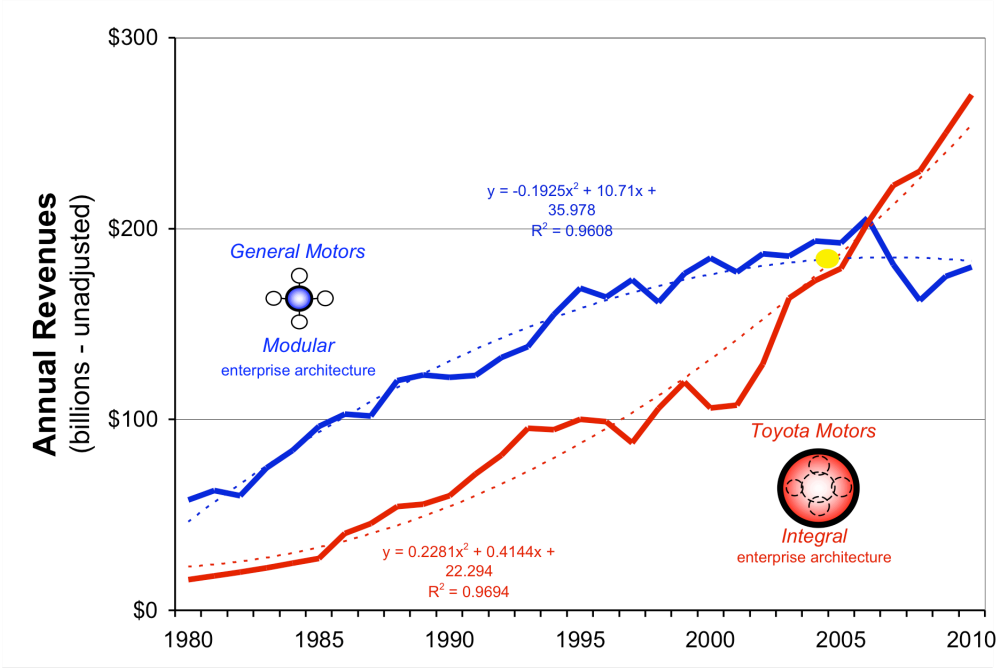
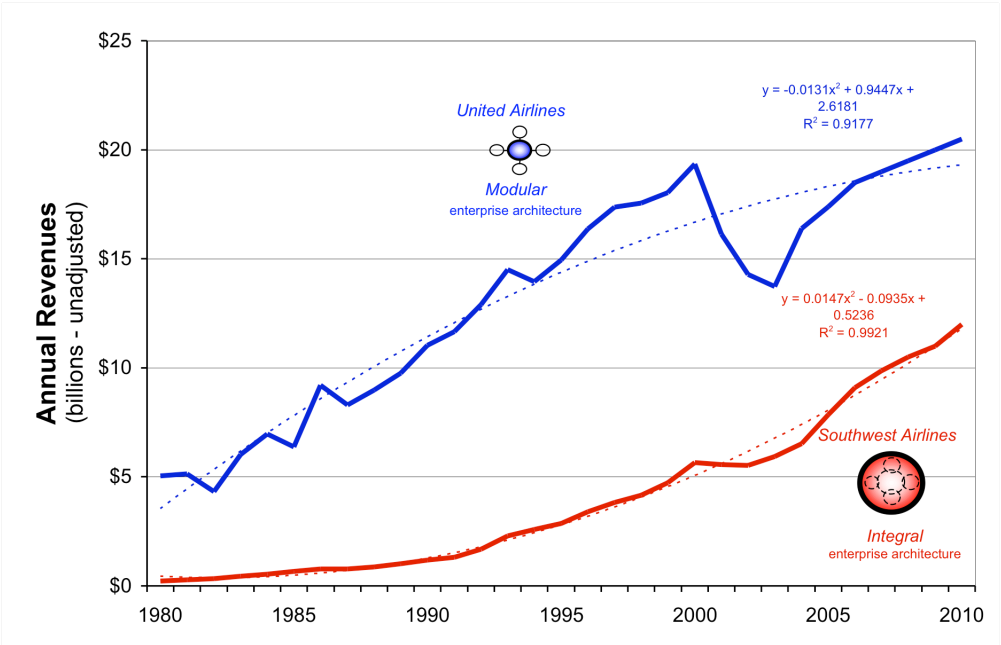


Figure 19: *Quantity* (Revenue) Growth in the *US Airline* Industry

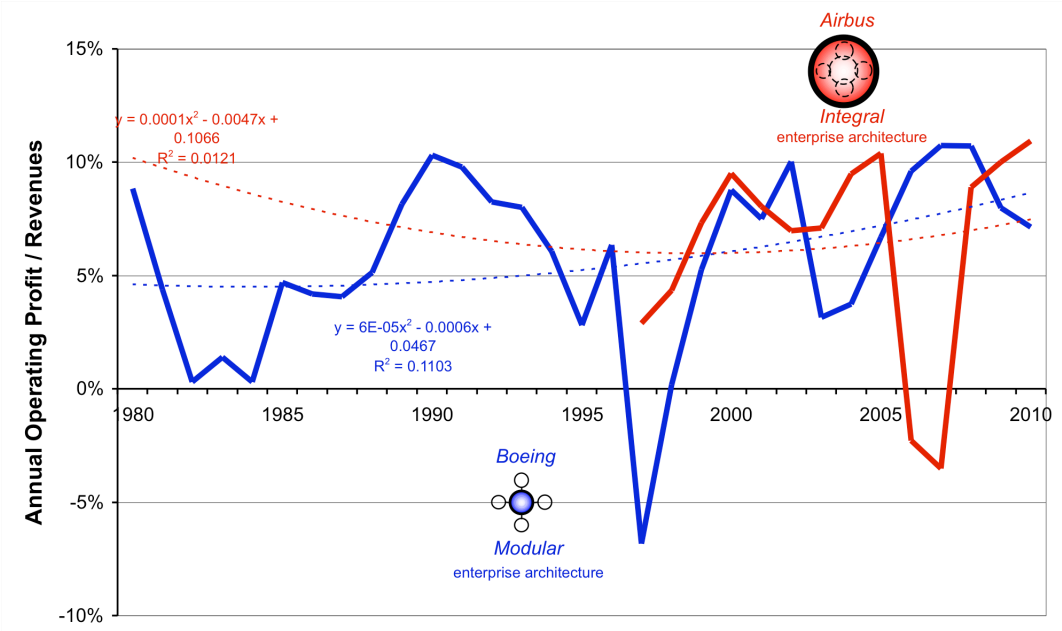


Proposition 2b: *Quality* of Firm Performance (Profitability). The second proposition relates enterprise function to firm performance expressed as long-term *quality* growth or *profits*.

> *Proposition 2b: When competing modular and integral enterprise architectures are observed empirically, the focal firm of the modular enterprise architecture will tend to have lower long-term rates of profit growth, relative to the focal firm of the integral enterprise architecture.*

Empirical Data. While the firm may be growing in terms of quantity of revenues, this does not speak about the quality of growth or the efficiency of converting such growth into residual cash flows or profits. Proposition 2b describes the rates of growth of profitability in enterprise architectures within an ecosystem. One would expect *Boeing's* more modular enterprise architecture to grow at higher short-term rates, while lower long-term rates (i.e. with less stability). Conversely, one would expect *Airbus'* more integral enterprise architecture to grow at lower short-term rates, while higher long-term rates (i.e. with greater stability). Figure 20 summarizes the profitability quantities for the competing focal firms in the primary sample, over periods for which data is publicly available.

Figure 20: *Quality* (Profitability) Growth in the *Commercial Airplane* Industry



Qualitatively, while *Boeing* grows its profitability more quickly than *Airbus* during an upturn, it shrinks its profitability much more rapidly than *Airbus* during a downturn, with the net result being that the long-term profitability growth rates of *Airbus* are significantly higher than *Boeing*. There is some evidence to support the proposition that high long-term revenue growth rates can be coupled with high long-term profitability rates by integral enterprise architectures.

Quantitatively, as both data sets show large variation, resulting in low R^2 values, only the most basic descriptive statistic is reliable. Over the period for which comparative data exists (1997-2008), both *Boeing* and *Airbus* have averaged 6% annual operating profits. This amount is in line with *Boeing's* longer term (1980-2008) average of 6%.

As illustrated in Figure 21 and Figure 22 below, similar trajectories can be seen in both the automotive and airline industries respectively. Quantitatively, over the long-term (1980-2010), *Toyota's* average profitability is 5% and increasing, while *GM's* average profitability is only -1% and decreasing. Similarly, *Southwest Airlines'* average profitability is 7% and stabilizing, while *United Airlines'* average profitability is only -1% and decreasing.

Figure 21: *Quality* (Profitability) Growth in the *Automotive* Industry

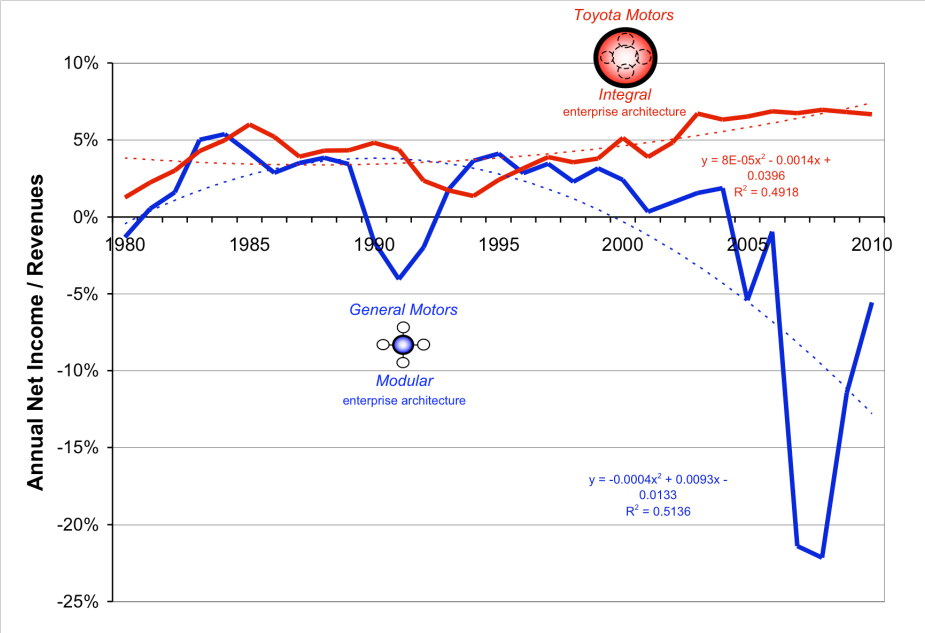
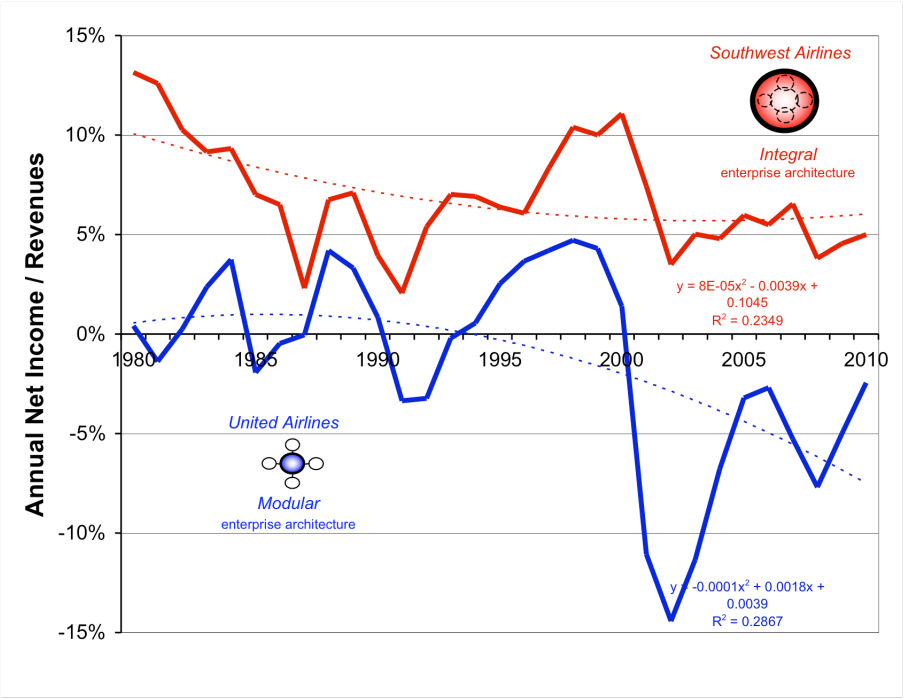


Figure 22: Quality (Profitability) Growth in the *US Airline* Industry



3. Competitive *Retention*: Performance-Environment Relationship

Construct Definitions & Measures

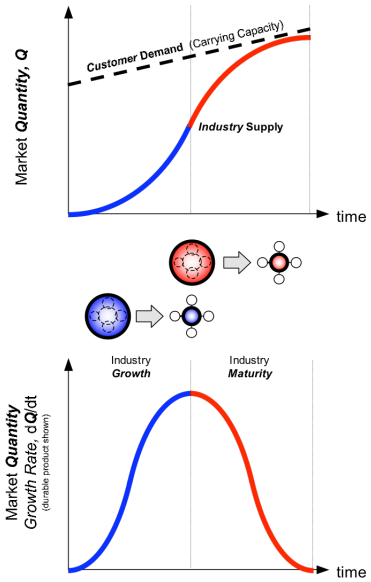
Both strategy (Porter, 1980, pg. 164) and organization (Lawrence and Lorsch, 1967, pg. 19) researchers have long recognized the importance rates of environmental change on competition and organizational forms. As far back as 1838, Cournot postulated a profit-maximizing firm which was subject to the constraints of *demand* and *technology*. This framework similarly distinguishes between two types of industrial evolution: *quantity* and *quality*, each possessing its own growth trajectories, which can be expressed stylistically as life cycle or S-curves. Just as the Architecture-Function relationship distinguished between quantity and quality at the firm level, the same distinction is made at the ecosystem level.

Proposition 3a: *Quantity* of Environmental Growth. The first proposition relates firm performance to environmental maturity in *quantity* terms, as summarized in Figure 23 below.[27]

Quantity space refers to the *amount* of products and services supplied and demanded in an ecosystem, which is influenced by such variables as population size, GDP growth, etc. This characterization of the environment is well-known in marketing research and has been modeled using Bass diffusion processes (Bass, 1969).

> *Proposition 3a: When considering the industry's rates of growth in customer demand, emerging industries, i.e. those that exhibit slow but increasing rates of quantity growth tend to be built by / reward integral enterprise architectures, which specialize in slow (equilibrium) behavior. Transitioning industries, i.e. those that exhibit high rates of quantity growth tend to be built by / reward modular enterprise architectures, which specialize in fast (opportunistic) behavior. Maturing industries, i.e. those that exhibit fast but decreasing rates of quantity growth tend to be built by / reward integral enterprise architectures, which specialize in slow (equilibrium) behavior.*

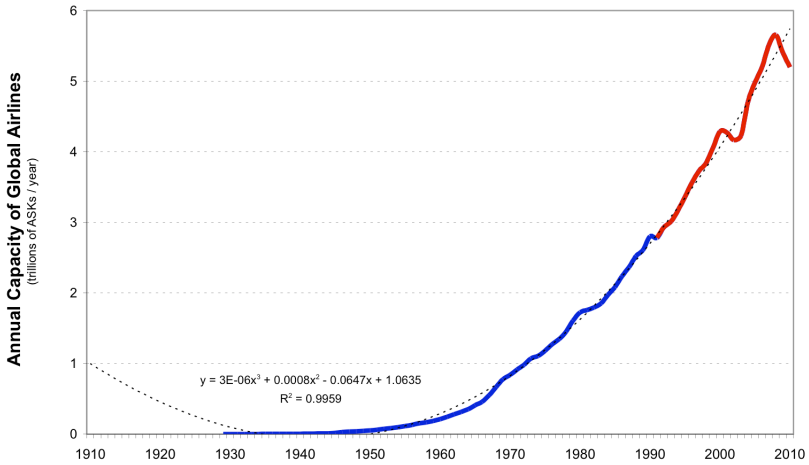
Figure 23: Co-Evolution of Firm Performance and Environment (*Quantity*)



[27] This "quantity" formulation captures organizational ecologists' construct of "*mass* dependence" (Barron, 1999).

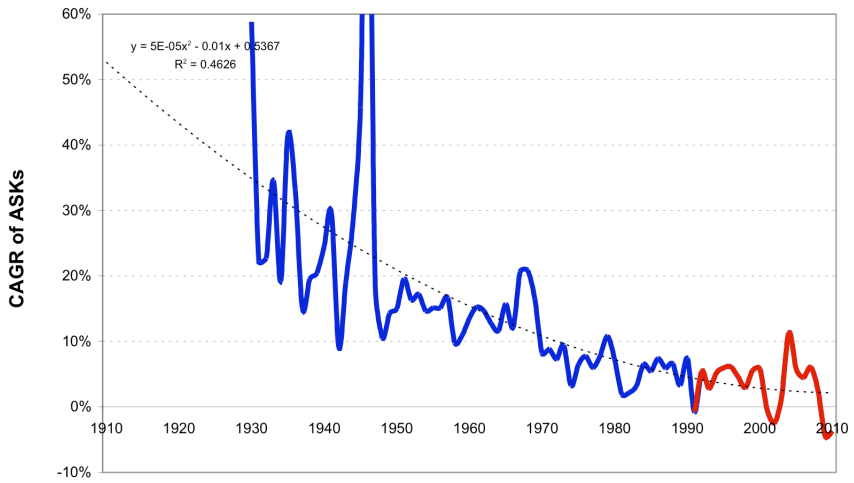
Empirical data. The carrying capacity of the ecosystem in *quantity* space can be defined by the underlying availability of critical environmental resources from any of the stakeholders in the organizational set. The data presented below[28] takes customer demand as the key ecosystem variable, which for the primary sample is the underlying market growth in the global airline industry. As can be seen in Figure 24 below, the exponential growth trajectory appears to be following the logistic S-curve.

Figure 24: *Market* Carrying Capacity of the *Global Airline* Industry



The critical question rate of change of this growth will reveal whether or not the market is beginning to saturate, creating the environmental conditions for re-integration of the dominant enterprise architecture. In order to determine if this ecosystem growth is speeding up or slowing down, Figure 25 below shows the compound annual growth rate (CAGR). While the industry is growing, the annual rate of change of this growth has been diminishing over time - signaling a "maturing" market – and is asymptotically approaching the CAGR of global GDP.

Figure 25: CAGR of *Market* Carrying Capacity of the *Global Airline* Industry



[28] Data source: Air Transport Association (ATA). Excludes data from the USSR prior to 1970.

As illustrated in Figure 26 and Figure 27 below, similar trajectories can be seen in both the global automotive[29] and US airline[30] industries respectively.

Figure 26: *Market* Carrying Capacity of the *Global Automotive* Industry

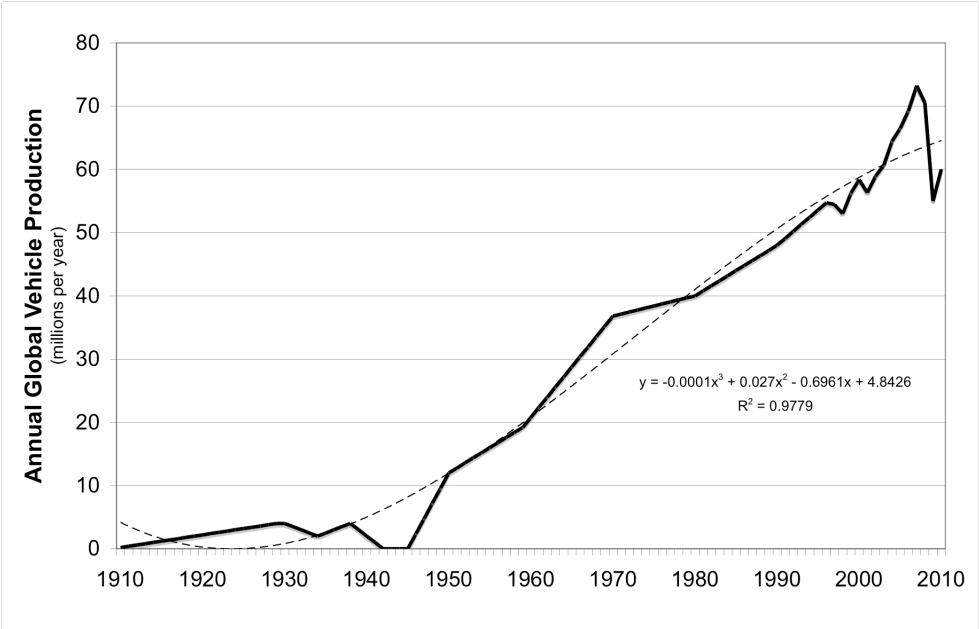
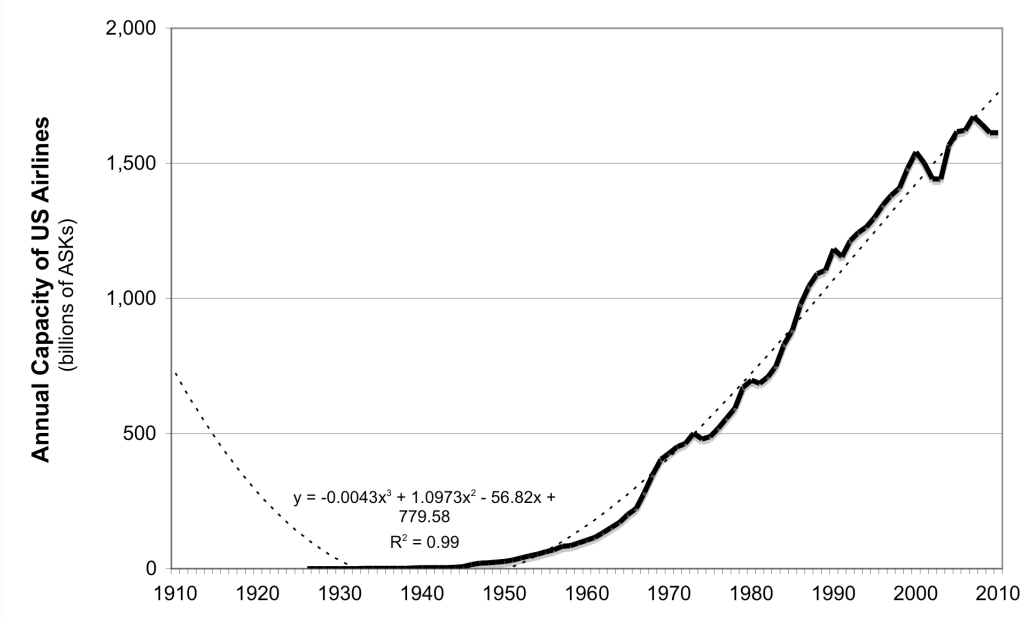


Figure 27: *Market* Carrying Capacity of the *U.S. Airline* Industry



[29] Automotive data source:s Organisation Internationale des Constructeurs d'Automobiles (www.oica.net) and Hirooka (2006), pg. 73.

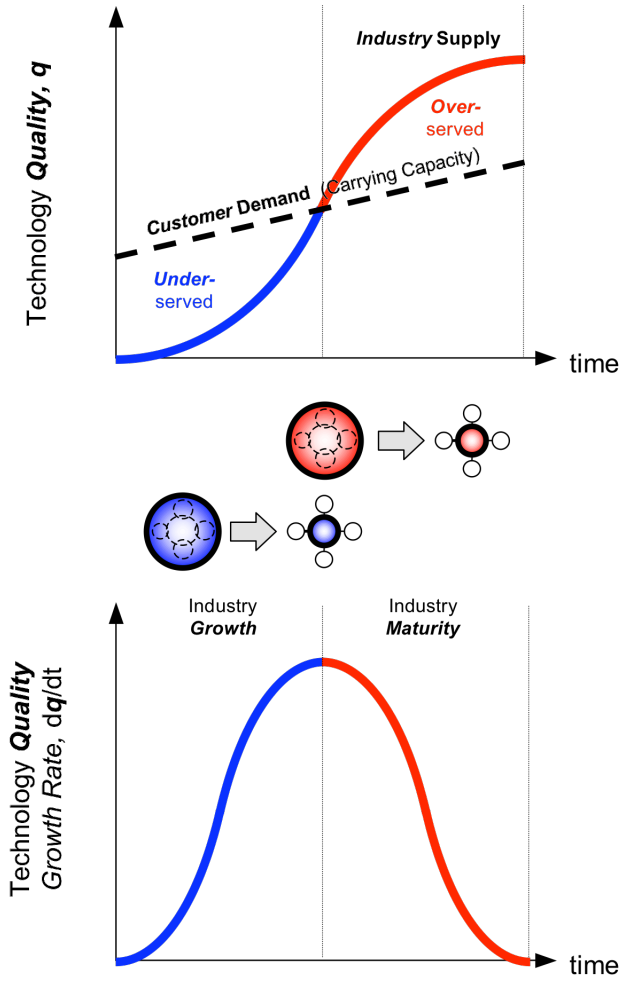
[30] Note, the data come from the Air Transport Association (ATA), and includes all US airlines passenger and cargo traffic for both domestic and international operations.

Proposition 3b: *Quality* of Environmental Growth. The second proposition relates firm performance to environmental maturity in *quality* terms and is summarized in Figure 28 below.

Quality space refers to the *type* of products and services supplied and demanded in an ecosystem, which is influenced by such variables as technological innovation, etc. This characterization of the environment is well-known in technology and innovation research (Christensen and Bower, 1996).

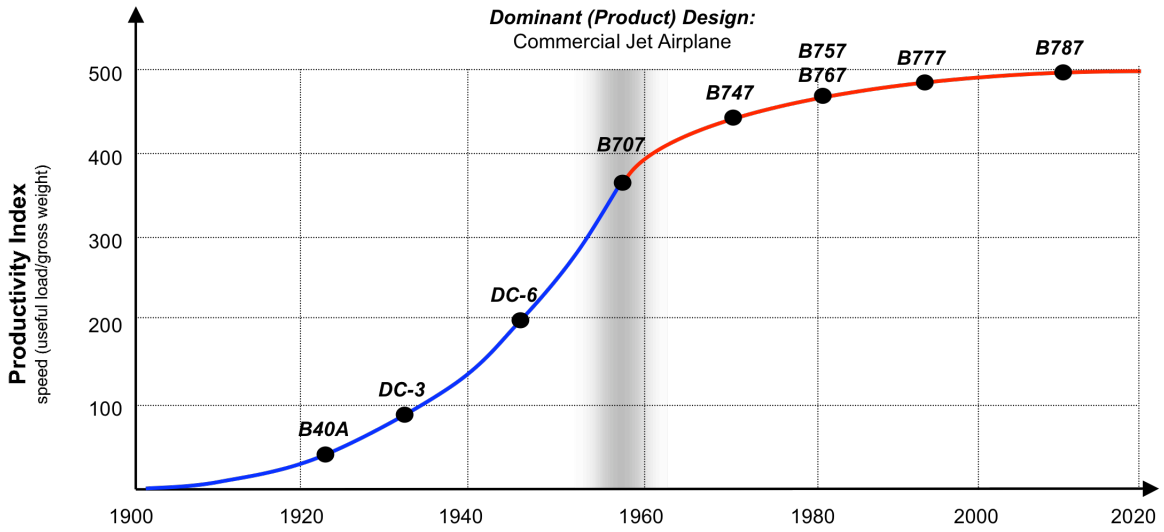
> *Proposition 3b: When considering the industry's rates of growth in technological innovation, emerging industries, i.e. those that exhibit slow but increasing rates of quality growth (i.e. under-served markets) tend to be built by and reward integral enterprise architectures, which specialize in radical product innovation (i.e. exploration). Transitioning industries, i.e. those that exhibit high rates of quality growth tend to be built by and reward modular enterprise architectures, which specialize in incremental product and process innovation (i.e. exploitation). Maturing industries, i.e. those that exhibit fast but decreasing rates of quality growth (i.e. over-served markets) tend to be built by and reward integral enterprise architectures, which specialize in radical process innovation (i.e. exploration).*

Figure 28: Co-Evolution of Firm Performance and Environment (*Quality*)



Empirical Data. The carrying capacity of the ecosystem in *quality* space can be defined by the underlying availability of critical environmental resources from any of the stakeholders in the organizational set. The data presented below takes supplier capability as the key ecosystem variable, which for the primary sample is the underlying growth in technological carrying capacity of the global airline industry as measured by an industry standard of airplane productivity (McMasters and Cummings, 2002). As can be seen in Figure 29 below, the growth trajectory appears to have followed the logistic S-curve, with the inflection point having occurred in the late 1950's with the emergence of the dominant product design of jet aircraft. Prior to this, competition existed in improving product performance, where rates of change in performance were increasing. After the emergence of the dominant design, when the rates of change of change in product performance began to diminish, competition is hypothesized to move toward other dimensions of cost, quality and delivery. The current state of technological carrying capacity is saturating around the asymptotic physical limits of speed, range, etc.[31]

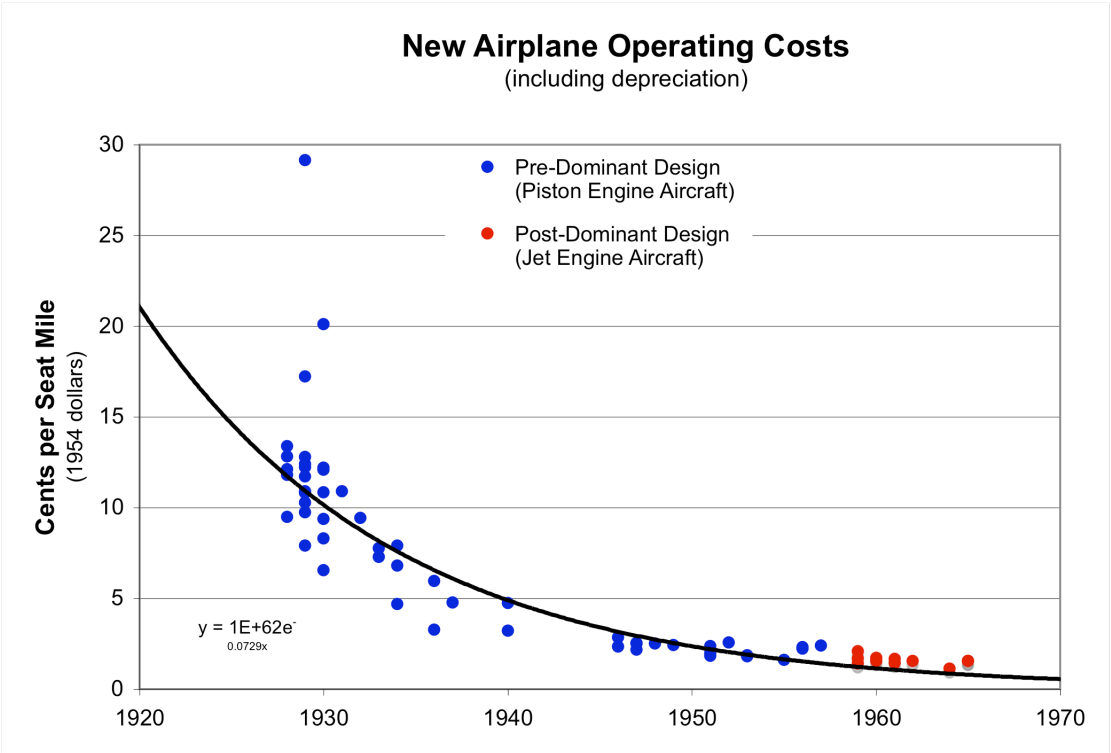
Figure 29: *Technological* Carrying Capacity of the *Global Airplane* Industry



In addition to saturation of product performance, the long-term trends in product operating costs have dropped asymptotically toward zero (Philips, 1971), as shown in Figure 30 below.

[31] Since the inception of the jet age, maximum speed (in economical mass transport) has been constrained to remain just below the drag divergence Mach number to avoid excessive fuel consumption. In addition, maximum range is confined to approximately half the earth's circumference.

Figure 30: *Technological* Limits of the *Global Airplane* Industry



4. Environmental *Variation*: Environment-Architecture Relationship

Construct Definitions & Measures

Enterprise architectures, through their competitive interactions, reflexively shape and are crucially shaped by their environment. It is through this interaction between organization and environment, or more precisely between organizational set and organizational field (Scott, 2003), that both co-evolve.

Organizational ecologists (e.g. Hannan and Freeman, 1977) focus on macro-level constructs of organizational founding (entry) rates, failure (exit) rates, and inertial (change) rates. In particular, they observe that while organizational change does in fact occurs it tends to unfold at rates that are lower than change demanded by the environment. This organizational momentum is captured by the construct of structural inertia, which helps explain failure rates and founding rates.

Structural contingency theorists (e.g. Burns and Stalker, 1961; Lawrence and Lorsch, 1967), have long postulated that the environment is an important factor in defining the organizations within it. In particular, they have pointed to rates of change of key environmental factors like technology and customer demand as driving the optimum structure of organizations operating within these environment. For them, however, the environment is considered as a static exogenous variable moderating organizational structure and successful performance.

Technology and innovation theorists (e.g. Abernathy and Utterback, 1978) and affiliated organizational theorists (e.g. Anderson and Tushman, 1990; Henderson and Clark, 1990) have taken steps to advance structural contingency theory by endogenizing technological evolution and its effect on organizational evolution. These researchers posit the existence of "dominant designs" in products, which fundamentally change the nature of competition from pre-dominant design focus on *product* innovation, to the post-dominant design focus on *process* innovation. Later theorists (Suarez and Utterback, 1995; Klepper, 1996) in this vein have posited ecological firm entry/exit relationships to the evolution of industries.

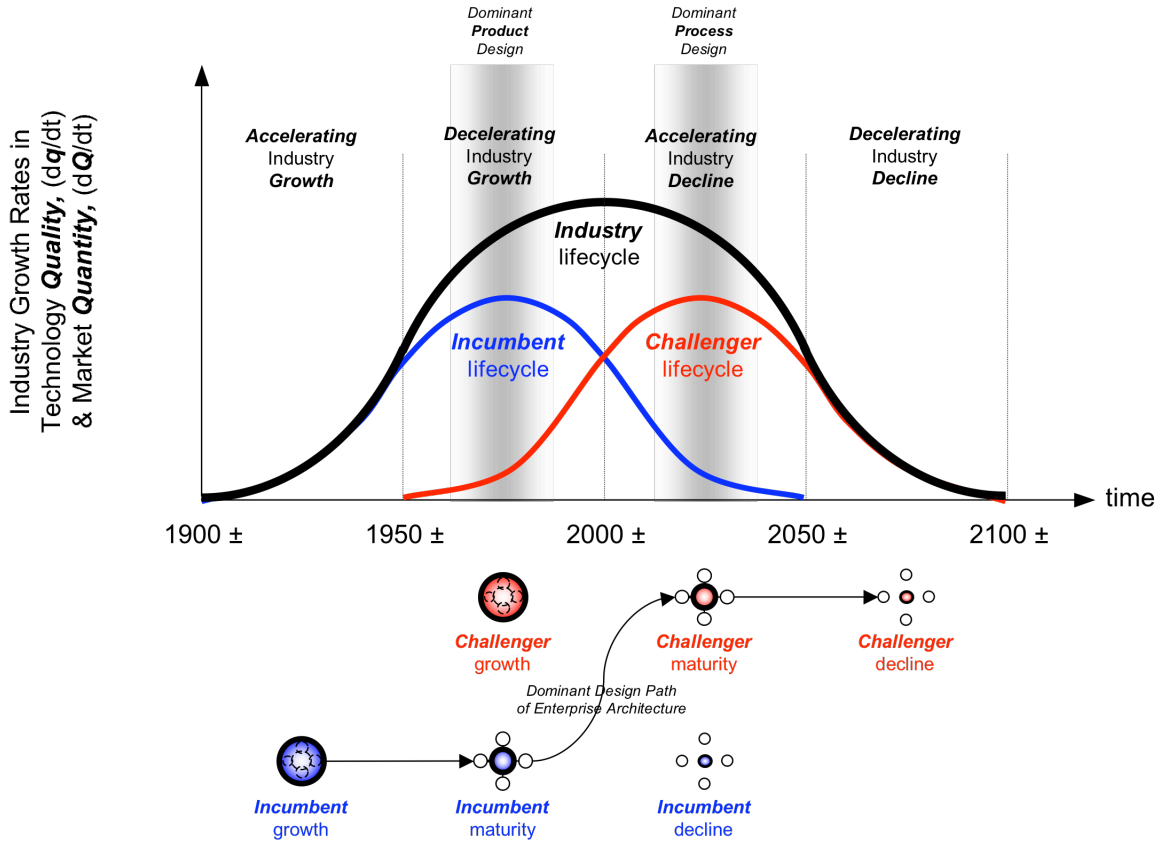
This framework, by co-opting more of the environment (i.e. the organizational set) into the causal explanation of organizational performance can begin to endogenize the dynamics of the evolution of the environment and the enterprises within it. In this sense it is contingency theory at a higher level of analysis than the organization, namely that of the organizational set, or *ecological* contingency theory. In addition, by formalizing "dominant designs" in an architectural framework, one can begin to integrate the organizational and environmental or technological evolution.

Proposition 4a: *Dominant Designs* in Enterprise Architectures. The first proposition relates environmental maturity to required levels of integration in enterprise architectures, which is summarized in Figure 31 below.

> *Proposition 4a: Dominant designs in enterprise architectures at the ecosystem level tend to oscillate between integral and modular states throughout the lifecycle of the industry.*

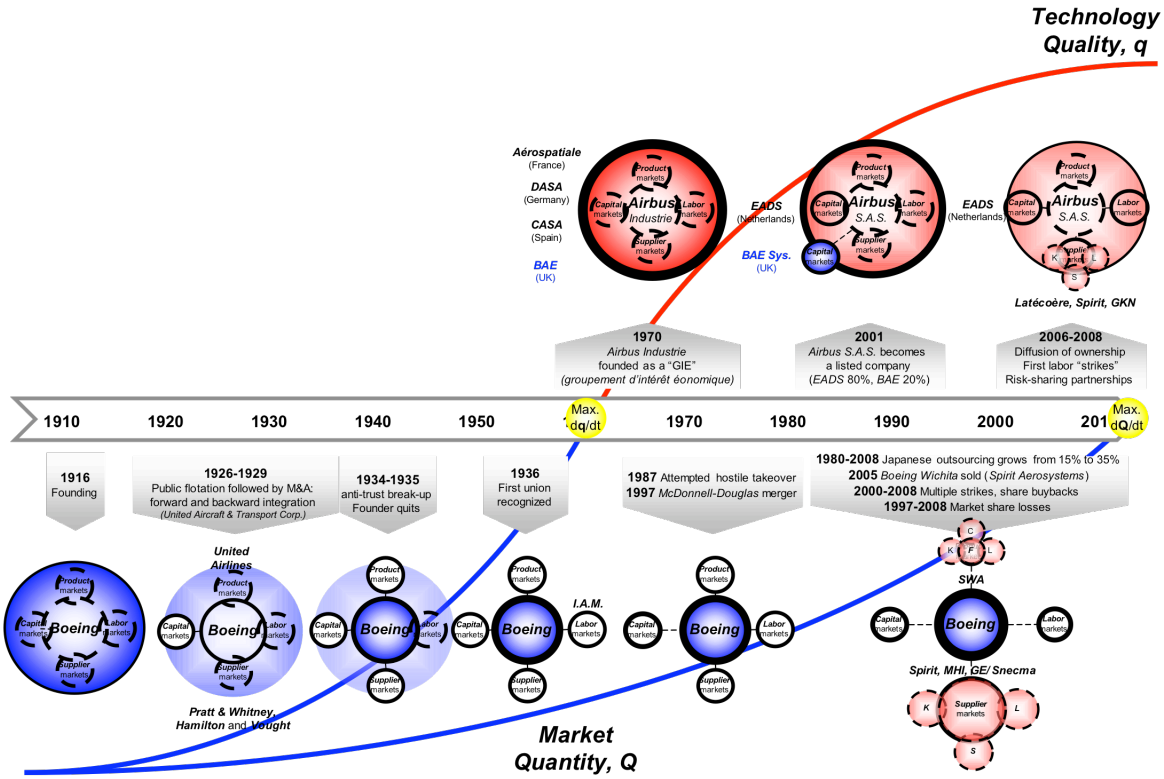
As the environment initially demands radical product innovation and patience, the dominant enterprise architectures tend to be integral. Subsequently, as the environment demands incremental product innovation, coupled with impatience, the dominant enterprise architectures tend to be modular. Then, as the environment demands radical process innovation and patience, the dominant enterprise architectures again tend to be integral. Finally, as the environment demands incremental process innovation, coupled with impatience, the dominant enterprise architectures tend to be integral.

Figure 31: Stylized Co-Evolution of Enterprises and Ecosystem



Empirical Data. Having established the birth dates and associated and founding conditions (e.g. population densities) of the two firms in the primary sample, Figure 32 below summarizes the qualitative evolutionary trajectories of the enterprise architectures of these firms.

Figure 32: Evolution of Dominant Designs in Enterprise Architectures: *Airplane* Industry:



The organizational *sets* appear to initially begin with an integral enterprise architectural form and subsequently disintegrate monotonically into a modular form over time. Note that this phenomenon appears to apply to both incumbent and challenger enterprises and be independent of the founding date of the enterprise.

At the ecosystem (or organizational *field)* level however, the dominant design in enterprise architecture appears to oscillate from integral to modular and back to integral forms. While re-integration of the incumbent enterprise architecture in order to achieve fit with the demands of the ecosystem is not theoretically precluded, empirically it is not observed. This suggests that in the theoretical sample analyzed, the incumbents reach a tipping point, whereby their reinforcing behavior tips from virtuous to vicious – that is, it is more efficient for the environment to *select* a new species, than for the existing species to be *retained* via managerial adaptation.

Superimposed on the evolutionary trajectories of the enterprise architectures, is a notional S-curve, representing the industry growth in both quantity and quality. One may begin to posit a relationship between the state of these key environmental variables and the states of the incumbent and challenger enterprise architectures. Empirical data will be offered in the following sections to refine this conceptual relationship.

As illustrated in Figure 33 and Figure 34 below illustrate similar trajectories in both the automotive and airline industries respectively.

Figure 33: Evolution of *Dominant Designs* in Enterprise Architectures: *Automotive* Industry

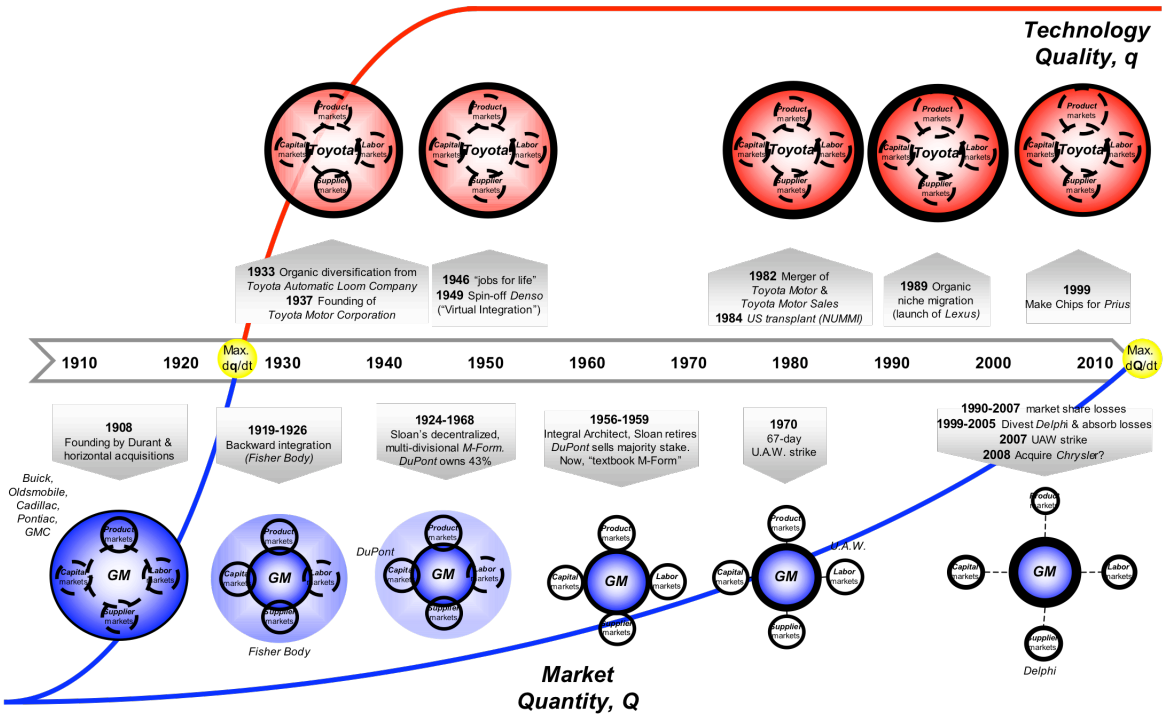
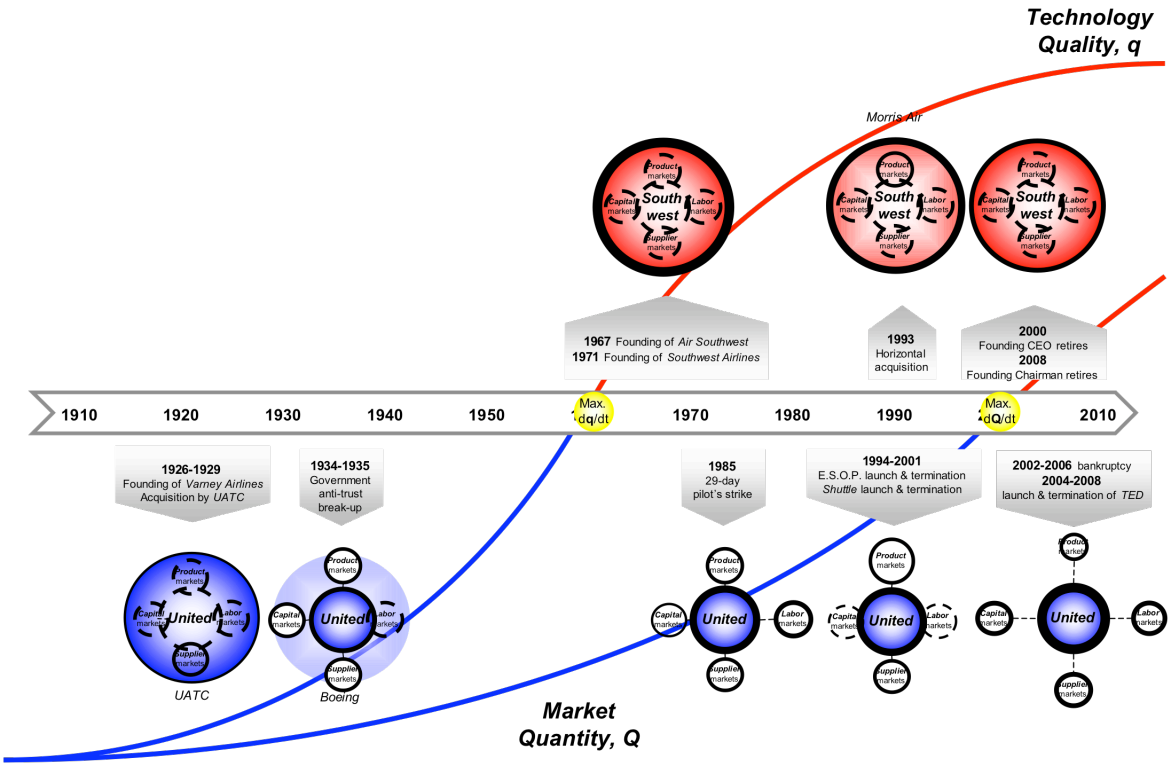


Figure 34: Evolution of *Dominant Designs* in Enterprise Architectures: *US Airline* Industry

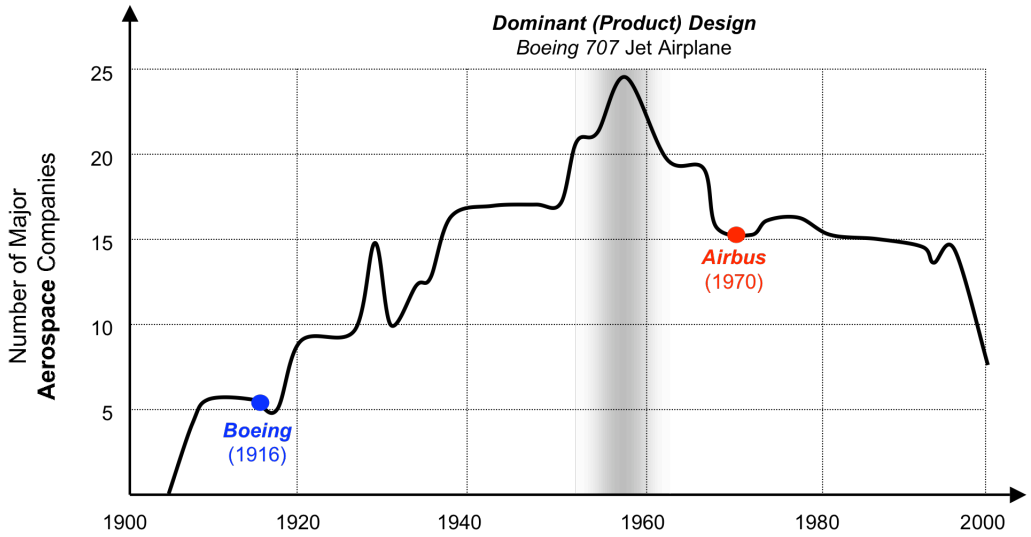


Proposition 4b: *Entry and Exit* of Enterprise Architectures. The second proposition relates environmental maturity to entry and exit of dominant enterprise architectures.[32]

> *Proposition 4b: Early entrant (incumbent) enterprise architectures tend toward monotonic disintegration, with increasing levels of architectural inertia inhibiting their reintegration. Thus it is easier for the environment to produce a new species of late entrant (challenger) enterprise architectures.*

Empirical Data. Figure 35 below summarizes the birth dates within the population densities for the firms in the primary sample.

Figure 35: *Commercial Airplane* Industry Concentration / Population Density



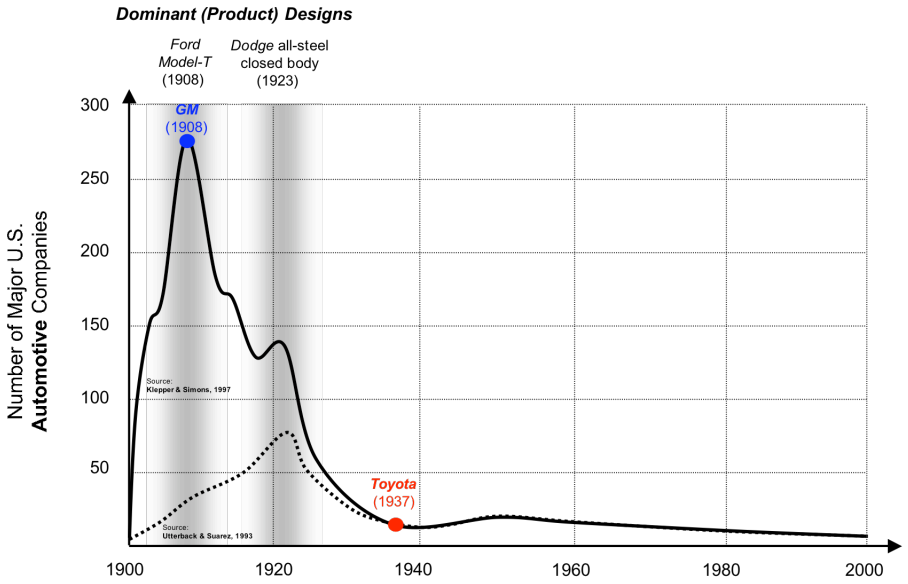
Soon after the invention of the airplane at the turn of the century, the number of firms in the aerospace industry grew for approximately fifty years during an era of ferment (Abernathy & Utterback, 1978) which was dominated by increasing product innovation resulting in improved product performance characteristics (i.e. "higher, faster, farther"). A "dominant design" in the product occurred in the late 1950's with the emergence of the commercial jet airplane[33], followed by a shake-out and consolidation of the industry, which continued for the next fifty years. Following the merger of *Boeing* with *McDonnell Douglas* in 1997, the large commercial airplane industry effectively became a global duopoly, with *Airbus* being the other producer.[34]

The founding dates of the two firms in the primary sample are also plotted in the figure above. *Boeing*, the incumbent was founded in 1916, well before the dominant product design and *Airbus* the challenger was founded in 1970, well after the dominant product design.

[32] Note: this "quantity" formulation captures the organizational ecologists' construct of "*density* dependence" (Barron, 1999).
[33] The *Boeing* 707 is considered representative of the "dominant design". Note however that other scholars (e.g. Tushman and Murmann, 1998) have cited an earlier "dominant design" in the *Douglas* DC-3 in 1936. See Piepenbrock (2008) for further discussion.
[34] As the market segment, "large commercial airplanes" is broadly defined as airplanes having over 100 seats, smaller airplane manufacturers (e.g. *Embraer*) have recently begun to enter this space.

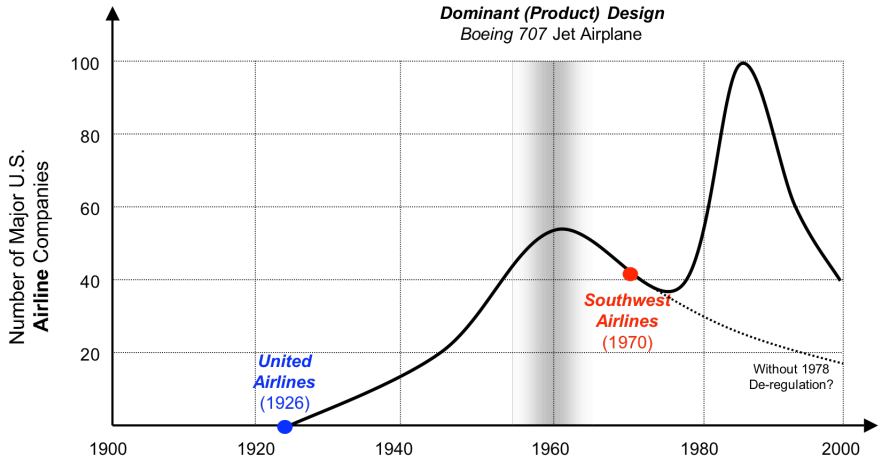
As illustrated in Figure 36 and Figure 37 below, similar phenomena in the trajectories in both the automotive and airline industries respectively are observed.

Figure 36: *Automotive* Industry Population Density, Dominant Design & Founding Dates



In the automotive industry, the dominant design was established in 1908 with *Ford's Model T*.[35] *General Motors*, the incumbent was founded in 1908, when the dominant design arrived and *Toyota* the challenger was founded in 1937, after the establishment of the dominant design.

Figure 37: *US Airline* Industry Concentration / Population Density



In the airline industry, the dominant design was established around 1960 with *Boeing's* 707 jet airplane.[36] *United Airlines*, the incumbent was founded in 1926, well before the dominant design and *Southwest Airlines* the challenger was founded in 1970, after the dominant design.

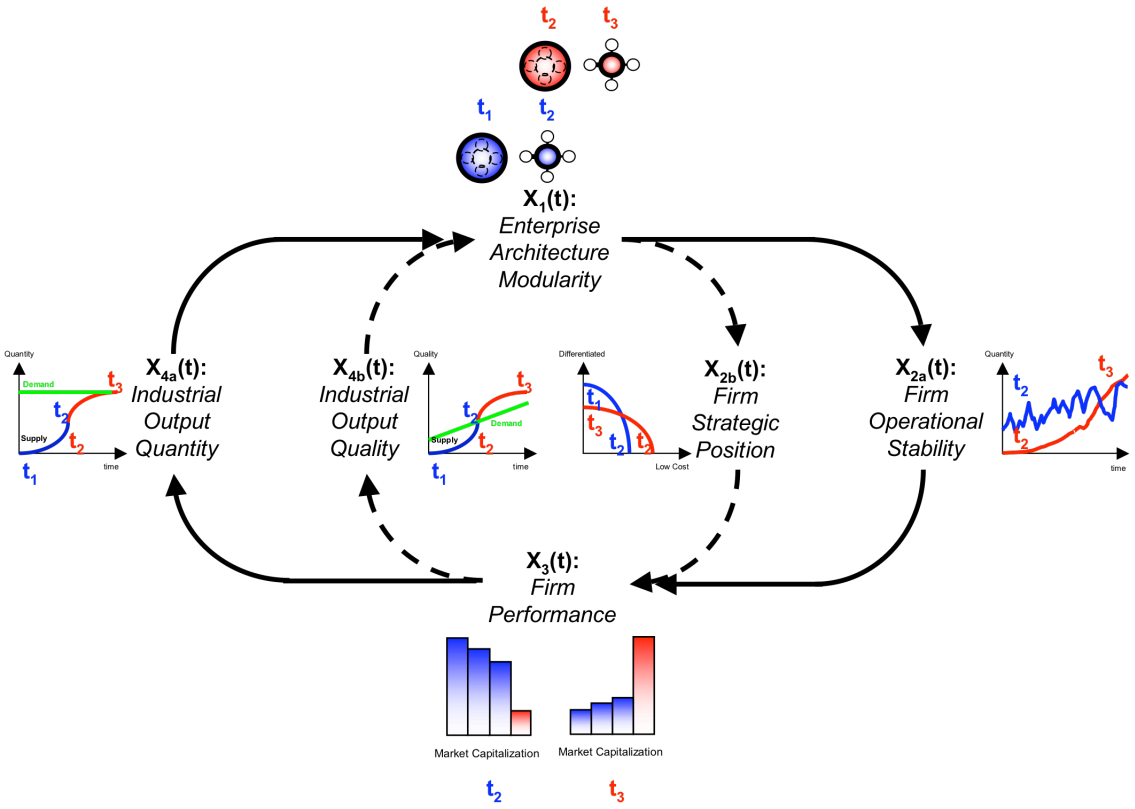
[35] Recent scholars (e.g. Klepper, 1997) argue that the US auto industry shakeout occurred in 1908, coincident with the arrival of the Ford Model-T as a candidate for dominant design. Utterback & Suarez (1993), citing a different data set, demonstrate shakeout in 1923 arguing that *Dodge's* all-steel, closed body automobile is the dominant design. See Piepenbrock (2009) for further discussion.

[36] See Tushman and Anderson (1986) and Kelly and Amburgey (1991).

Summary of Theoretical Framework

The theoretical framework, which traces the dynamic evolution of a generic business ecosystem is summarized in Figure 38 below.[37] Two main causal loops describe the co-evolution of the ecosystem and its constituent enterprises in terms of both product quantity (solid outer loop) and quality (dashed inner loop) that is demanded and supplied. Beginning with the industrial output variables $X_{4a}(t)$ and $X_{4b}(t)$ shown on the left of the figure, we will trace out two clockwise revolutions of the causal loop diagram to describe how the ecosystem grows and eventually matures[38], and how concurrently incumbent firms' enterprises build the industry and are ultimately overtaken by late-entrant challenger firms' enterprises.

Figure 38: *Simplified* Summary of Theoretical Framework



Industry *Growth* Phase. At time t_1, when an industry is born, a significant gap exists between the quantity and quality of a new product's supply and demand potential (shown in green). Firms that can bring higher performing products to market will gain early competitive advantage. In this phase of product innovation, integration is required in the product, firm and enterprise architectures. Such integral enterprise architectures have relatively low rates of growth due to their relatively "patient" capital, labor, customers and suppliers. Spatio-temporal boundaries begin as relatively broad, with the firm's relationship with its stakeholders being long-term, using trust-based relational contracts, and the resulting enterprise value being divided in a positive-sum cooperative game among stakeholders.

[37] A more detailed summary of the theoretical framework including the major balancing loops is discussed in Piepenbrock (2009).

[38] This framework traces the evolution of the business ecosystem from growth to maturity phases. For simplicity, it does not play out the evolution beyond maturity into the decline phase.

As the industry approaches time t_2, the gap between the quantity and quality of a new product's supply and demand potential diminishes at a faster rate as the rates of change of industry growth are rising. In order to meet the demands of the rapidly growing mass market, firms that can rapidly build capacity reap economies of scale. High rates of radical product innovation diminish, and are replaced by efficiencies of functional specialization. In this phase, disintegration (or modularization) of product, firm and enterprise architectures provide competitive advantage. Such modular enterprise architectures have relatively high rates of growth due to their relatively "impatient" capital, labor, customers, and suppliers. Spatio-temporal boundaries of the enterprise diminish, with the firm's relationship with its stakeholders becoming short-term, using arm's length contracts, and the resulting enterprise value being divided in a zero-sum competitive game among stakeholders.

Industry *Maturity* Phase. At time t_2, the industrial output S-curves are near their inflection points. After the industry reaches time t_2, the gap between the quantity and quality of a new product's supply and demand potential begins to diminish at a slower rate as the rates of change of industry growth begin to slow down. New customers are being added at slowing rates, and the appetite for higher performance products is now being dominated by a demand for cheaper products. At this inflection point in the industry's quantity and quality S-curves, two scenarios now occur.

Incumbent firms continue to over-serve the market by chasing smaller and smaller market segments consisting of higher and higher profit-margin customers (Christensen, 1997). Under new cost pressures, they continue to outsource, compete suppliers and unions harder and continue to attract more and more impatient capital. Although the industry is slowing down, the incumbent enterprise architectures continue to speed up, with their stocks of structural inertia and their impatient capital growing.

Challenger firms, having a different enterprise architecture can enter and take advantage of the industry's changing characteristics. Now, the rates of technological innovation begin to slow down, as the dominant product design has been established by the dominant enterprise architecture, which is now in a modular form. This slowing down of the industry, both in quantity and quality terms, provides the conditions for a new firm with a different enterprise architecture to enter and to bring supply and demand back in balance both in quantity terms (i.e. slower) and quality terms (i.e. *process* innovation for higher quality, lower cost, faster delivery). As in the birth of the industry, innovation requires integration of product, firm and enterprise architectures. Such integral enterprise architectures have relatively low rates of growth due to their relatively "patient" capital, labor, customers, and suppliers. Spatio-temporal boundaries of the enterprise increase, with the firm's relationship with its stakeholders becoming long-term, using trust-based contracts, and the resulting enterprise value being divided in a positive-sum cooperative game among stakeholders.

The competition to establish the dominant product architecture by the now-modular incumbent enterprise architectures has sown the seeds of their own destruction. The emergence of a dominant design in product architecture has established the conditions for the emergence of a new dominant design in enterprise architecture. The dominant enterprise architecture oscillated throughout the industry's lifecycle from integral to modular to integral.

MATHEMATICAL MODEL and NUMERICAL SIMULATION

Generic Equations of Motion. The evolution of business ecosystems will be expressed formally by a system of simultaneous differential equations,[39] where the state variables, X_n are stocks which accumulate net flows (dX_n/dt) over time.

$$dX_1/dt = f_1(X_1, X_2, \ldots, X_n)$$
$$dX_2/dt = f_2(X_1, X_2, \ldots, X_n)$$
$$\vdots$$
$$dX_n/dt = f_n(X_1, X_2, \ldots, X_n)$$

Note that such equations form a feedback system that generates system dynamics endogenously, via information from the various state variables, which feed back to influence their own rates of change.

Model Build-Up. In the following subsections, the model will be constructed progressively, each time adding a higher level of sophistication in order to more clearly understand the underlying assumptions, parameters, structure and behavior of the model at each stage of complexity. The following stages will be discussed sequentially:

- Single Firm Growth in an *Infinite* Market
- Single Firm Growth in a *Constant* Market
- *Intra*-species Competition in a Constant Market[40]

- *Diffusing* Market (Quantity)
- *Intra*-species Competition in a Diffusing Market
- *Inter*-species Competition in a Diffusing Market

- *Commoditizing* Market (Quality)
- *Intra*-species Competition in a Commoditizing Market
- *Inter*-species "Competition" in a Commoditizing Market

- *Diffusing, Commoditizing* Market (Quantity and Quality)
- *Intra*-species Competition in a Diffusing, Commoditizing Market
- *Inter*-species Competition in a Diffusing, Commoditizing Market

[39] In the traditions of the general system theory (e.g. Von Bertalanffy, 1950), cybernetics (e.g. Ashby, 1952), system dynamics (e.g. Forrester, 1961); as well as organizational ecology (e.g. Hannan and Freeman, 1977).

[40] We will not cover the case of *inter*-species competition in an unchanging environment here, because theoretically, significant sustained environmental variation is required in order to produce and sustain significant variation in organizational species. Inter-species competition in a constant market would be a special parametric study when exploring inter-species competition in a logistic growth market, in which the market diffusion rate is much greater than the competitor growth rates.

Single Firm Growth in an Infinite Market. First, we assume a monopolist operating under increasing returns to scale. This assumption captures a variety of business phenomena including economies of scale, learning curve effects, etc. Under this reinforcing feedback, the more market the firm accumulates, the faster it continues to be accumulated.

Second, we assume initially that the firm exists in a market of unlimited growth potential – unlimited carrying capacity. The firm then is able to grow at its maximum fractional rate, r which is assumed to be constant and is determined by a number of goals and constraints which might include the rate of return on residual cash flows promised to risk bearers.[41]

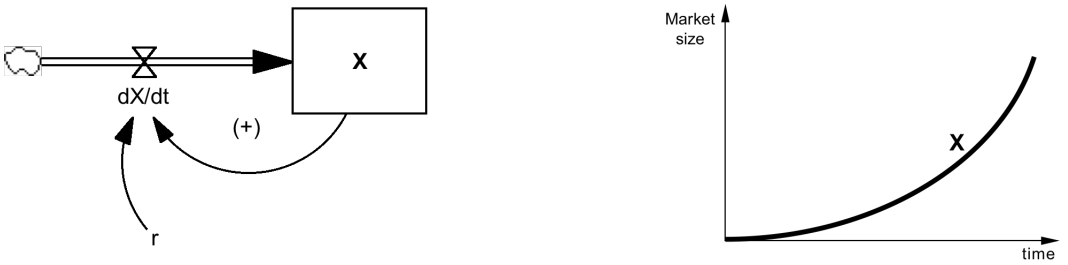
Most models in organizational ecology focus on population size or density - expressed as number of organizations - as the primary state variable, which accumulates net flows of organizational entries and exits (e.g. Hannan and Freeman, 1977). Population size is of lower importance in these formulations. This paper however focuses instead on organizational size as approximated by the amount of environmental resources an organization accumulates, or more specifically in the case of business ecosystems, the amount of a market a firm possesses. In this way, a population could consist of a spectrum of organizations ranging from a large number of equally sized firms, each possessing the same percentage of the total market; to a single firm operating as a monopolist possessing the entire market. We will derive equations of motion for a firm accumulating sales, X over time.[42]

The following differential equation captures this simple reinforcing feedback:

	$dX/dt = rX$	(1)

Figure 39 below illustrates the causal structure[43] and resulting behavior of this *linear* first-order formulation, which results in unrestrained exponential growth of the firm's market acquisition.

Figure 39: Structure and Behavior of Single Firm Growth in an *Infinite* Market

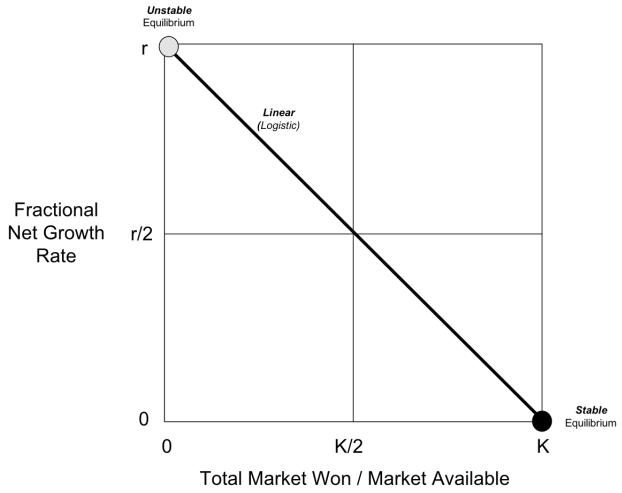


This equation also describes the early growth of a firm in a finite market, when its accumulated quantity of market, X is far from the carrying capacity of the market. This will be covered in the subsequent section.

[41] This is actually the fractional net growth rate, and has the units of percent of market growth per unit of time.
[42] For the present discussion, we assume that the firm converts demand into supply instantaneously or without any delays associated with order backlogs, inventory backlogs etc. Such delays in a balancing loop can account for cyclical oscillatory behavior. As the time horizon of interest in this evolutionary research is measured in centuries, the oscillations which manifest themselves over timeframes of decades are of secondary importance.
[43] In the diagrammatic representations of the differential equations, the variables within "boxes" represent stocks or accumulations, while the variables below the "valves" represent rates or flows in and out of the stocks.

Single Firm Growth in a *Constant* Market. As no firm exists in an infinitely rich resource environment, we next constrain the model by imposing finite but constant market carrying capacity, K, which might represent the size of population of potential customers or sales. The assumption here is that, as the firm acquires more of the finite market, K, the rate of firm growth, r begins to reduce linearly[44], making the organization's rate of growth dependent upon the proportion of the carrying capacity that remains unexploited[45], as shown in Figure 40.

Figure 40: Fractional Net Growth Rate Assumption

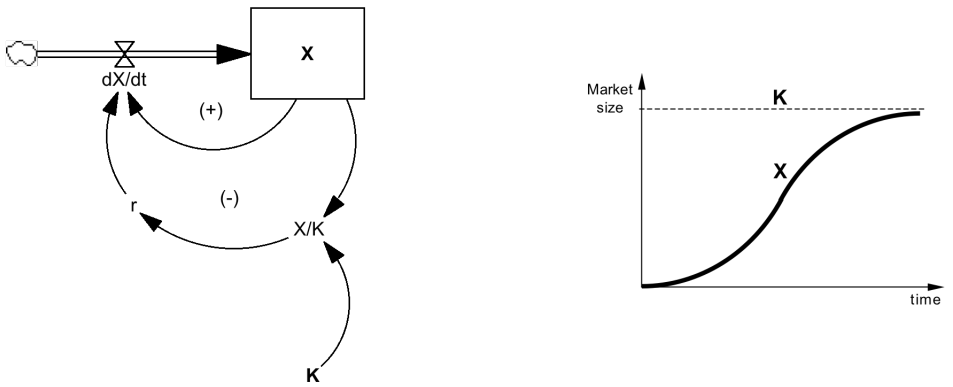


We therefore extend the previous differential equation (1) to capture the mode-switching from reinforcing to balancing feedback as the firm approaches the carrying capacity of the market. This new logistic equation is shown below:[46]

	$dX/dt = rX - rX^2/K$	(2)

Figure 41 below illustrates the causal structure and resulting behavior of this *nonlinear* first-order formulation, which results in sigmoid or S-shaped growth of the firm's market capture.

Figure 41: Structure and Behavior of Single Firm Growth in a *Constant* Market



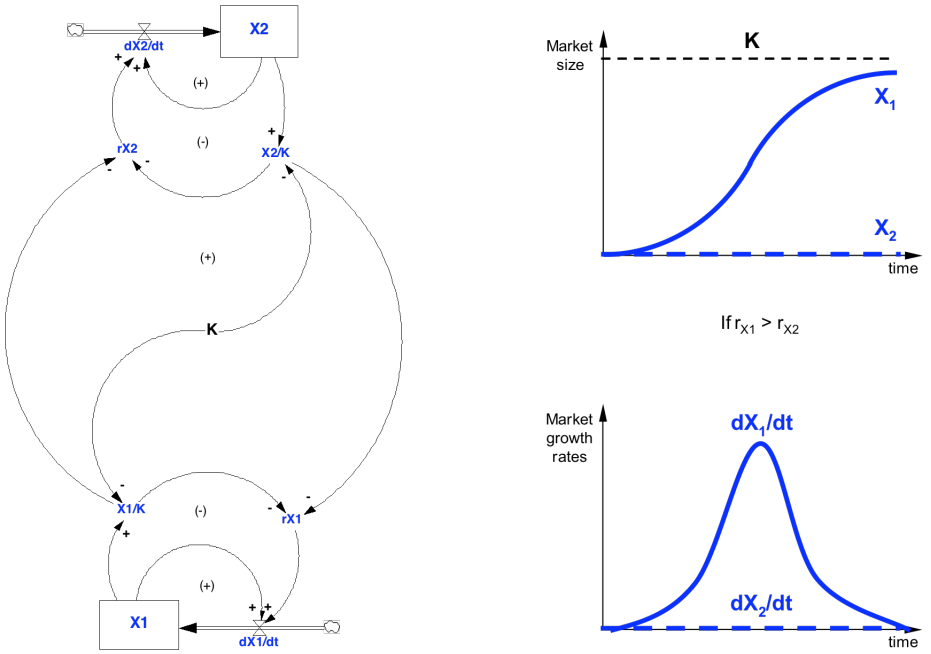
[44] This linear relationship, which produces logistic growth, will be relaxed in subsequent sections which explore interspecies competition.
[45] This is called "mass dependence" in the organizational ecology literature.
[46] This was first formulated in social systems by Verhulst (1838) in his logistic population growth model.

***Intra*-species Competition in a Constant Market.** In most markets, no firm exists without competition; we therefore need to next introduce competition between firms for customers in a common market. At this point, we assume two identical isomorphic competitors, X_1 and X_2 having homogeneous enterprise architectures occupying the same mathematical point niche. We therefore extend the previous differential equation (2) to account for the simple fact that the addition of sales to either competitor decreases the rate of growth of the other competitor.[47] Both competitors are now connected via a reinforcing loop that amplifies differences in market share resulting in an unstable equilibrium.[48] The new, coupled system of differential equations is shown below:[49]

	$dX_1/dt = r_{X1}X_1 - r_{X1}X_1^2/K - r_{X1}X_1X_2\alpha_{12}/K$	(3a)
	$dX_2/dt = r_{X2}X_2 - r_{X2}X_2^2/K - r_{X2}X_2X_1\alpha_{21}/K$	(3b)

Figure 42 below illustrates the causal structure and resulting behavior of this nonlinear *second*-order formulation, which results in sigmoid or S-shaped growth of each competitor's market capture. Provided that both firms have identical forms and occupy the same market niche, no two-firm (or more generally, two-population) equilibrium can be stable – any exogenous shock to the system will result in the elimination of one of the firms (or populations).[50]

Figure 42: Structure and Behavior of *Intra-species Competition* in a Constant Market



[47] In ecology, this is called "exploitation" (vs. "interference") competition (Brian, 1956). Other dynamic models formulate competition using more operational variables (Sterman, Henderson, Beinhocker and Newman, 2007).
[48] This severe "winner-takes-all" competitive assumption is akin to Bertrand (price) competition, rather than the weaker form of Cournot (quantity) competition where the market is shared in proportion to relative firm growth rates. Under this assumption, the "competition coefficients", α_{12} and α_{21} equal 1.
[49] This system of equations formed the basis for modeling competition within the seminal organizational ecology framework (Hannan and Freeman, 1977: 942). It is based on the classic Lotka-Volterra equations for *competing* populations, after Lotka (1925) and Volterra (1931). Note that this is different from the classic Lotka-Volterra equations for *predator-prey* populations which generate chaotic oscillation due to a central *balancing* loop.
[50] This is known in ecosystem theory as the "principle of competitive exclusion" (Gause, 1934).

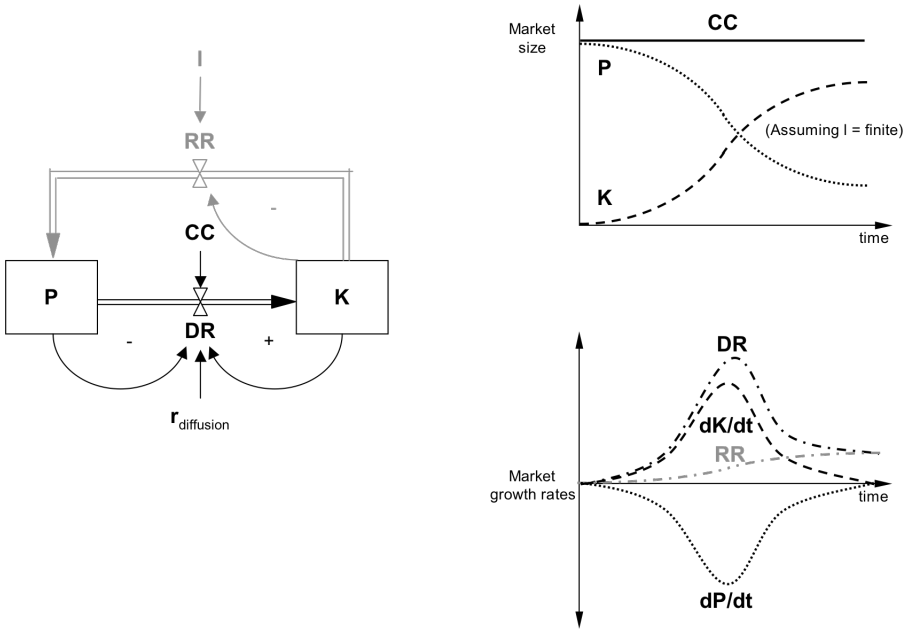
***Diffusing* Market (Quantity).** Next, we relax the assumption of a constant carrying capacity of the resource environment, K (Brittain, 1994). Instead, we permit sigmoid growth as it approaches its own inherent carrying capacity.[51] This assumption captures the scenario of a new product/service that either: 1) diffuses logistically throughout a constant population of potential consumers (Bass, 1969), or 2) diffuses instantaneously through a logistically-growing population of potential consumers (Verhulst, 1838), or 3) some combination of the two.[52]

The new, coupled system of differential equations is shown in its most simple form below:

	$dP/dt = RR - DR = K/l - r_d PK/CC$	(4a)
	$dK/dt = DR - RR = r_d PK/CC - K/l$	(4b)

Here, P denotes the *potential* market; K denotes the *adopting* market; CC denotes the carrying capacity of the system; DR denotes the *diffusion* rate; r_d denotes the fractional *diffusion* rate; RR denotes the *replacement* or *repurchase* rate; l denotes the average product life. Figure 43 below illustrates the causal structure and resulting behavior of this nonlinear *first*-order formulation, which again results in sigmoid or S-shaped growth for the resource environment.

Figure 43: Structure and Behavior of a *Diffusing* Market



For simplicity, we will assume that the average product life, l approaches infinity (i.e. the market consists of durable goods)[53], making the replacement rate, RR approach zero. Noting that P = CC – K, the new differential equation which captures the dynamics of *diffusion* is:

	$dK/dt = r_d K (1 - K/CC)$	(4c)

[51] For simplicity, we model a linear relationship between the diffusion rate and available carrying capacity, which results in logistic growth.

[52] The more general formulation of a resource environment comprising an interaction of logistic consumer population growth with logistic diffusion of an innovation is discussed in Piepenbrock (2009).

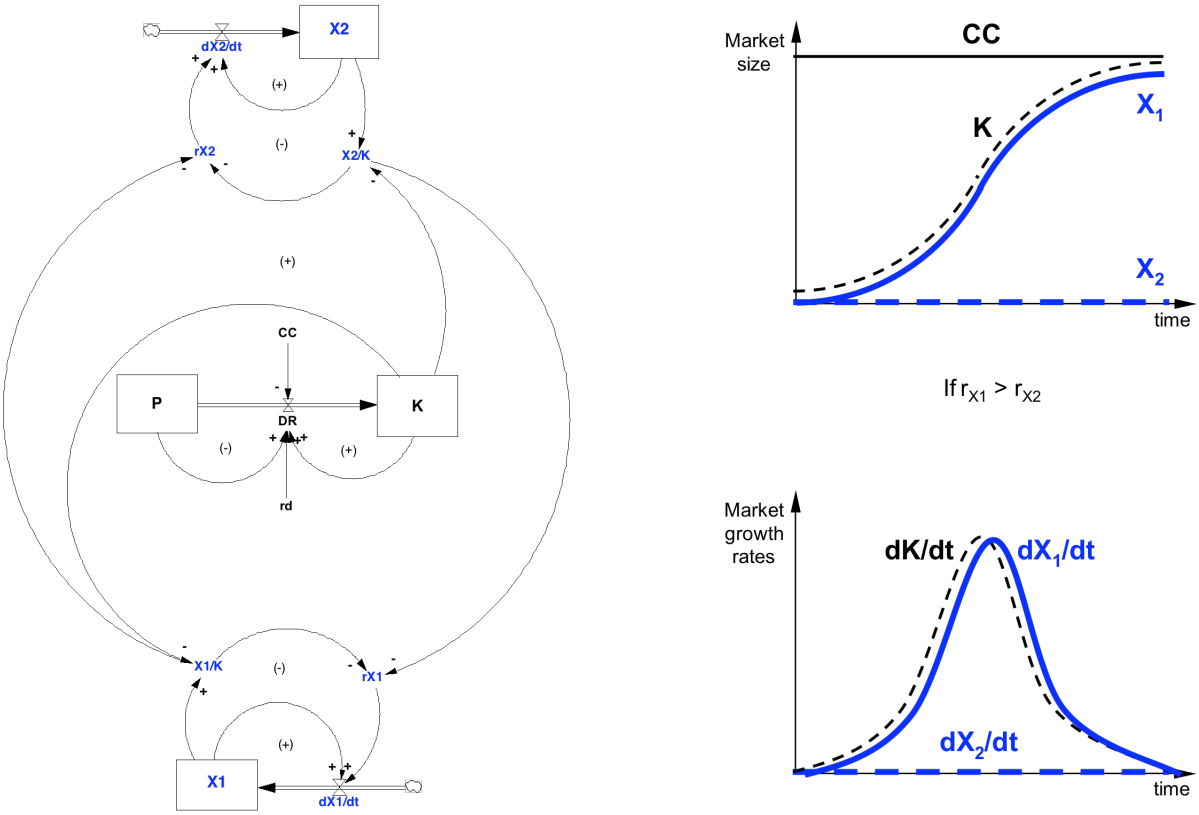
[53] This assumption is not an unreasonable approximation for the primary case study of large commercial airplanes, with average product lives ranging from 25-50 years.

Intra-species Competition in a *Diffusing* Market. Next, we reintroduce two members of the same species, competing for the logistically growing market. The new, coupled system of differential equations is shown in its most simple form below:

	$dX_1/dt = r_{X1}X_1 - r_{X1}X_1^2/K - r_{X1}X_1X_2\alpha_{12}/K$	(5a)
	$dX_2/dt = r_{X2}X_2 - r_{X2}X_2^2/K - r_{X2}X_2X_1\alpha_{21}/K$	(5b)
	$dK/dt = r_K K - r_K K^2/CC$	(5c)

Figure 44 below illustrates the causal structure and resulting behavior of this nonlinear *third*-order formulation, which again results in sigmoid or S-shaped growth for both the resource environment and the dominant firm (or population of firms) that created it.

Figure 44: Structure and Behavior of Intra-species Competition in a *Diffusing* Market

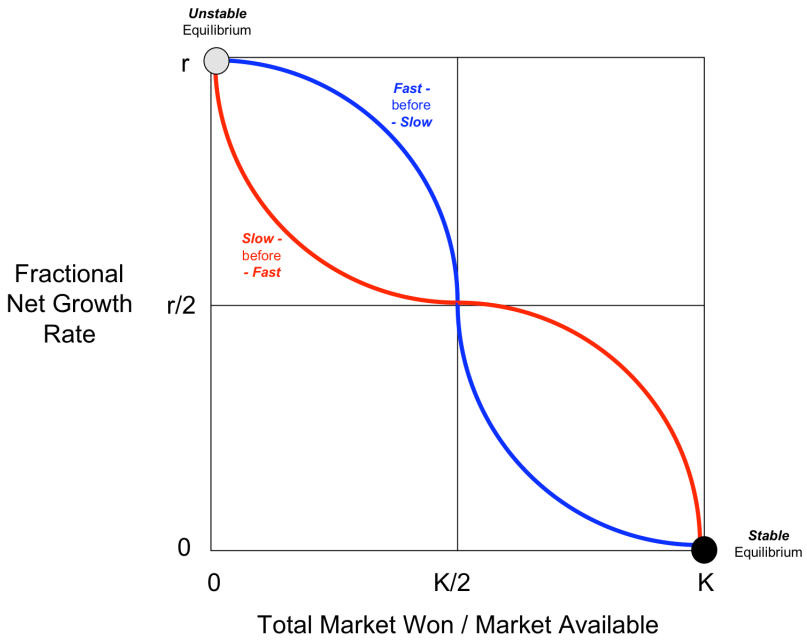


Although this refinement of Hannan and Freeman's (1977) classic does not itself add new insights into the behavior of competing organizations or populations, it is a necessary building block for the next step of the formulation of the evolution of business ecosystems, namely, it establishes the condition necessary for the establishment of interspecies competition, resulting in an extension of the theory of competitive exclusion (Gause, 1934).

***Inter*-species Competition in a Diffusing Market.** Since in the previous stage, we have allowed the environment to grow logistically, we can now acknowledge the possibility of variation in organizational forms as a consequence of variation in environmental rates of growth. This gives rise to the potential for dominance switching: i.e. the late entry of a new species of organization, and the associated early exit of the incumbent species. The two types of competing organizational species modeled therefore reflect either increasing rates or decreasing rates of environmental growth.

The incumbent species, X which builds the market is known in bio-ecology as an *r-strategist*, and the late-entrant challenger species, Y which takes the market is known as a *K-strategist* (MacArthur and Wilson, 1967). The primary difference between this formulation and the previous, is that each competitor's fractional net growth rates are no longer linearly density-dependent, with the (*Modular*) *r-strategist* growing faster when the environment is experiencing rapid growth, and the *(Integral) K-strategist* growing faster when the environment's rate of growth is slowing down, as shown in Figure 45 below.

Figure 45: Fractional Net Growth Rate Assumptions

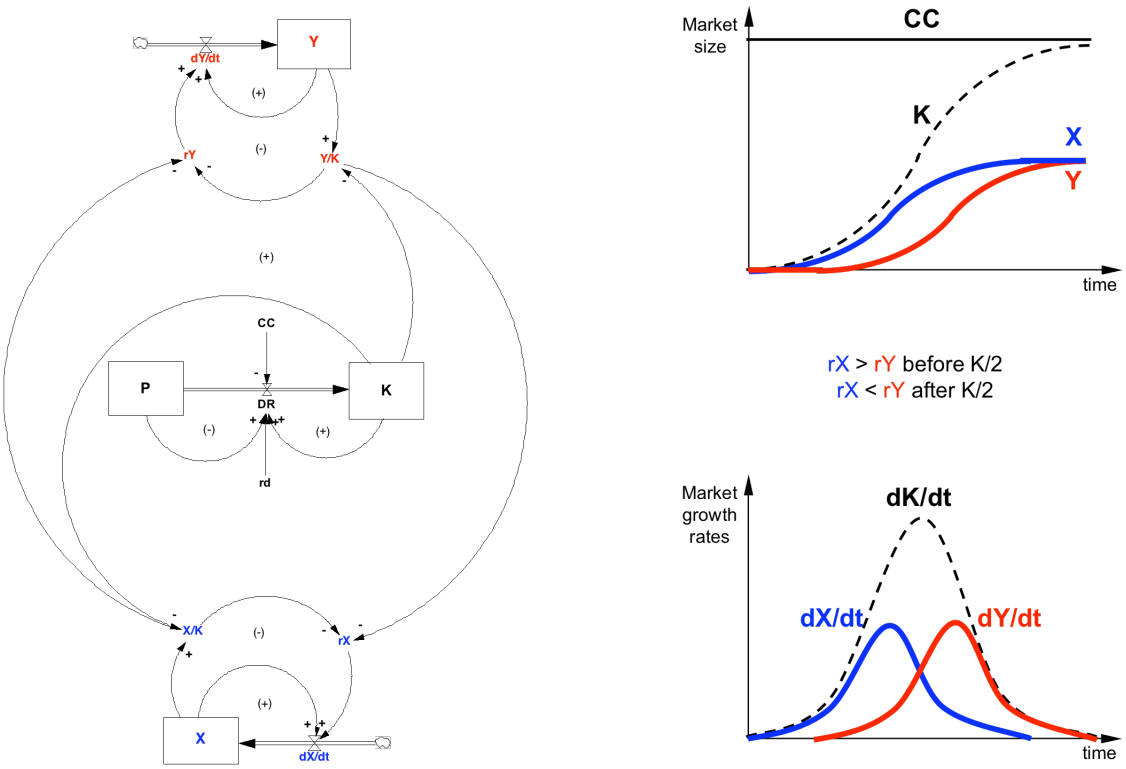


The new, coupled system of differential equations is shown below:

$r_X > r_Y$ when $(X+Y) < K/2$ $r_X < r_Y$ when $(X+Y) > K/2$	$dX/dt = r_X X - r_X X^2/K - r_X XY\alpha_{XY}/K$ $dY/dt = r_Y Y - r_Y Y^2/K - r_Y XY\alpha_{YX}/K$ $dK/dt = r_d K - r_d K^2/CC$	(6a) (6b) (6c)

Figure 46 below summarizes the causal structure and resulting behavior of this nonlinear *third*-order formulation which results in S-shaped (but no longer logistic) growth for the competitor's state variables. Crucially note that the r-strategist tends to exit when the growth rate of the market begins to drop below its own growth objectives. Environmental variance therefore produces variance in the architectures of the organizational sets, which creates symbiotic inter-species competition, with a more complex theory of competitive exclusion.

Figure 46: Structure and Behavior of *Inter*-species Competition in a Diffusing Market



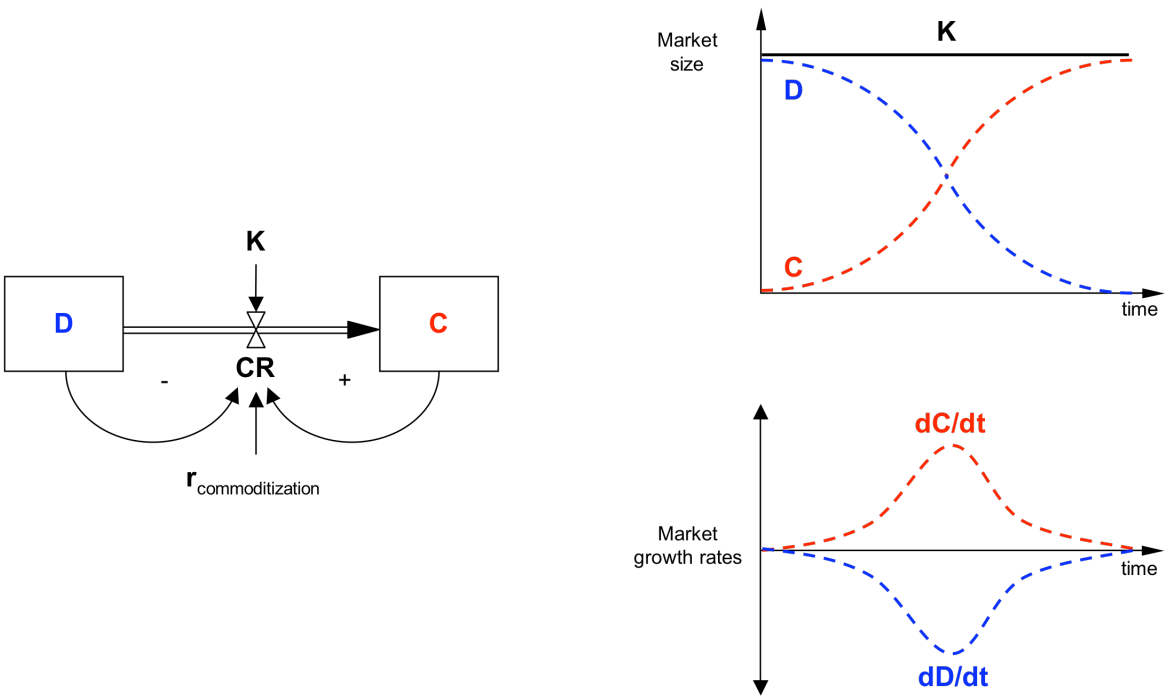
***Commoditizing* Market (Quality).** Having permitted the carrying capacity of the market, K to grow logistically, we now go back to a constant market assumption, but instead allow the *quality* of the market customer preferences to diffuse from high-performance *differentiated* products and services towards *low-cost* products and services (Abernathy and Utterback, 1978; Christensen, 1997). This in effect allows market niches to evolve, which has the potential to shape the entry and exit of different species of organizational sets.

The new, coupled system of differential equations is shown in its most simple form below:

	$dD/dt = - CR = - r_c DC/K$ $dC/dt = CR = r_c DC/K$	(7a) (7b)

Here, C denotes the *cost-based* market; D denotes the *differentiation-based* market; K denotes the adopting market's *capacity*; CR denotes the *commoditization* rate; r_c denotes the fractional *commoditization* rate. Figure 47 below illustrates the causal structure and resulting behavior of this nonlinear *first*-order formulation, which again results in sigmoid or S-shaped growth for the transforming resource environment.[54]

Figure 47: Structure and Behavior of a *Commoditizing* Market



Noting that D + C = K, the new differential equations which capture the dynamics of *commoditization* is shown below:

	$dD/dt = r_c D\ (1 - D/K)$ $dC/dt = r_c C\ (1 - C/K)$	(7c) (7d)

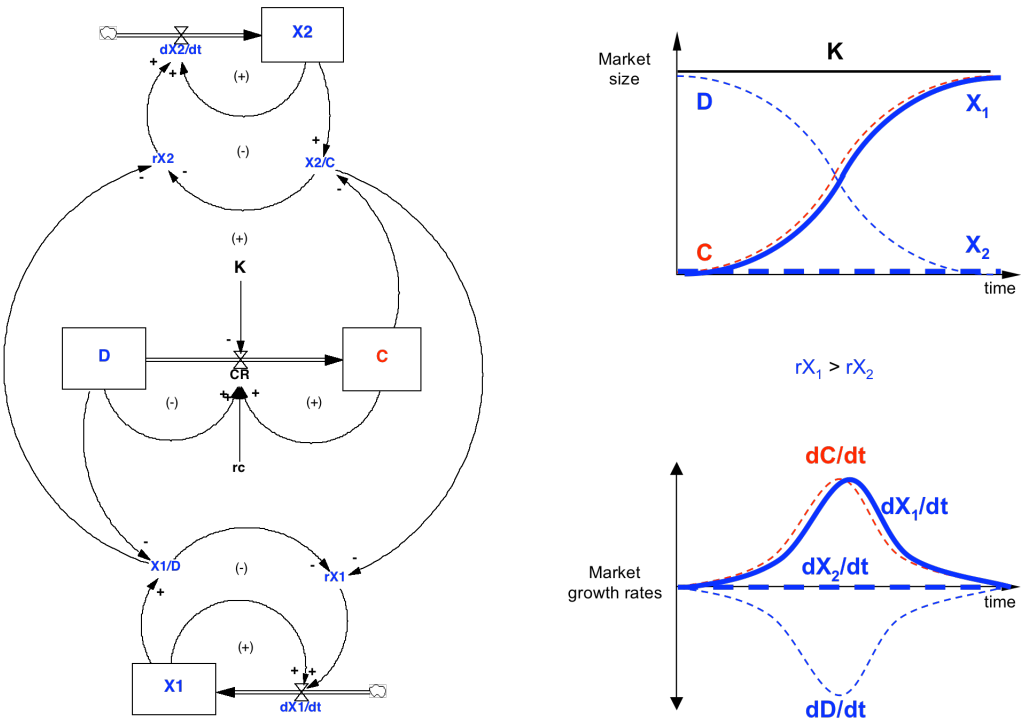
[54] Again, as in the characterization of the diffusing market, the commoditizing market's sigmoid growth is assumed to proceed logistically, for analytical simplicity.

***Intra*-species Competition in a *Commoditizing* Market.** In the previous stage, the resource environment was characterized as existing in one dimension: the rate of change of *market* growth, dK/dt. This formulation extends the model to include a second dimension: the rate of change of *technology* commoditization, dC/dt. This captures the construct of a *dominant design* in the product offering (Abernathy and Utterback, 1978), which marks the shift in market demand from increasing rates of change of improvement in product performance, where competition is based on *product* innovation, to increasing rates of change of improvement in product cost, where competition is based on *process* innovation.[55] In order to control for the previous effects of market growth, we hold the market size, K constant.[56] The new coupled system of differential equations is shown below:

	$dX_1/dt = r_{X1}X_1 - r_{X1}X_1^2/D - r_{X1}X_1X_2\alpha_{12}/(D + C)$	(8a)
	$dX_2/dt = r_{X2}X_2 - r_{X2}X_2^2/C - r_{X2}X_2X_1\alpha_{21}/(D + C)$	(8b)
	$dD/dt = r_cD\,(1 - D/K)$	(8c)
	$dC/dt = r_cC\,(1 - C/K)$	(8d)

Figure 48 below summarizes the causal structure and resulting behavior of this nonlinear *third* order formulation[57] which results in sigmoid or S-shaped transition from a market dominated by sales of products/services based on *differentiation*, D to a market dominated by sales of products/services based on *cost*, C. Note that this formulation represents *direct* competition between organizations within the environment.

Figure 48: Structure and Behavior of *Intra*-species Competition in a *Commoditizing* Market



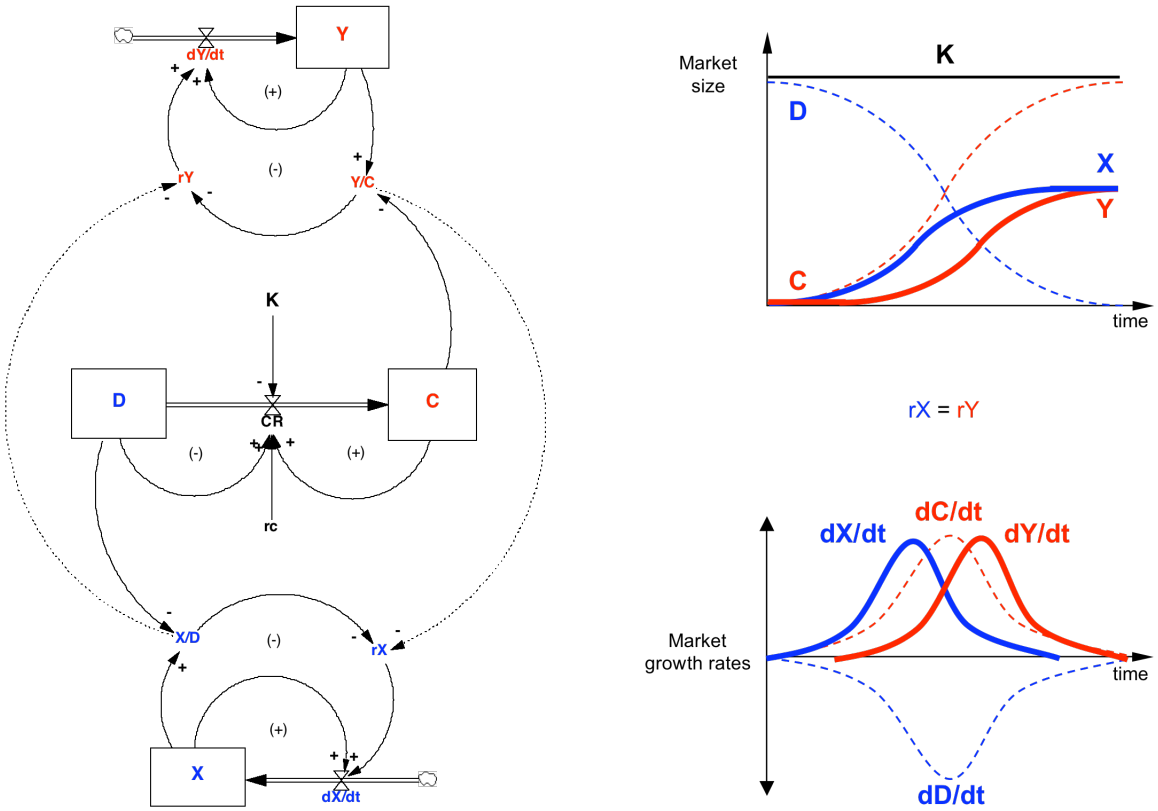
[55] Although a "dominant design" is often seen as a *discrete* event, the market is modeled as a *continuously* evolving.
[56] This control will relaxed in the next section, where both market size, K and type, C will grow logistically.
[57] The addition of two state variables is only a first-order addition as one is completely determined by the other.

Inter-species "Competition" in a *Commoditizing* Market. In the previous stage, both competitors were assumed to be of the same species, and therefore broadly able to compete in both the differentiation-based and cost-based niches (i.e. the competition coefficients α were at or near 1) – for example both intra-species competitors, *GM* and *Ford* can transition from a differentiated product focus towards a cost focus. However, the emergence of a new species, having an integral enterprise architecture (like *Toyota*) is much better suited towards cost-leadership, making their competition coefficient α approach zero. In this extreme case of interspecies competition, each species focuses on the niche that they are best suited to, and "competition" takes on a symbiotic nature, due to the presence of architectural inertia. The new coupled system of differential equations is shown below:

	$dX/dt = r_X X - r_X X^2/D - r_X XY\alpha_{XY}/(D + C)$	(9a)
	$dY/dt = r_Y Y - r_Y Y^2/C - r_Y XY\alpha_{YX}/(D + C)$	(9b)
	$dD/dt = r_c D\,(1 - D/K)$	(9c)
	$dC/dt = r_c C\,(1 - C/K)$	(9d)

Figure 49 below summarizes the causal structure and resulting behavior of this nonlinear *third* order formulation[58] which results in sigmoid or S-shaped transition from a market dominated by sales of products/services based on *differentiation*, D to a market dominated by sales of products/services based on *cost*, C. Note that this formulation represents *indirect* competition between organizations occupying different niches within the environment.

Figure 49: Structure and Behavior of Inter-species "Competition" in a *Commoditizing* Market



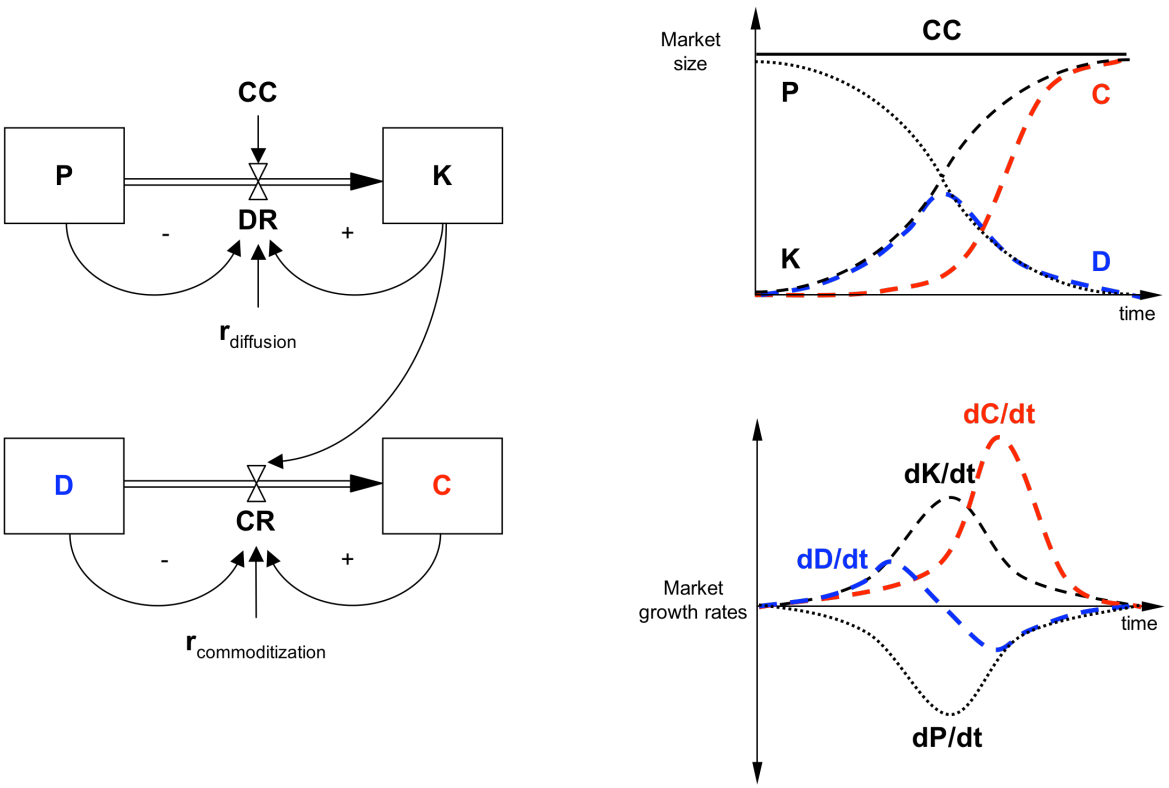
[58] The addition of two state variables is only a first-order addition as one is completely determined by the other.

***Diffusing, Commoditizing* Market (Quantity and Quality).** We now combine the previous two descriptions of the market environment, where the *quantity* of the market, K grows logistically (Bass, 1969), while simultaneously, the *quality* of the market customer preferences diffuses from high-performance *differentiated* products and services towards *low-cost* products and services (Abernathy and Utterback, 1978). This allows the entry and exit of different species of organizational sets for two reasons: the rate of change in market *quantity* and the rate of change in technological *quality* enable market niches to evolve. The new, coupled system of differential equations is shown below:

	$dP/dt = -r_d P\ (1 - P/CC)$	(10a)
	$dK/dt = r_d K\ (1 - K/CC)$	(10b)
	$dD/dt = -r_c D\ (1 - D/K)$	(10c)
	$dC/dt = r_c C\ (1 - C/K)$	(10d)

Figure 50 below illustrates the causal structure and resulting behavior of this nonlinear *second*-order formulation. Although the total market, K again results in logistic sigmoid or S-shaped growth, niches D rises and falls, while niche C rises in S-shaped growth to eventually characterize the entire market. Note, however that if the fractional diffusion rate, r_d >> than the fractional commoditization rate, r_c, then the behavior approaches that shown in Figure 43.

Figure 50: Structure and Behavior of a *Diffusing, Commoditizing* Market

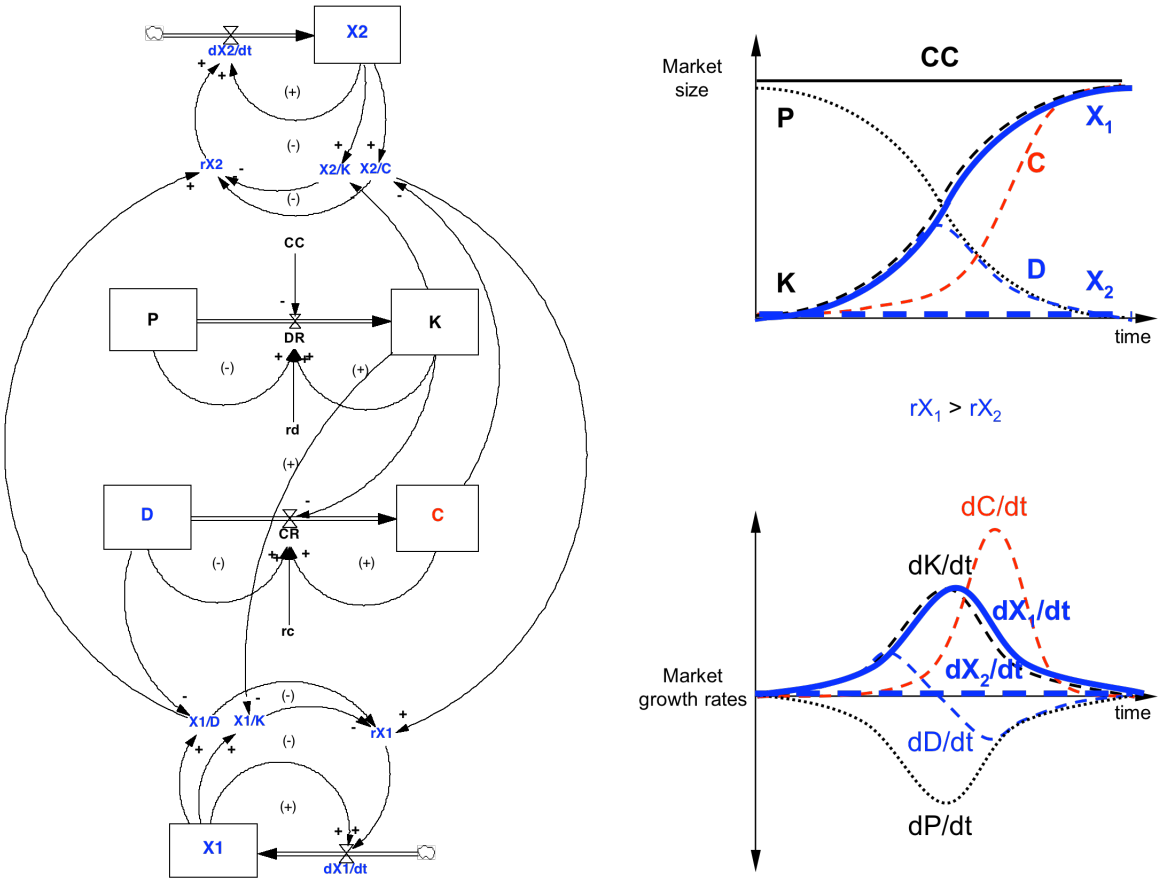


***Intra*-species Competition in a *Diffusing, Commoditizing* Market.** The model now has two different ways of defining the state of evolutionary maturity of the environment: *quantity* and *quality* – that is, *how much* product is produced/consumed, and *what type* of product is produced/consumed. This section therefore combines these two characterizations of the market environment into one model, where two firms of the same species (characterized by the architectures of their respective extended enterprises) compete. The extent of competitive intensity is defined by the ability of each firm to overcome architectural inertia and transition from niche D to niche C as the market evolves. A summary of the coupled system of differential equations is shown below.

	$dX_1/dt = r_{X1}X_1 - r_{X1}X_1^2/D - r_{X1}X_1X_2\alpha_{12}/K - r_{X1}X_1X_2\alpha_{12}/(D + C)$	(11a)
	$dX_2/dt = r_{X2}X_2 - r_{X2}X_2^2/C - r_{X2}X_1X_2\alpha_{21}/K - r_{X2}X_2X_1\alpha_{21}/(D + C)$	(11b)
	$dK/dt = r_dK\,(1 - K/CC)$	(11c)
	$dD/dt = -r_cD\,(1 - D/K)$	(11d)
	$dC/dt = r_cC\,(1 - C/K)$	(11e)

Figure 51 below summarizes the causal structure and resulting behavior of this nonlinear *fourth*-order formulation which results in S-shaped growth of the general market K, and the niche, C. Due to architectural inertia, each species is constrained to its own niche resulting in early exit, late entry and dominance-switching throughout the life-cycle of the industry.

Figure 51: Structure/Behavior of *Intra*-species Competition in a *Diffusing, Commoditizing* Market

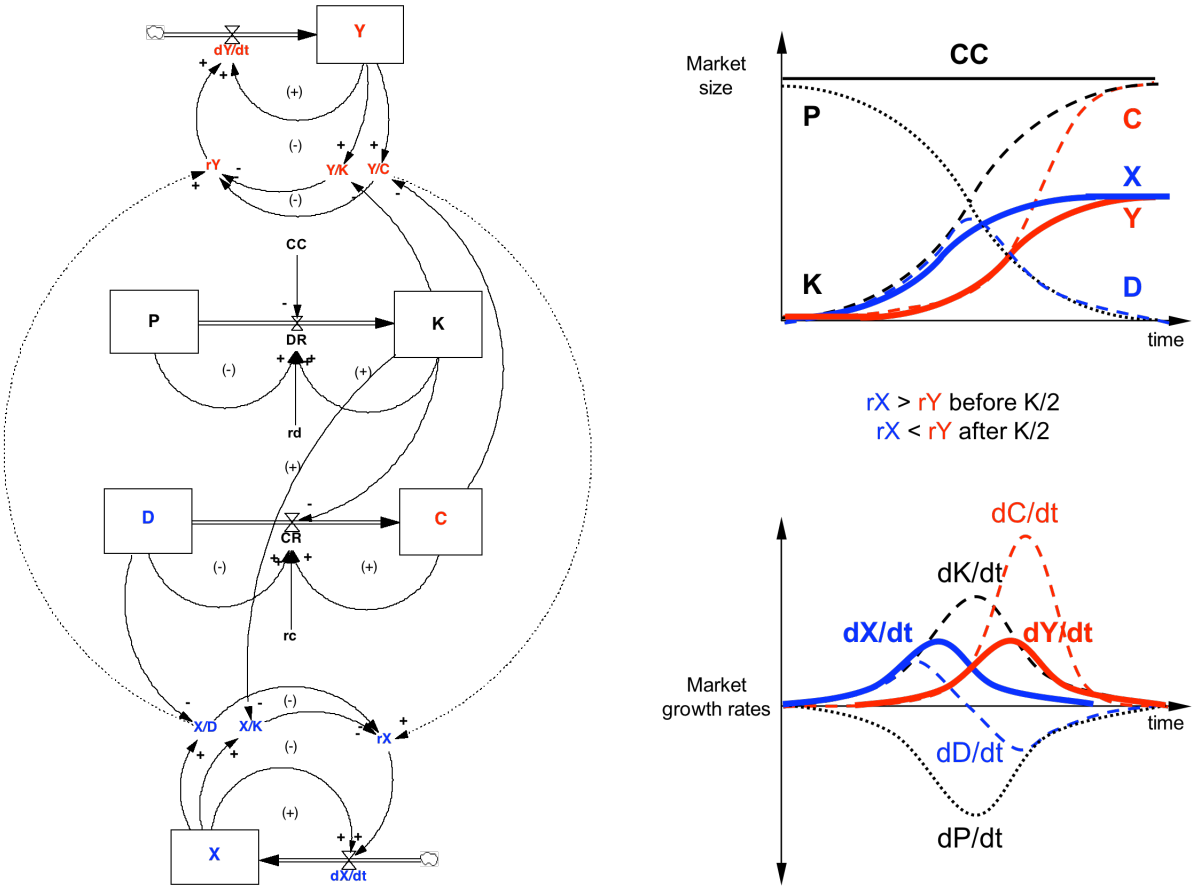


***Inter*-species Competition in a *Diffusing, Commoditizing* Market.** The model now has two different ways of defining the state of evolutionary maturity of the environment: *quantity* and *quality* – that is, *how much* product is produced/consumed, and *what type* of product is produced/consumed. This final section therefore combines these two characterizations of the market environment into one model, where two different species of firms (characterized by the architectures of their respective extended enterprises) compete. The extent of competitive intensity is defined by the ability of each firm to overcome architectural inertia and transition from niche D to niche C as the market evolves. A summary of the coupled system of differential equations is shown below.

$r_X > r_Y$ when $(X+Y) < K/2$ $r_X < r_Y$ when $(X+Y) > K/2$	$dX/dt = r_X X - r_X X^2/D - r_X XY\alpha_{XY}/K - r_X XY\alpha_{XY}/(D+C)$ $dY/dt = r_Y Y - r_Y Y^2/C - r_Y XY\alpha_{YX}/K - r_Y XY\alpha_{YX}/(D+C)$ $dK/dt = r_d K\,(1 - K/CC)$ $dD/dt = -r_c D\,(1 - D/K)$ $dC/dt = r_c C\,(1 - C/K)$	(12a) (12b) (12c) (12d) (12e)

Figure 52 below summarizes the causal structure and resulting behavior of this nonlinear *fourth*-order formulation which results in S-shaped growth of the general market K, and the niche, C. Due to architectural inertia, each species is constrained to its own niche resulting in early exit, late entry and dominance-switching throughout the life-cycle of the industry.

Figure 52: Structure/Behavior of *Inter*-species Competition in a *Diffusing, Commoditizing* Market



DISCUSSION and CONCLUSIONS

Summary of Findings and Results

Industry-leading firms like *Airbus*, *Toyota Motors*, and *Southwest Airlines* in the manufacturing and services sectors respectively while not trying to solely maximize shareholder value have ironically delivered significantly more of it than their competitors who are trying to maximize this metric. In the process, these late-entrant challengers have displaced significant market-making incumbents – in fact, the dominant competitors of their species – in *Boeing, General Motors* and *United Airlines* respectively. The key to this puzzle lies in understanding the how such firms interact with their environments – that is, in the *architecture* of their organizational sets. The theoretical sample revealed the integral enterprise architectures (or K-strategists) can be successfully grown in socio-economic environments as diverse as Europe, Japan and the United States.

Discussion of Plausible Rival Hypotheses

At the outset of the is paper, we clearly stated that the objective of the research was to begin to answer a fundamental question in strategy and organization:

> "Why do firms in the same industry vary *systematically* in performance *over time*?"

The theory presented herein attempted to explicitly pose a *systematic* explanation for a *longitudinal* phenomenon: namely, how does a firm interact with its external stakeholders as a system, and how does this interaction evolve over time. Most plausible rival hypotheses concerning the explanation of long-term firm performance, however seem to be non-systemic and focused on short-term "noisy" data. Another way of stating this is that they tend not to focus on the evolution of the environment and the subsequent evolution of the competing species of competitors. Such explanations implicitly assume intra-species competition, which relies on explanations of *exogenous* events, simple *execution* problems or even *legitimacy*.

Exogenous Events. One of the most common non-systemic explanations is that *GM, United* or *Boeing* are experiencing events beyond their control, whether they are labor strikes, oil shocks or global credit crunches. This overlooks that their competitors *Toyota, Southwest* and *Airbus* experience the same events with fewer consequences, as their enterprise architectures endogenize or co-opt (Selznick, 1948) environmental constraints more effectively, for example by offering employment stability in return for year-on-year productivity improvements, thus avoiding labor strikes; by using a conservative hedging strategies to minimize the effects of high oil prices; or by maintaining conservative balance sheets with reserve cash to assist customers with financing of their products and services.

Execution. Another common non-systemic explanation frequently put forward by the leaders of their organizations is that *GM, United* or *Boeing* are simply experiencing execution problems. This class of plausible rival hypothesis, which focuses on poor execution of strategy, rather than on poor strategy itself or even more fundamentally, enterprise architectural misfit with environmental conditions is embedded in the focus on increasing *efficiency*, given a fixed strategy or enterprise architecture. A problem with this hypothesis may develop if longitudinal evidence demonstrates that such execution problems are persistent. Clearly, if a firm consistently and persistently is unable to execute its strategy successfully over the long term, then perhaps it has the "wrong" strategy, or an enterprise architecture which constrains its ability to pursue the most effective strategy.

Legitimacy. Another more ideologically-based non-systemic explanation is that *Toyota, Southwest* and *Airbus* are "cheating" due to their unusually close relationships with capital, labor and supplier markets or government and are therefore "illegitimate" forms of business systems. This is manifested by their competition referring to them as "Japan Inc.", Texas Inc.", or "Europe Inc." respectively. This explanation may in fact be defensible, provided that an external refereeing organization had the power to declare their illegitimacy and enforce rules systematically and longitudinally against their existence. The fact that such refereeing organizations do not exist, or are not able to enforce rules legitimating only one enterprise architecture, might seem to imply that a plurality of architectures may in fact exist and thrive empirically in real business ecosystems.

Liability of Maturity. One of the most common plausible rival hypotheses which attempts to explain firm success is that the younger the challenger firm, the lower its costs, and the easier it is to be the cost-leader; or conversely, the older the incumbent firm, the higher its costs (e.g. due to pensions for an aging work-force), and the harder it is to be the cost-leader.

This can be questioned for example by looking at the evolution of the US airline industry, which is currently populated by a collection of expensive "legacy" carriers who created the industry and the relative late arrival of the challenger, *Southwest Airlines*. *Southwest's* long-term cost leadership has sustained a thirty-year attack from a series of newer and therefore (potentially) less expensive competitors, who arrived nearly a decade after *Southwest's* founding, due to deregulation of the US market.[59] What distinguishes *Southwest*, is the relative integrality of its enterprise architecture relative to younger challengers. This supports the claims of the organizational ecologists, who contend that mortality rates should be high for late entrants.

It is interesting to note that organizational ecologists have determined across a broad range of industries that in populations of isomorphic organizations, late entrants have statistically higher mortality rates than early entrants. In these cases however, the late entrant not only survives, but it overtakes the incumbent. In other words, the explanation for *integral* enterprise architectures' success as late entrants is that the form of its enterprise architecture is more adapted to a maturing environment – it is a new species in an evolving environmental niche.

[59] See Kelly and Amburgey (1991, pg. 603) for their analysis of entry and exit in the US airline industry.

Interest, Importance and Contributions
As business ecosystems continually evolve, a framework exploring the co-evolution of organizations and their environment would be of theoretical interest to strategic management, organization science and complex systems researchers, as well as of practical interest to senior executives in industry, particularly those facing significant environmental change and potential lack of organization-environment fit, and those engaged in "inter-species" competition. By adapting organizational ecology's focus on multiple organization *density* to strategic management's focus on single organizations, we attempt to bridge the two domains.

***Firm-Industry* Debate in Strategic Management.** It was from this open-ended intensive, in-depth, longitudinal inductive study of both focal firms, that the data revealed something that the literature had not allowed for: a different species of organizational set which possessed fundamentally different architectural form, function, structure and behavior from its competitor. This allowed us to revisit and shed new light on Porter's (1996) classic construct of an *efficiency frontier* in light of heterogeneous enterprise architectures. Later analysis of the environment revealed fundamentally different conditions at the founding of each organizational set, which promoted their growth and development. In addition, the data revealed that both organizational sets served a symbiotic function for the other. While both were locked in conventional competition, one created the environmental conditions that enabled the other to grow and ultimately dominate. Concurrent analysis of the secondary samples confirmed that the same evolutionary processes and symbiotic inter-species competition occurred in a variety of settings ranging from manufacturing to services and across national boundaries from the US to Japan to Europe.

***Adaptation-Determinism* Debate in Organization Science.** The framework acknowledges the concurrent roles of managerial adaptation and environmental selection in the co-evolution of firms and industries through the construct of organizational set architecture, which simultaneously enables and constrains agency. Rather than diminishing the role of agency, the framework identifies an enhanced role of top management, namely CEO not as chief executive, but as "chief architect" who defines and maintains the objective function, boundaries and interfaces of the organizational set. These findings contribute to the understanding of *strategic leadership* as an architecting activity which focuses upward and outward of the organization (Durbin, 1979), as opposed to downward and inward. As such, these findings refocus the attention of strategic management scholars from their traditional focus on *efficiency* (i.e. doing things right) to a focus on *effectiveness* (i.e. doing the right things) for a broader set of stakeholders than just customers or investors. This in turn implies that new models firms and their leaders, may focus again on power (Pfeffer and Salancik, 1978) and politics (March, 1962).

Although the theoretical framework developed herein was constructed inductively from multiple case studies, it does confirm and support both theoretical propositions from the literature's illustrious past (e.g. Burns and Stalker, 1961 and Lawrence and Lorsch, 1967), as well as from its more recent cutting edge. For example, Lenox, Rockart and Lewin (2006 & 2007) recently developed numerical simulations of Kaufmann's (1993) NK model to demonstrate theoretically that for industries with high interdependency among activities, there will be only a few high performers earning profits well above the industry average and a relatively large number of laggards. The three pairs of case studies presented herein support not only this claim, but also present a theoretical model which describes how such interdependencies evolve at both the ecosystem and organizational levels.

***Modular-Integral* Debate in Complex Systems.** This research attempts to shed more light on the classic intra-organizational architectural forms implied in Lawrence and Lorsch's 1967 classic: *Organization and Environment: Managing Differentiation and Integration*. From the title, we can see clear references to modularity and integrality within organizations as reflected in the demands of their environments. Their proposition that when the environment demands increasing intra-organizational differentiation, this must be accompanies with associated increasing intra-organizational integration (no matter how difficult combining these two may be). The research presented in this paper however, demonstrates how such apparent difficulties of matching these two opposing activities actually occur in modular enterprise architectures, and how and why this can both lead to competitive advantage and competitive disadvantage.

The framework also engages the classic premises of theories of systems architecture, and in doing so, begins to expose an apparent contradiction regarding the relative "*evolvability*" of modular vs. integral systems. Architectural theorists from Simon (1962) to Baldwin and Clark (2000), have posited that modular (or loosely-coupled) systems create an "option value" which copes well with future environmental design uncertainties, resulting in a more adaptable system architecture.

However, this research begins to demonstrate that by applying the same principles of system architecture to the more complex settings of organisms - and crucially - organizations, one can begin to observe empirically from the case studies discussed herein, that integral (or tightly-coupled) systems may in fact have higher evolutionary capabilities than modular systems – the key being the time horizon over which design evolution occurs. If the environment is relatively stable and certain, requiring only continuous albeit incremental design changes, then wholesale system-wide change is possible, and it is the integrality of the architecture of the enterprise that creates the setting for such organizational learning. If, however, the environment is relatively unstable and uncertain, the potential for radical design changes over a relatively short period of time is beneficial, and it is the modular architecture that enables such short-term flexibility.

The establishment of a universal "design rule" of architectural evolvability, appears to be contingent therefore in the epistemological characterization of the system under consideration, with modularity apparently conferring adaptability in mechanistic systems in turbulent environments, while integrality appears to confer adaptability in organic systems in stable environments.

Finally, the framework also engages another classic premise of the theory of systems architecture, and in doing so, begins to expose an apparent contradiction regarding the relative "*performance*" of modular vs. integral systems. Architectural theorists like Ulrich (1995), whose research is confined to physical products, have posited that integral (or tightly-coupled) systems exhibit efficiency due to function-sharing, resulting in a higher performance system architecture. Our theory however demonstrates that "high-performance" is a relative property which is contingent upon the demands of the environment, whereby modular (or loosely-coupled) enterprise architectures can exhibit higher performance than integral, provided that the environment demands and rewards short-term speed and flexibility.

***Varieties of Capitalism* & *Mixed Duopoly* Research.** While most of the recent research in applying theories of the political economy to the firm (Hall and Soskice, 2000) has focused on descriptive models of macro-organizational forms, few have focused on firm performance as the dependent variable, explaining the environmental contingencies (e.g. market maturity) under which firms embedded in each of the national institutional archetypes (Liberal Market Economies vs. Coordinated Market Economies) tend to dominate.

This research empirically identifies a significant outlier (i.e. *Southwest Airline's* integral enterprise architecture), a Coordinated Market Economy-based firm, which is embedded within the archetypal US Liberal Market Economy. It has not only survived, but has grown to dominate the US airline industry comprising a population of incumbent LME firms. This case appears to offer significant counter-intuitive insights for both managers and a rich data set for researchers on how to create an inter-organizational architecture which does not utilize the apparent "natural" strengths of a national institutional archetype.

Similarly, in recent micro-economic research about mixed duopolies (e.g. Lambertini & Rossini, 1998), much has focused on theoretical models which determining equilibrium states, whereas this research attempts to demonstrate dis-equilibrium dominance-switching dynamics, and presents empirical evidence for such preliminary claims.

Limitations of Theoretical Framework
The framework presented herein aspires to initiate a theoretical basis for explaining the evolution of business ecosystems, by building from the foundations of the intellectual domains of strategic management and ecological-level organizational theory, and bridging across them with system architecture theory. Inevitably, such an endeavor will fall far short of its aims, some of the limitations of which are briefly discussed below.

External (Spatial) Validity. While the framework possesses reasonably strong internal validity, it is clearly limited in its external validity, i.e. in its generalizability or the scope of its applicability. This is due both to the small N theoretical sample size inherent in this initial exploratory study, as well as due to the rather narrow boundary around the environmental conditions for applicability: i.e. industries which exhibit product & process innovation (Klepper, 1996, pg. 565.). Such limited generalizability is likely to limit the utility of the framework, provided that the pursuit of greater generalizability is possible with such dynamically and functionally complex systems.

External (Temporal) Validity. The framework is limited temporally in its ability to explain the evolution of business ecosystems only from growth through maturity phases. Empirical data, upon which the framework was founded does not yet exist for industrial decline phases.

Future Research
As such a framework undoubtedly raises more questions than it answers, a rich research agenda can be developed which seeks to characterize the structure, function, and evolution of various species of organizational sets and their ecosystems. Some examples of this research might include the following:

Increase External Validity. The most important next steps would include additional longitudinal field-based case studies of competitors in other industries, exhibiting significant long-term variance in dependent and independent variables, enterprise architecture and firm performance respectively. This is needed not only to improve the external validity of the existing theoretical framework, but more importantly to begin to map out the key parameter ranges, which might alter the structure and behavior of the industry's evolution. For example, what is the effect of rapid changes to the exogenous variables like technology supply? Would *environmental selection* create a new enterprise architecture in such an environment, or would *managerial adaptation* evolve the incumbent firm due to the perpetually low levels of structural inertia?

Expand Temporal Scope of Framework. Additional empirical work is required in the case studies involved in this paper to determine what happens as industries evolve into later stages of maturity and eventually decline. Do all enterprise architectures begin as integral for exploration and eventually disintegrate for exploitation, creating a law of enterprise entropy? Conversely, do late entrants with integral architectures increase their integrality as the industry matures and declines, as the mathematical formalism would suggest?

Acknowledgements
The authors would like to thank the *Engineering Systems Division*, the *Leaders for Manufacturing* program, the *Lean Advancement Initiative* and the *Communications Future Program* at the Massachusetts Institute of Technology, as well as *Oxford Executive Education* at the Saïd Business School of the University of Oxford for their support of this research.

Part I: RESEARCH DESIGN

Chapter 1 Research Introduction

1.1 Introduction

This chapter will briefly answer the key "what?" and "why" questions regarding the research design. Chapter 2 will then go on to answer the "how?", "where?" and "when?" questions.

> *"It is not the strongest of the species that survive, nor the most intelligent, but the one that is **most responsive to change**."*[60]

> *"In the natural world, **species evolve** – that is, they change to meet new challenges – or they die. The same **genetic imperative operates in business**."*[61]

At its fundamental level, this research is about explaining long-term organization performance, at an architectural or morphological level – namely how do organizational species evolve, via managerial action or via environmental selection?

1.1.1 *Research Abstract*

> *"This is a **comparative study** of **six organizations*** [three pairs, each] *operating in the same industrial environment. The subsystems in each organization were differentiated from each other in terms of subsystem **formal structures**, the member's **goal orientation**, member's **time orientations** and member's **interpersonal orientations**. A relationship was found between the extent to which the states of **differentiation** and **integration** in each organization met the requirements of the **environment** and the **relative economic performance** of the organizations."*[62]

This research aims to contribute to a fundamental debate in the field of strategic management regarding the source of long-term firm performance – namely does it reside within the firm or in the firm's environment? The answer is hypothesized to lie neither exclusively within the firm, nor in its environment, but in *how the firm interacts with its environment* – i.e. in the nature of the *architecture* of the firm's *extended enterprise*[63].

> *"One of the **enduring problems** facing the field of **strategic management** is the lack of theoretical tools available to describe and predict the **behavior of firms and industries**. The fundamental problem is that industries evolve dynamically over time as a result of **complex interactions** among firms, government, labor, consumers, financial institutions, and other elements of the **environment**. Not only does industry structure influence firm behavior, but firm behavior in turn can alter the structure of an industry and the **contours of competition**."*[64]

Using concepts from the emerging field of *engineering systems* taken from the intellectual domains of *system architecture* and *system dynamics*, a framework is developed which traces the co-evolution of firms and their environments using their most abstract system properties of *form, function, structure, behavior* and *environmental fit*. The framework, which is rooted in the intellectual traditions of contingency and configuration theories, posits

---

[60] Charles Darwin.
[61] Charles Fine (1998), pg. 3.
[62] Lawrence and Lorsch (1967b), pg. 1.
[63] Fine (1998) and Dyer (2000) argue that competition is between supply and value chains. This research dissertation attempts to develop and extend such research to stakeholders beyond the supply chain.
[64] Levy, D. (1994), pg. 167.

the evolution of "dominant designs" in enterprise architectures throughout an industry's life-cycle, which oscillate deterministically and chaotically between *modular* and *integral* states.

> *"From a complexity perspective, research will have to focus on hypotheses about **whole systems, their dynamics** and the **relationship between the dynamic and success**."*[65]

The research builds grounded theory based initially on a five-year, multi-level, multi-method, longitudinal case study of the enterprises of *Boeing* vs. *Airbus*, the global duopoly in the commercial airplane industry. The theory is further tested and generalized across a theoretical sample of firms in manufacturing and service sectors, with nonlinear dynamic simulation models developed to capture the governing dynamics of long-term firm performance. The developed framework is grounded empirically, analytically as well as theoretically by synthesizing a broad literature of enquiry ranging from economics to organizational theory.

> *"A fundamental understanding of **industry evolution** is critical to **strategy research**. The mechanisms that impart advantage for some firms over others should be evident in their effects on industry dynamics, and their efficacy will likely be altered with the course of industry evolution. The study of the effects of **interdependency** on industry evolution provides a very useful mechanism for strengthening the connections between both past and future strategy research at the firm and industry levels."*[66]

1.1.2 *Rhetorical Style*

This dissertation is written in the style of "scholarly dialogues". As opposed to merely citing relevant references, original quotations from prominent researchers are used throughout in order to capture the richness and clarity of their original arguments.[67]

[65] Stacey, R.D. (1995), pg. 493.
[66] Lenox. M.J., Rockart, S.F. and Lewin, A.Y. (2007), pg. 613.
[67] Bold has been added *ex post* by this author in order to emphasize points made in this dissertation.

1.1.3 *Doctoral Committee*

The doctoral committee is designed to meet the overall logic inherent in the research plan. Its composition is an integral part of the research design supporting the research question and methodology. The committee represents the academic institutions upon which this research is based: the MIT *Engineering Systems Division*, the *MIT Sloan School of Management*.

The committee individually and collectively has functional, epistemological and industry-based domain expertise. In support of the international case study upon which this research is based (which will be outlined in detail in this document), the committee is based out of the following geographical centers[68]:

- Dr. Charles Fine
  Professor*, Sloan School of Management* and *Engineering Systems Division*
  Massachusetts Institute of Technology, USA

- Dr. Deborah Nightingale
  Professor, *Engineering Systems Division* and *Aeronautics & Astronautics*
  Massachusetts Institute of Technology, USA

- Dr. Yossi Sheffi
  Professor, *Engineering Systems Division* and *Civil & Environmental Engineering*
  Massachusetts Institute of Technology, USA

- Carolyn Corvi
  Vice-President / General Manager of Airplane Programs
  Boeing Commercial Airplanes

[68] The faculty are listed alphabetically within their group.

1.2 Research Questions

> *"Hinnings and Greenwood (2002) bemoan the fact **that organizational scholars have stopped asking big, important questions** and instead have devoted an increased focus on **technical precision and manageable research projects**."*[69]

This research dissertation is driven to answer some of the most fundamental academic questions within the field of strategic management as well as some of the most pressing questions facing senior leaders in some of the most competitive environments in industry. In this sense, theory and empiricism are tightly coupled and are the driving impetus behind this research endeavor.

> *"Often by definition, **truly important research questions** do not have clear solutions until after the research has been conducted. If solutions are well known in advance of the research, the question may be appropriate for **consulting practice**, but clearly not for **basic scientific research**… At issue here is not that strategic management research incorporates elements of consulting practice. The issue is one of formulating and addressing important research questions that **capture the attention and motivation of scholars and practitioners alike** in the merits for studying them."*[70]

1.2.1 Primary *Research Questions*

This research attempts to answer a set of *primary* questions seeking explanations for firm performance and the nature of competition as well as a set of *secondary* questions regarding the origins of firm performance and the nature of strategic choice. The *primary* set of research questions focus on "what" is the relative explanatory power of different determinants of firm performance. The *secondary* set of research questions focus on "how" the different determinants of firm performance are formed.[71] Each set of questions will be discussed briefly in the following sections.

1.2.1.1 *High*-level question

In its highest, most abstract form, this research plan focuses on the following question:

> *"Why do firms in the same industry vary **systematically** in performance **over time**?"*[72]

This fundamental question, which lies at the center of an ongoing debate in the strategic management research community, is the most generalized form of the research question posed by the doctoral plan described herein.[73] The debate in question is between those who assert that the sources of differential firm performance and competitive advantage lies in

---

[69] Pfeffer (2005), pg. 99.
[70] Van de Ven, A.H. (1992), pp. 181-182.
[71] Farjoun, M. (2002), pp. 565.
[72] This question has been posed by numerous researchers, including Nelson, R. (1991) and Hoopes, D.G. et al. (2003). I am indebted to Prof. Mari Sako for pointing this out to me.
[73] Population ecologists are interested in the general question on why firms differ in disequilibrium as well as equilibrium states, while strategic management researchers are implicitly interested in a subset of firm heterogeneity: namely why firms differ in equilibrium or, why successful firms differ (Carroll, G., 1993).

firm positioning within the *external* environment of the industry versus those who assert that advantage lies in a firm's *internal* resources.

The industry structure proponents argue that in a competitive environment, firm heterogeneity is a short-lived phenomenon, and that any internal advantage would be quickly discovered and competed away. The resource-based theorists argue that such sustainable advantages arise from rare and inimitable capabilities.[74]

While recent empirical studies (Hansen and Wernerfelt, 1989; Rumelt, 1991; Powell, 1996; Roquebert et al., 1996; McGrahan and Porter, 1997; Wiggins and Ruefli, 2002; Hawawini et al., 2003)[75] have in fact begun to quantify the relative importance of each point of view, other researchers have noted that this debate in fact misses the point:

> *"The debate as to which of the resource-based or the industry structure perspectives on firm strategy is the more valid is not a particularly useful one as **both** organizational capabilities and the firm's environment drive strategy and performance."*[76]

Noted economist Alfred Marshall characterized the irony of choosing in this external-internal debate via analogy:

> *"**Context** and **capability** provide two blades of strategic scissors that come together in the creation of a corporately value-added output."*[77]

This research therefore attempts to discover the deep underlying foundational nature of long-term firm competitive performance as the dependent variable, and the evolutionary systemic interactions between the firm's capabilities and its environment. This research therefore attempts to:

> *"...respond to the lack of understanding about **co-evolutionary processes** within the field of **strategic management** and to calls for more studies that **synthesize firm- and industry-level** perspectives in strategy and organization research."*[78]

> *"The **interplay** between organizational processes and industry dynamics in determining the firm's 'capability trajectory'... [as] an **open systems** perspective is clearly **not new**. However, the **strategy field** has not been terribly effective at **bridging such levels of analysis** and perspectives."*[79]

In particular, the notion of *enterprise architecture* is developed to provide a guiding causal explanation for the observed phenomena, as shown in Figure 53 below.[80] It is hypothesized that this meso-level *enterprise architecture* reflexively shapes and is shaped by the firm's internal capabilities as well as simultaneously shapes and is shaped by the external environment. In the spirit of *structuration* theory (Giddens, 1979), an enterprise's

[74] Wiggins and Ruefli (2002) explore the sustainability of competitive advantage using a rare longitudinal sample comprising 6,772 firms in 40 industries over 25 years, demonstrating just how rare the phenomenon is.
[75] See Appendix B for a summary of the external-internal debate.
[76] Henderson, R. and Mitchell, W. (1997).
[77] Loveridege, R. (2003), pg. 99.
[78] Huygens M. et al. (2001), pg. 972.
[79] Levinthal, D. and Myatt, J. (1994), pg. 49.
[80] The original pilot research study which explored these concepts is Piepenbrock T.F. (2004).

architecture simultaneously enables and constrains managerial action, but does not necessarily determine it.

Various "species" of enterprise architectures will be described which have varying degrees of designed environmental fit. Instead of the environmental determinism defining managerial action or vice versa, we will investigate the conditions under which managers reflexively "define how the environment defines my organization." This theory therefore attempts to build on theories of influential scholars like Edith Penrose:

> *"Firms not only alter the environmental conditions necessary for the success of their actions, but, even more important, they know that they can alter them and that the* ***environment is not independent*** *of their own activities."*[81]

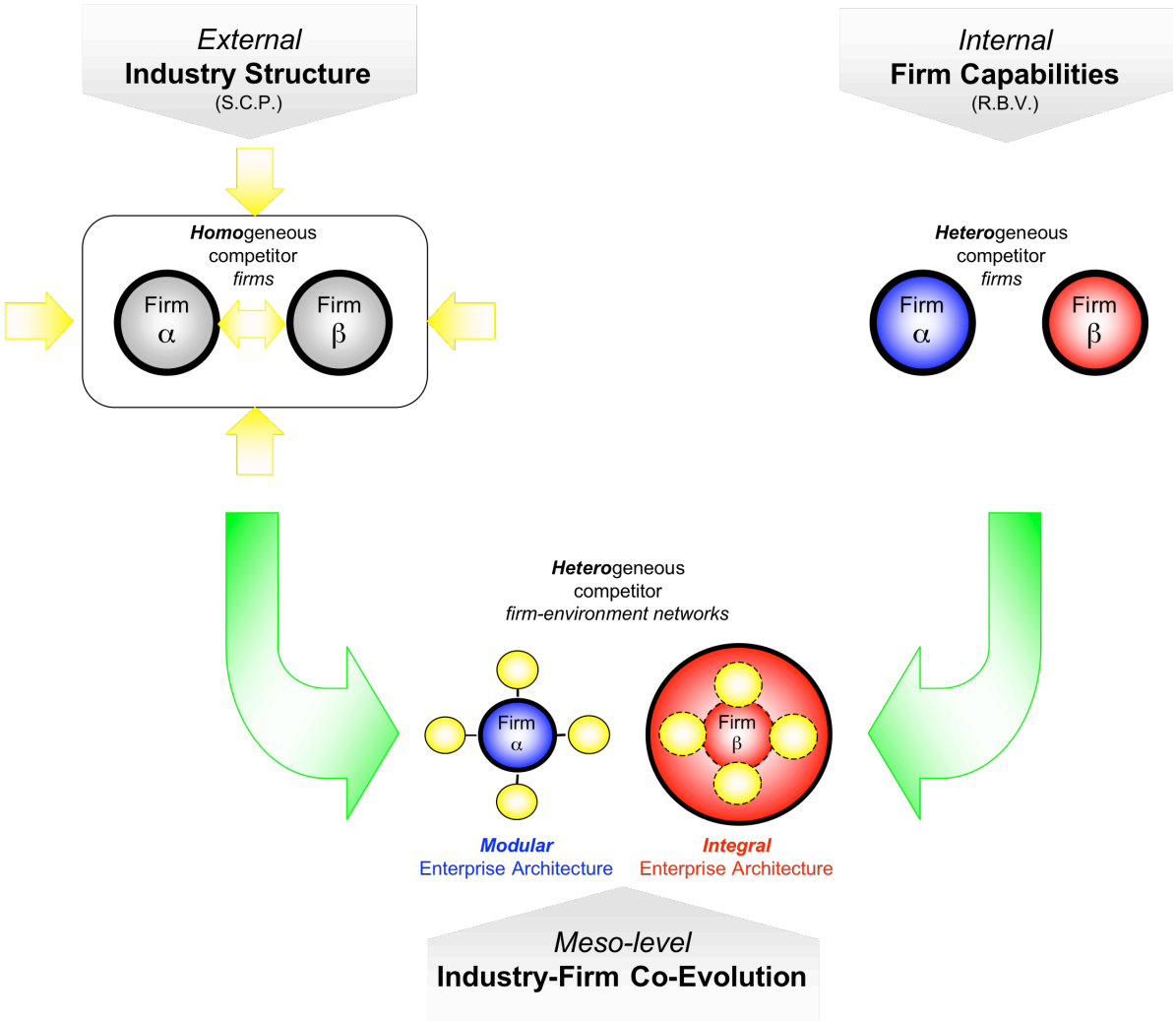


Figure 53: *Enterprise Architecture* as a synthesis of External-Internal Theories

[81] Penrose, E. T. (1959), pg. 42.

In addition to merely describing enterprise architectures as static phenomena, this research also aims to explore how they compete diachronically, and finally how this diachronic competition shapes the evolution of the enterprise architectures themselves over time.

1.2.1.2 *Mid*-level question

Embedded in the preceding discussion lies a slightly lower-level, less abstract, and more specific question which derives from Penrose's (1959) original research:

> *"How do firms that have a **stakeholder approach** differ in competitiveness, commitment, and strategic flexibility from firms that maximize **stockholder wealth**?"*[82]

This question actually forms the central focus of the research. In fact, as will be demonstrated in Chapter 3, the question will be stated more provocatively as "How do firms whose primary objective is to maximize shareholder value, deliver significantly less of it than those firms who are not trying to maximize shareholder value?" Figure 54 below summarizes the question as applied to two world-class companies, *Toyota Motors* in the manufacturing sector, and *Southwest Airlines* in the services sector.

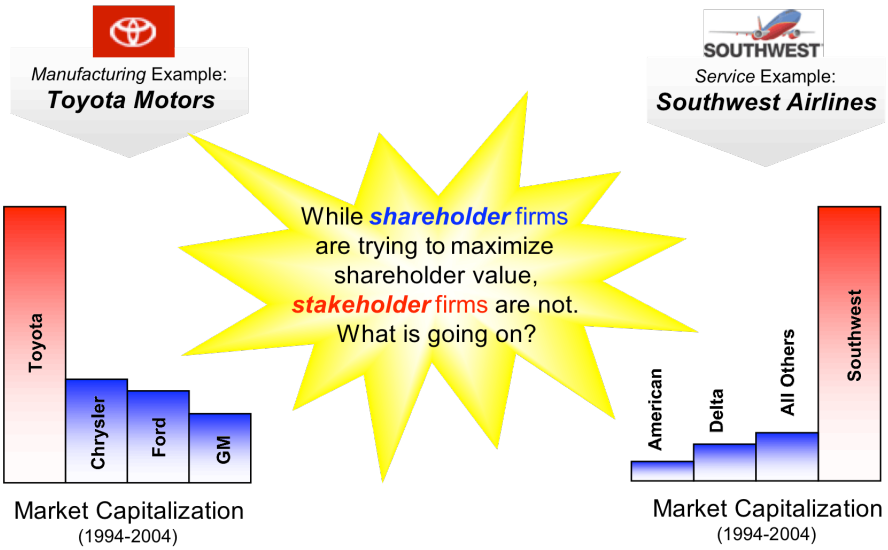


Figure 54: Comparing the Performance of *Share*holder- vs. *Stake*holder-focused Firms

The answer will be hypothesized to lie in how firms manage their firm-environment ecosystems; in whether or not cause and effect are perceived to be close or distant in space and time. Such a complex and counterintuitive question will drive the need for a research design that embraces both dynamic and behavioral complexity, as will be discussed in Chapter 2.

Although clearly a subset of the original abstract, high-level firm performance question, this question focuses the problem more clearly on those firms that have different objective functions. It is important to note that this question therefore focuses the research away from the more generalized question of competition among firms regardless of their objective functions, whether they be the same or different.

[82] Rugman, A. M. and Verbeke A. (2002).

It will be hypothesized later in this research, that the firm's objective *function* drives the firm's relationship with its immediate environment or extended enterprise – both spatially and temporally. More explicitly, enterprise architectural *form follows function.*

1.2.1.3 *Low*-level question

Finally, the above high- and mid-level questions ultimately derive from the idiosyncratic, context-specific, low-level question that arose from industry:

> *"How did **Airbus** emerge from obscurity in the commercial aircraft industry and unseat **Boeing** as the premier commercial aircraft company in the world?"*[83]

This question is interesting given previous research studies (Collins and Porras, 1994) have classified *Boeing* as "built to last" - that is "visionary", "successful" and "enduring" compared to its lifelong rival, *McDonnell Douglas* (which it ultimately acquired).

> *"How did **Boeing** emerge from obscurity in the commercial aircraft industry and unseat **McDonnell Douglas** as the premier commercial aircraft company in the world?"*[84]

Again, this form of the question is clearly a subset of the original abstract, high-level firm performance question. In addition, is can be demonstrated to be a form of the more specific mid-level question regarding the stakeholder-shareholder dichotomy.

In attempting to provide an answer to this low-level question, this research plan will in addition attempt to move back up in abstraction to provide a more general, mid-level theory explaining systematic long-term performance differences between competing enterprise architectures. While no explicit claims will be made for a higher-level theory, this research attempts to incrementally contribute to the original debate of firm performance in the field of strategic management.

[83] This question, which originated from *Boeing* senior executive committee during the initial two-year pilot study is an example of other industry and firm-specific questions like explaining *Toyota* & *Southwest Airlines* success over their dominant rivals *GM* & *Ford* and *American* & *United Airlines* respectively.
[84] Collins and Porras (1994), pg. 17.

1.2.2 Secondary *Research Questions*

While the *primary* research questions come from the applied field of strategic management, a second set of questions arose as the research progressed from strategic management's foundational disciplines: economics and sociology as shown in Figure 55 below. These surrounded the fundamental nature of firms (vs. markets) as well as the epistemological nature of strategic choice (vs. determinism).

> *"I advance two related theses. First, **economic theory** predicts that organizations will be a **mess** but not a **mystery**. Second, classic case studies conducted by **organizational sociologists** support this prediction. Fully defending and articulating these theses will require a **book**…"*[85]

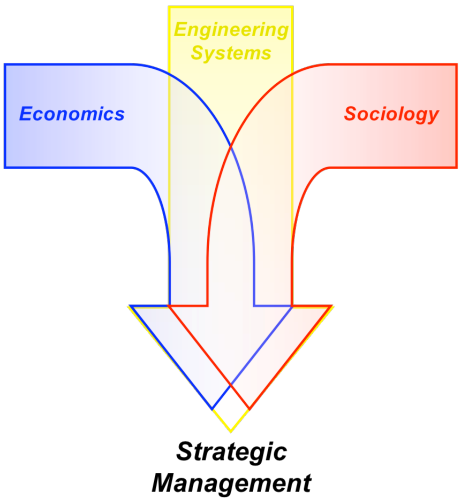


Figure 55: Primary Intellectual *Social Science* Fields

> *"I suspect that there is an enduring reason that the **neoclassical 'economic man' theories** seem to have more reach, resonance, and staying power than **people-centered stakeholder relations theories. They are easier to teach, easier to do. Economic theories are neat. People are messy. Analytics are crisp, emotions are messy**."*[86]

[85] Gibbons, R. (1999), pg. 145.
[86] Kanter (2005), pg. 94.

1.2.2.1 Debates in *Economics*

1.2.2.1.1 Markets vs. Hierarchies

A fundamental question in the field of economics surrounds the very nature of the firm (Coase, 1937; Williamson, 1975, 1985), positing their existence is due to the failure of markets.

The fundamental construct posited by this research dissertation – enterprise architecture – attempts to engage this market-hierarchy debate by challenging the boundaries of the firm as a unit of competitive advantage via such mechanisms as transaction costs and relational contracting.

1.2.2.1.2 Firm Boundaries and Minimization of Transaction Costs

Williamson's (1975, 1985) transaction cost economics (TCE) proposed that firms should organize their spatial boundaries to minimize transaction costs. This proposed research attempts to enrich the TCE dialogue by exploring the nonlinear dynamic relationships governing which time horizons do Williamson's prescriptions apply. As shown in Figure 56 below, do temporal boundaries affect the spatial boundaries? Does short-term minimization of transaction costs result in different firm boundaries than those for long-term minimization of transaction costs?

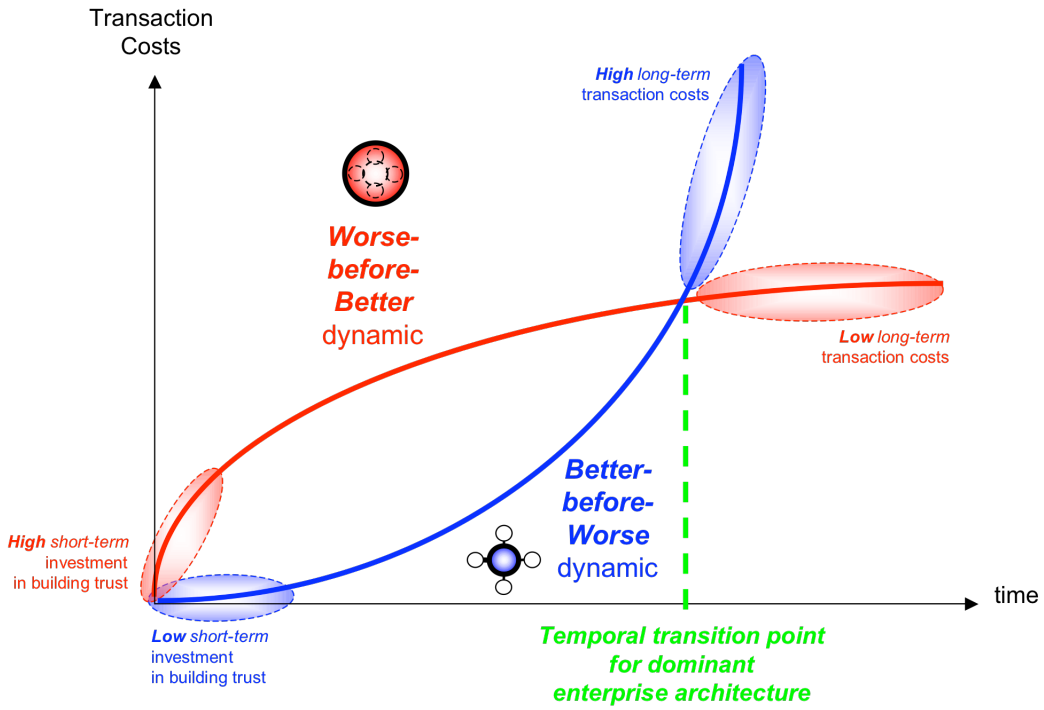


Figure 56: The Relationship between *Spatial* and *Temporal* Boundaries of the Firm

1.2.2.2 Debates in *Sociology*

1.2.2.2.1 Debates in *Organizational Theory*

This firm-environment interaction forms a central and ongoing debate in strategic management and organization theory. The richness and complexity of this debate is captured through the following two "diagonal" questions of Astley and Van de Ven's (1983) integrative meta-theoretical framework and shown in Figure 57 below.[87] Namely, the northwest-southeast diagonal:

> *"Is organizational life determined by **intractable environmental constraints**, or is it actively created through **strategic managerial choices**?"*

and the equally challenging southwest-northeast diagonal:

> *"Are organizations **neutral technical instruments engineered** to achieve a goal, or are they **institutionalized manifestations of the vested interests and power structure** of the wider society?"*

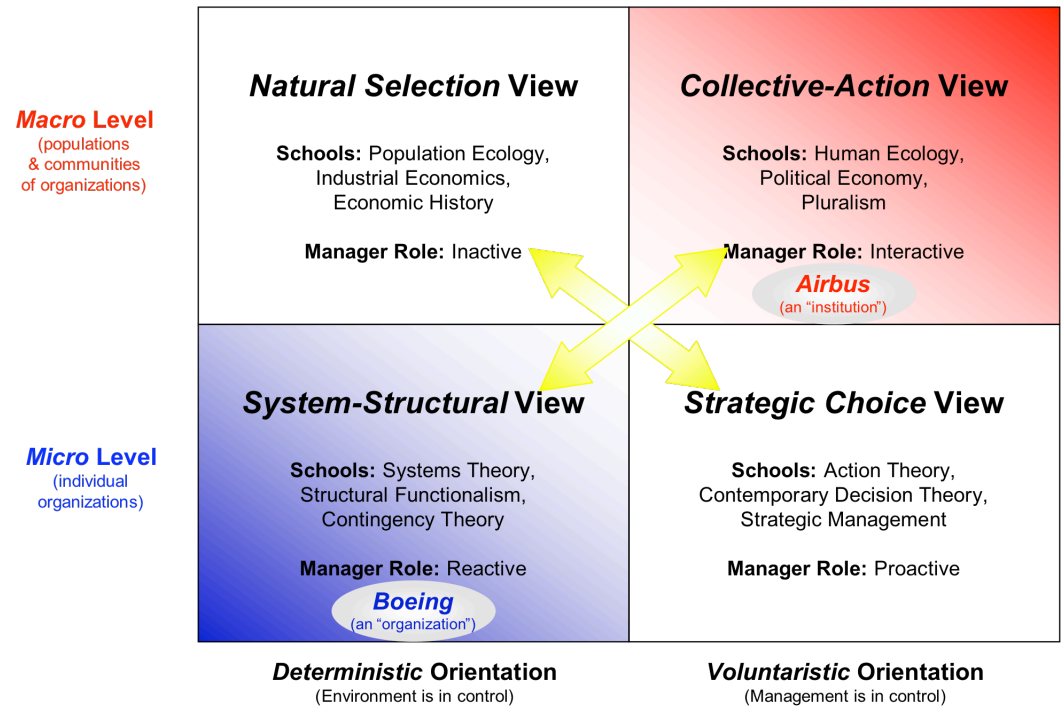


Figure 57: Central Debates in Organization Theory[88]

[87] Astley and van de Ven (1983), pp. 245-273.
[88] Astley and van de Ven (1983).

1.2.2.2.1.1 Social Determinism vs. Human Choice

In the first question, the enterprise architecture is either defined by the environment - leaving no room for managerial action, or it is built endogenously by powerful proactive leaders.[89]

1.2.2.2.1.2 Macro-Industry vs. Micro-firm

In the second question, the firm is seen as being either overwhelmed by the exogenous forces of the environment, or as being an integral part of an endogenized extended enterprise. The implications are that managers should either *react* to the contingent demands of the environment, or they should *interact* with their extended enterprise.

What these two questions clarify is that long-term firm performance is a complex interaction played out on at least two dimensions: the macro- (industry) vs. micro- (firm) level, and the social determinism vs. free will duality of human nature.

> *"As far as '**choice vs. determinism**' is concerned, the alternative perspective focuses on the possibility of open-ended choices available to agents made possible by chaotic dynamics, but constrained by the feedback structure of the system. Even though the system may be **deterministic** with regard to **structure**, it is **open-ended** with regard to **outcome.**"*[90]

As will be discussed in subsequent chapters, this research proposes an intermediate vehicle for explanation between the choice-determinism debate. The enterprise architecture construct simultaneously enables and constrains, but does not determine the outcomes.

1.2.2.2.1.3 Differentiation vs. Integration

Organizational theorists – and most notably structural contingency theorists (Lawrence and Lorsch, 1967) – noted that tasks tended to be differentiated and then reintegrated. This research dissertation empirically clarifies that *successful* firms match appropriate levels of differentiation with integration, while in less successful firms, levels of differentiation tend to exceed levels of integration.

---

[89] Empirically, this question arises when examining the origin of integral enterprise architectures like *Southwest Airlines* and *Airbus Industrie*. In the *Southwest* example, it is hypothesized that the enterprise architecture is built proactively and internally (or endogenously) by the visionary founder and chairman, Herb Kelleher. Conversely, in the *Airbus* example, it is hypothesized that the enterprise architecture is built inactively and externally (or exogenously) by the governments of the founding European nations.

[90] Stacey, R.D. (1995), pg. 490.

1.2.2.2.2 Debates in *Population Ecology*

1.2.2.2.2.1 High Mortality Rates of Late Entrants

The sociological sub-field of population ecology has long observed that late entrants in an industry's evolution (e.g. those arriving post-dominant design) tend to have higher mortality rates (Hannan and Freeman, 1984). Plausible hypotheses and explanations have focused on firm age and inertia, both as a strength and a weakness in determining firm mortality.

This research dissertation however identifies a special "species" of late entrant, who not only survive against the odds, but in fact thrive and go on to dominate the industry. This research further moves beyond the traditional theories of inertia and explores the hypothesis of firm-environment co-evolutionary fit.

1.2.3 Tertiary *Research Questions*

While the *primary* research questions centered on the field of strategic management, and the *secondary* research questions centered on its constituent fields of economics and sociology, the *tertiary* research questions focus on the enabling fields of organization and operations.

In recent years, there has been a move towards a reintegration of such fields as strategy-organization, strategy-operations, and operations-organization. As shown in Figure 58 below, this research attempts to synthesize all three domains.

Figure 58: Research at the Intersection of *Strategy, Organization* and *Operations*

1.3 Research Objectives

The purpose and objectives of the research are three-fold: First to *describe* empirically the evolutionary trajectory of internal capabilities of selected competing firms and the evolutionary characteristics of the external environment within which they compete. Second, to *explore* the evolutionary trajectories of the strategies employed by these firms, and finally to *explain* how the external environment and internal capabilities interact over time to produce performance trajectories - that is how, when and why these firms dominate their industry.

> *"The final product of building theory from case studies may be concepts, a conceptual **framework, propositions**, or possibly **mid-range theory**."*[91]

Although admittedly ambitious, the intended output of this research is a meta-theoretical framework or model whose purpose is to organize and advance existing mid-range theoretical models.[92]

1.3.1 *The* Rigor-Relevance *Dialectic*

The dialectic between the thesis (rigor) and antithesis (relevance) is well-known in the academic and practitioner literatures.

> *"**Academic fights** are more brutal than fights in the real world because the **stakes are so low**."*[93]

> *"Organizations have become the dominant institution on the social landscape. Yet the body of knowledge published in academic journals has practically **no audience in business**."*[94]

> *"**Cooperation** between **academics** and **managers** is so rare that when it happens, it makes national newspaper headlines. **It is hard to be both rigorous and relevant**. This dilemma occurs because the set of skills, values, mind-sets, and attitudes that are needed to conduct rigorous academic research are **fundamentally different** from the set of skills, values and attitudes needed to conduct managerial research. The two skill sets also **conflict**. By trying to do both, an academic researcher runs the risk of **paying a huge straddling cost**... one has the trade-offs that arise from inconsistencies in an academic's **image or reputation**... Although **great ideas are always welcome**, the truth of the matter is that **most good managerial research is not of this kind**... One type of managerially relevant research is the one intended to develop **grand new theories** without the necessary empirical evidence to support them. The idea is to develop these theories and then **have future researchers empirically test them for accuracy and validity (think of Darwin's theory of evolution)**. This type of research requires a writer to **take creative leaps** an offer ideas and insights not immediately supported by available data. **This is risky business, and we should enourage young colleagues to avoid this type of research**. It is better suited to*

[91] Eisenhardt, K. (1989), pg. 545.
[92] This ambition was similarly stated by Farjoun, M. (2002), pp. 572.
[93] This quote is most recently from an interview with Dr. Henry Kissinger (Summer 2003 issue of *Bulletin*, the American Association of Neurological Surgeons). He embraced both sides of the relevance-rigor debate as a professor for nearly 20 years at Harvard University, US national security advisor, secretary of state under two US presidents, and Nobel laureate. He playfully highlights both sides by acknowledging the importance of rigor, but evaluates it within the relevance frame.
[94] Daft & Lewin (1990), pg. 1, in their paper launching the new academic journal, *Organization Science*.

> *academics who can afford to take such risks – perhaps* ***academics who have already received tenure in the system****."*[95]

> *"Analyzed are 32 established organizational science theories in terms of their rated* ***importance, validity, and usefulness****.* ***Little evidence of any relationships among these variables is found****."*[96]

The resolution of this dialectic between thesis and antithesis into a workable synthesis - while difficult - requires a higher level of abstraction.

> *"I have striven in these writings of mine, without defacing the truth, to satisfy* ***everybody****; and perhaps I have not satisfied* ***anybody****, and if this should be so, I shall not be astonished by it, because I judge it impossible, without angering* ***many****, to write of the affairs of their own times."*[97]

As shown in Figure 59 below, these complementary objectives refer to the classic 'rigor-relevance' debate in management (Argyris and Schon, 1991), which are distinguished as 'mode 1' knowledge production which is primarily driven by academic concerns, and 'mode 2' which is primarily an intense interaction between knowledge production and knowledge dissemination and application (Gibbons et al., 1994).

[95] Markides, C. (2007), pp. 762, 764 and 766.
[96] Miner, J. (1984), pg. 296. The relevance-rigor dialectic is posed by Vermeulen, F. (2005).
[97] From Niccolo Machiavelli's *The History of Florence*, quoted in Feaver, G. (1984), pg. 564.

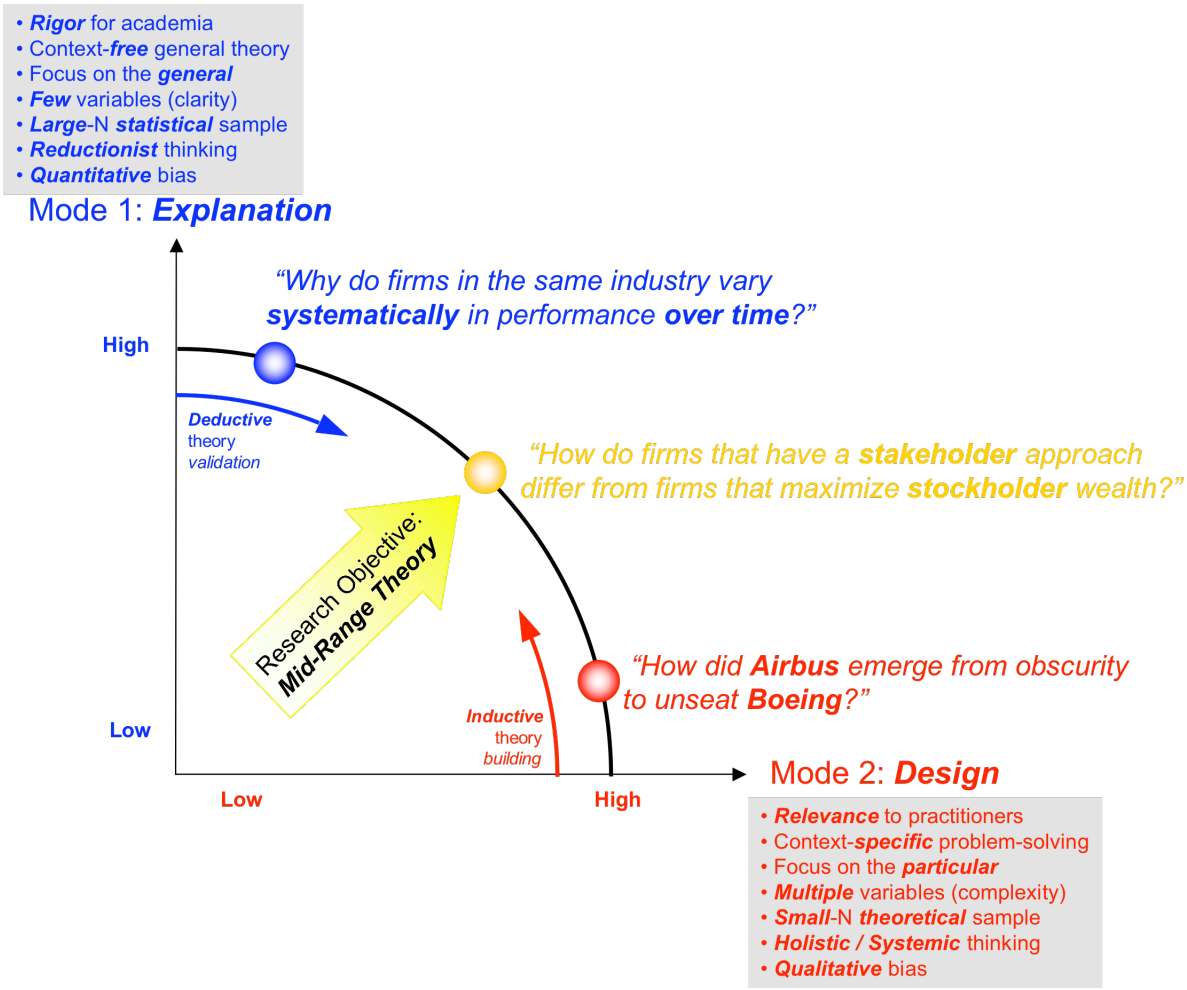


Figure 59: Rigor-Relevance Interaction

*"Somewhere between the specific that has no meaning and the general that has no content there must be, for each purpose and each level of abstraction, an **optimum degree of generality**".*[98]

[98] Boulding, K.

1.3.2 *Multi-modal Objectives*

> *"To **predict** requires that we posit a correlation between **present and future** events; to **explain** we posit a correlation between **present and past** events."*[99]

The objectives of this research are divided in the following subsections into the primary objectives rooted in the *explanatory* sciences, and the secondary objectives rooted in the *design* sciences (van Aken, 2004) or *policy* sciences (Etzioni, 2006).

1.3.2.1 Mode 1 objective: *Explanation / "Prediction"*

> *"**Evolutionary explanations** are **scientifically legitimate**, even if they can't be used to **predict the exact nature of changes.**"*[100]

Due to the inherently complex, highly nonlinear and potentially chaotic nature of the phenomenon being studied, long-term prediction is not feasible in a *deterministic* sense. However, as the theory developed herein is evolutionary, processes of variation, selection and retention act to make *probabilistic* predictions.

> *"**Hypothetical probability predictions** do not have any value for actual prediction except insofar as the conditions mentioned in the hypothesis are predictable or experimentally producible; hence there will be cases where we can **explain why** certain animals and plants survived even when we could not have **predicted** that they would."*[101]

The research does however aspire toward understanding and explanation by uncovering the underlying causal structure which drives behavior. While the establishment of the causal structure is possible, the variety of parameters in the form of decision rules, ultimately makes behavior impossible to predict. It is the pursuit of this "generic" causal structure that is "universal" and that allows for "generalization" of the theory, not in the prediction of the resulting behavior.

> *"The **complexity**, situation specificity, and changing nature of the firm and its environment strains conventional approaches to **theory-building** and hypothesis testing."*[102]

> *"From a **complexity** perspective research will be unable to yield **predictors** of or prescriptions for long-term success – research will have to focus on **explanation** instead, on hypotheses about **whole systems, their dynamics**, the conditions under which they will display different kinds of dynamic, and the **relationship between the dynamic and success**."*[103]

Figure 60 below summarzes the objectives of explanation and "prediction" superimposed on the phenomena of interest – namely, interspecies competition and the co-evolution of business ecosystems. These objectives will be matched by a research method as discussed in chapter 2.

---

[99] Aldrich, H.E. (1979), pg. 52.
[100] Aldrich, H.E. (1979), pg. 52.
[101] Scriven (1959), pg. 478.
[102] Porter, M.E. (1991), pg. 97.
[103] Stacey, R. (1995).

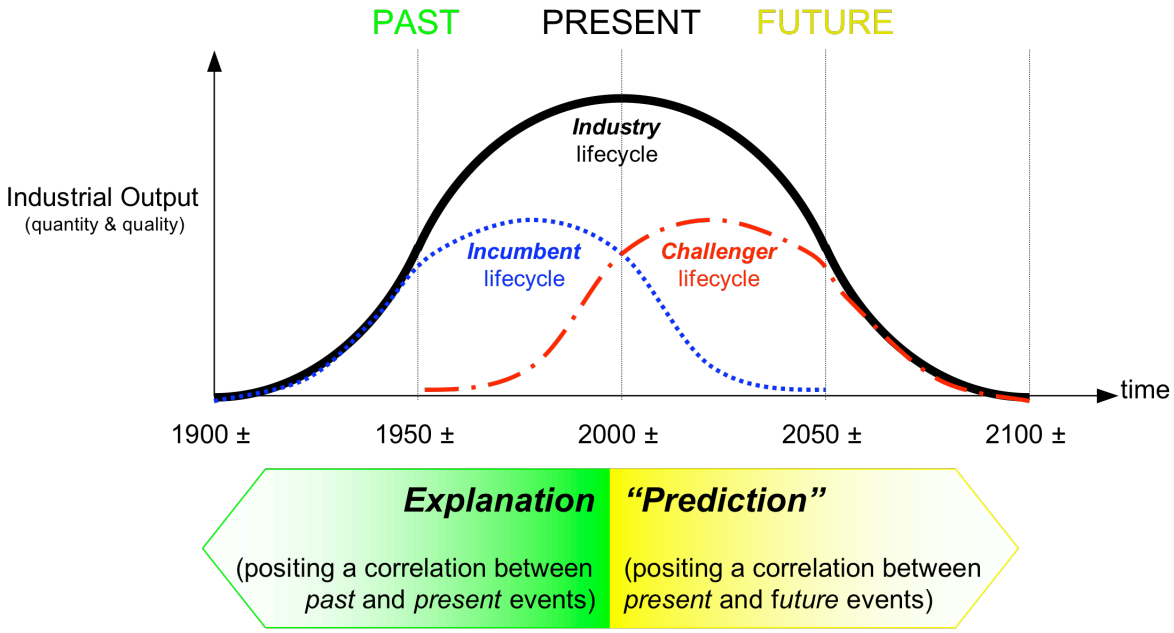


Figure 60: Research Objectives of *Explanation* and "*Prediction*"

1.3.2.2 Mode 2 objective: *Design*

> *"The **scientist discovers** that which exists, the **engineer creates** that which never was."*[104]

> *"**Policy research** is always dedicated to changing the world while **basic research** seeks to understand it as it is."*[105]

The difference between the objective of the scientist and the engineer is vast. In fact social "scientists" (like Jay Forrester) who came to management from an engineering background, tended to transport a design objective for organizations.

> *"The goal is **'enterprise design'** to create more **successful management policies** and organizational structures…which influence **growth and stability**."*[106]

However, it was Nobel prize laureate, Herbert Simon (1988) who noted that the design objective was not private domain of engineers:

> *"Engineers are not the only professional designers. Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that… devises a new sales plan for a company. Design, so construed, is the core of all professional training: it is the principal mark that distinguishes the professions from the sciences. **Schools of Engineering as well as schools of architecture and business… are all centrally concerned with the process of design.**"*[107]

[104] From aerodynamicist, Theodore von Karman (1881-1963).
[105] Etzioni, A. (2006), pg. 833.
[106] Forrester, J.W. (1961).
[107] Simon, H. (1988), pg. 67.

Unlike engineering in the physical sciences or medicine in the biological sciences, management did not evolve from administrative sciences. In the field of organization studies, the design objective languished.

> *"Social scientists are trained to do good empirical research and descriptive theory building without being overly concerned with implications for organization design or **performance outcomes**. Researchers try to develop parsimonious theories based on a small number of variables that can explain phenomena across a range of organizations. **Prescriptive research**, however, requires **comprehensive understanding** of a **specific situation** that is not often generalizable to other settings. Most scientific journals do not encourage publication of papers whose objective is prescription or design application. Scientific journals typically favor manuscripts that provide generalizable theories from comparative empirical studies, which frequently are not sufficiently concrete or detailed enough to yield design suggestions."*[108]

With regard to the field of strategic management, Porter (1991) notes that the two primary approaches to theory building in strategy include rigorous, situation-specific, mathematical *models* of limited complexity vs. multivariate *frameworks* like the "competitive forces" approach, which capture the complexity.[109]

> *"The need to **inform practice** has demanded that strategy researchers ... pursue the building of **frameworks** rather than restrict research only to theories that can be **formally modeled**."*[110]

For these reasons, while this research ultimately aims for mid-range theory, it simultaneously strives for building a conceptual framework, generating rich propositions and ultimately testable hypotheses.

Although much strategy research has progressed quickly from the descriptive to the normative as it has transitioned from theory to practice, this work aims to cautiously engage the normative debate. Due to the relative immaturity of the theories developed from this research, much more confirmatory work is needed before confident normative recommendations can be made.

> *"The field of strategic management is avowedly **normative**. It seeks to guide those aspects of... management that have material effects on the survival and success of the business enterprise."*[111]

Normative prescription limitations notwithstanding, this research plan does not aim to stop with a rich, complex description of the case study. Rather, it adopts a *positivist* view of research, in which the goal is to develop testable hypotheses and theory which are generalizable across different settings (Eisenhardt, 1989).

> *"A more ambitious result would be an effective partnership of **descriptive**-driven and **prescriptive**-driven research."*[112]

---

[108] Daft and Lewin (1990), pg. 4.
[109] Porter, M.E. (1991, pg. 98) notes that the use of frameworks can be challenged because their complexity makes it difficult to falsify arguments.
[110] Porter, M.E. (1991), pg. 98.
[111] Teece, D. J., Pisano, G., and Shuen A. (1997).
[112] van Aken (2004), pg. 242.

This research plan therefore takes its queues from Forrester (1961), Simon (1969, 1988), van Aken (2004) and Etzioni (2006) for the development of *design* knowledge, which occupies the middle ground between descriptive theory and actual application.

1.3.3 *Four Types of Scholarship*

> *"In his book* Scholarship Reconsidered*, Ernst Boyer (1990) described four different kinds of scholarship: the scholarship of discovery (**research**), the scholarship of integration (**synthesis**), the scholarship of practice (**application**), and the scholarship of teaching (**pedagogy**). Historically, business schools have celebrated and accommodated as equals the practitioners of all four kinds of scholarship. Over the last 30 years, **we have lost this taste for pluralism**. Those with primary interests in synthesis, application, or pedagogy have been eliminated from our milieu or, at best, accommodated at the periphery and **insulated from the academic high table** that is now only reserved for the scientists."*[113]

It is important at the outset to set the expectations of the reader of this research. While by the very definition of doctoral *research*, this work intends to focus on the scholarship of discovery, it moreover attempts to embrace the pluralism of the other three forms of scholarship: integration, practice and teaching (Boyer, 1990). One of the primary reasons for such attempted plurality of scholarship is that it is in the process of engaging these "lesser" three (integration, practice and teaching) that the "primary" research form emerged. In fact, stated in a more counter-intuitive way, although the desired *end* is "good" research, the *means* employed is clearly the pursuit of the other three forms of scholarship.

> *"We need to temper the pretense of knowledge and **re-engage with the scholarships of integration, application, and pedagogy to build management theories that are broader and richer than the reductionist and partial theories we have been developing over the last 30 years**."*[114]

As shown in Figure 61 below, as a piece of doctoral research, this work is likely to be judged by conventional standards as below the norm in the scholarship of discovery, while it is hoped and intended to be judged as above the norm in the scholarships of integration, practice and teaching.

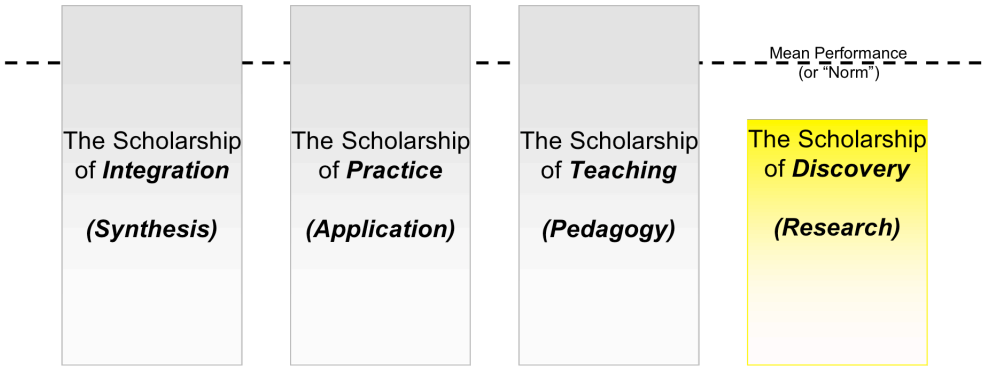


Figure 61: Proposed Research and the Four Types of Scholarship

[113] Ghoshal, S. (2005), pg. 80.
[114] Ghoshal, S. (2005), pg. 87.

*"More and more business schools are currently embarking on campaigns to hire significant numbers of **clinical professors** (sometimes called '**professors of practice**'). These clinical professors typically excel at what Boyer called the **scholarships of practice, synthesis and pedagogy**."*[115]

[115] Hambrick, D.C. (2005), pg. 105.

1.3.3.1 The Scholarship of *Integration* (Synthesis)

As will be discussed in more detail in chapter 2, much of the value of this research lies in its integration of a variety of disparate intellectual traditions, ranging from economics to sociology in the social sciences to engineering and architecture in the physical sciences.

1.3.3.2 The Scholarship of *Practice* (Application)

As was discussed briefly in this chapter, much of the impetus for the development of this research was grounded in the application of real problems rooted in practice.

1.3.3.3 The Scholarship of *Teaching* (Pedagogy)

As was alluded to in the acknowledgements section, much of the actual content of this research framework was derived from the teaching and learning from research participants in the spirit of knowledge "co-creation". This included the opportunities to "teach" graduate students, faculty and senior executives at MIT and the University of Oxford, as well as executives in numerous companies within *Boeing* and *Airbus*' ecosystem.

1.3.3.4 The Scholarship of *Discovery* (Research)

Finally, although the ultimate aim of this project is to pursue the process of academic discovery within the bounds of "normal science," it must be said that any success or lack thereof will be largely constrained by the trade-offs inherent in the active pursuit of the other three forms of scholarship.

1.4 Research Framework

1.4.1 *Unit of Analysis*

The unit of analysis will be presented using both economics and sociological terminology, which while not identical in meaning, convey a richness of constuct unavailable with only one convention.

1.4.1.1 *Economics*-based terminology

While the dependent variable focuses on the long-term *firm* performance, this research hypothesizes that a source of this performance lies in the firm's relationship with its *environment*, therefore the unit of analysis is the firm's *extended enterprise.*

> *"The importance of the concepts of **differentiation** and **integration** to the analytic scheme developed here can best be indicated by the definition of the **primary unit of analysis** in this study – the **organizational system**. An organization is defined as a system of interrelated behaviors of people who are performing a task that has been differentiated into several distinct subsystems, each subsystem performing a portion of the task, and the efforts of each being integrated to achieve **effective performance of the system**."*[116]

The above definition of "organization" taken from Lawrence and Lorsch's classic 1967 work was used to describe *intra*-firm subsystems or functional divisions. In this research, the same definition of "organization" can be applied, only this time, defining *inter*-firm subsystems or stakeholder groups.

> *"By these definitions, the **boundaries of organizations** will not always coincide with their legal boundaries: some institutions, such as large corporations, encompass a number of organizations by our definition; while others, such as certain subcontractors, do not constitute a single complete organization."*[117]

The following definitions briefly draw distinctions among the various levels of analysis.

[116] Lawrence, P.R. and Lorsch, J.W. (1967), pg. 3.
[117] Lawrence, P.R. and Lorsch, J.W. (1967), pg. 4.

1.4.1.1.1 Firm

Within the firm, this research more specifically aims to focus on a subset of the firm, namely the "strategic business unit" (or SBU) as shown in Figure 62 below. This research thereby focuses on long-term firm performance in the realm of *business* strategy, as opposed to *corporate* strategy.

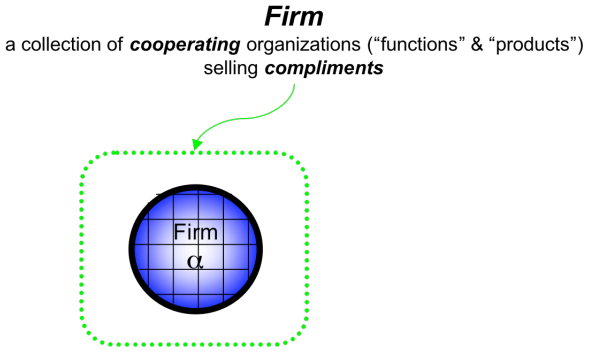


Figure 62: Working Definition of *Firm*

One of the reasons that the strategic business unit was selected as the unit of analysis is its relative importance in determining variance in profitability. Researchers (Rumelt, 1991; Powell, 1996; Roquebert et al., 1996; McGrahan and Porter, 1997; Hawawini et al., 2003) have demonstrated that 32%-45% of variance in firm profitability is directly attributed to SBU effects while only 1%-18% is attributed to corporate effects, and 10%-20% attributed to industry effects.[118]

1.4.1.1.2 Industry

In ecomonics, an *industry* is the supply side of a *market*. For clarity, this research uses Porter's (1980) definition of "industry" as a collection of firms selling substitute goods or services as shown in Figure 63 below.

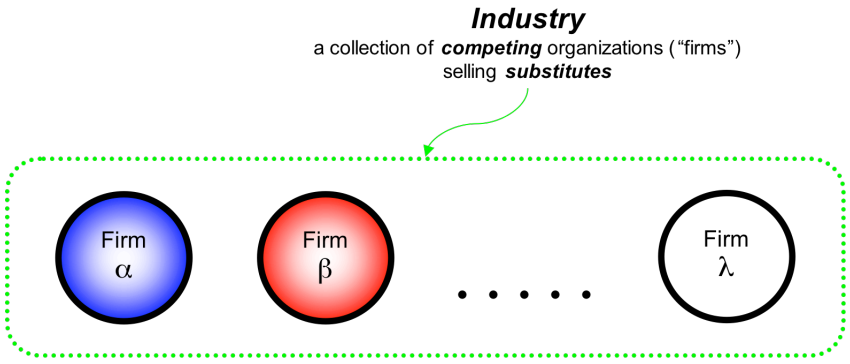


Figure 63: Working Definition of *Industry*

[118] See Appendix B.

1.4.1.1.3 Extended Enterprise

> *"The battlefront in today's **competitive wars**, and the **ultimate core competency** of a business organization, is the design of the… extended enterprise."*[119]

Instead of taking an "engineering" perspective, by looking downwards and inwards into the firm itself for answers, this research takes an "architectural" perspective, by looking upwards and outwards into the firm's ecosystem[120] or extended enterprise[121] as shown in Figure 64 below. The enterprise is defined as those organizations which impact the firm's success. In this sense, the enterprise can be thought of as the "environment" in traditional organizational theory.

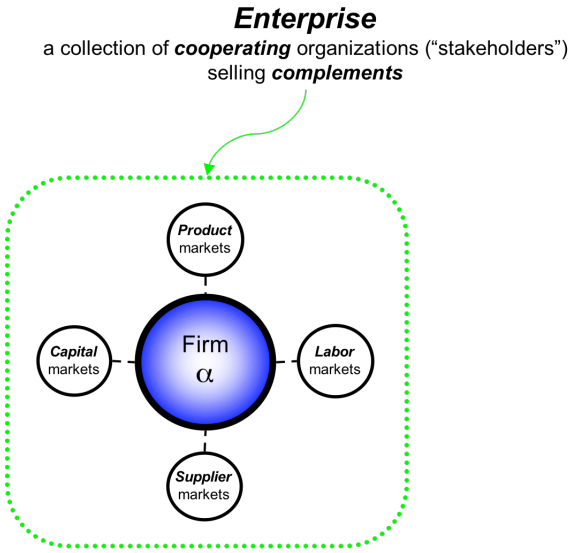


Figure 64: Working Definition of *Enterprise*

This definition of an enterprise draws upon Barnard's (1938) concept of organizations as *cooperative* systems. Note that the stakeholder axes and constituent stakeholders will be discussed in detail in essay #1, as will a discussion of the firm as a "nexus of contracts" / "nexus of relationships".

The name of the firm at the center of the extended enterprise will be the "*keystone*" firm, borrowed from biological ecosystem theory.[122]

> *"In strategy courses, we have presented the 'five forces' framework (Porter, 1980) to suggest that **companies must compete not only with their competitors but also with their suppliers, customers, employees and regulators**."*[123]

---

[119] Fine, C.H. (1998).
[120] In the biological ecology literature, the organism, whose presence in the ecosystem drives the behavior and performance of many others is known as the "keystone" organism.
[121] As a diversified firm's SBU is the unit of analysis, one cannot ignore the parent firm's relationship to the SBU when taking an architectural perspective of the extended enterprise.
[122] Recently, Iansiti, M. and Levien. R. (2004) applied this metaphor to business ecosystems.
[123] Ghoshal, S. (2005), pg. 75.

1.4.1.1.4 Ecosystem

Finally, if an *industry* is defined as a collection of competing organizations (firms), and an *enterprise* is defined as a collection of cooperating organizations (stakeholders), then as shown in Figure 65 below, an *ecosystem* is defined as a collection of competing enterprises or "competing cooperators".

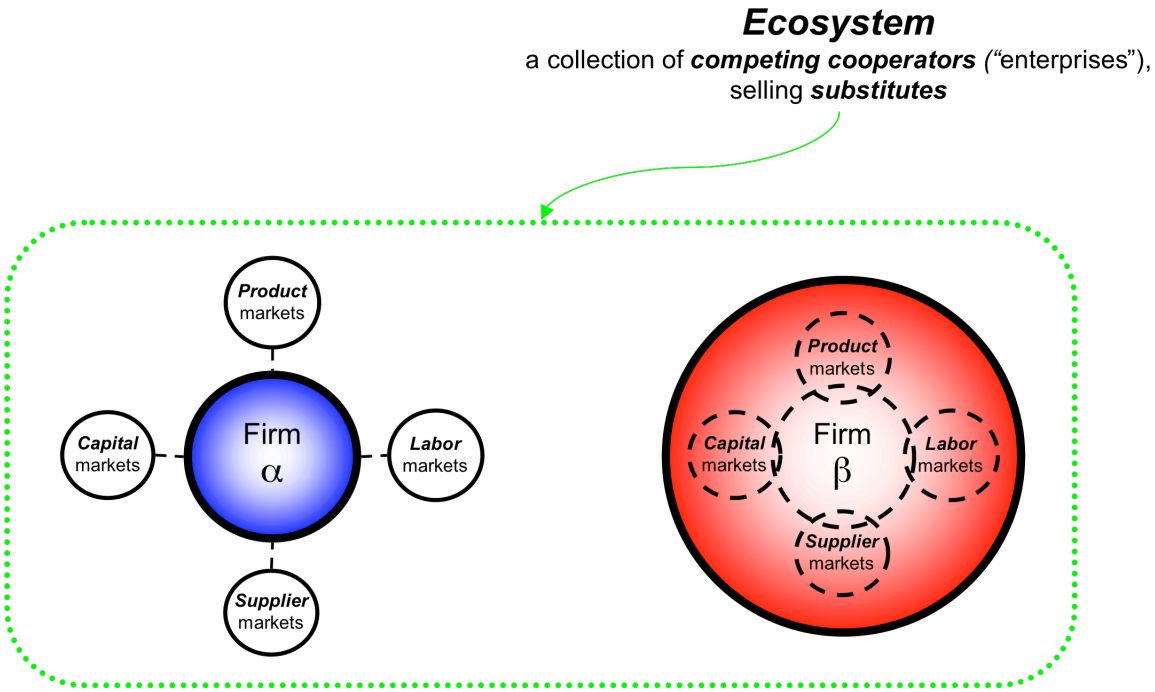


Figure 65: Working Definition of *Ecosystem*

From above it should be noted that in theory, competing enterprises can be coupled through any or all stakeholders, the most common of which can be customers (i.e. product markets).

As will be discussed in the next chapter, this research dissertation will focus on the competitive dynamics of a *duopoly ecosystem*, that is, not just two competing firms, but two competing enterprises. We will also begin to explore when such "competing cooperators" become "cooperating competitors".

1.4.1.2 *Sociology*-based terminology

1.4.1.2.1 Organization

> *"Organization is the arrangement of personnel for facilitating the accomplishment of some agreed **purpose** through the allocation of **functions** and responsibilities"*[124]

Although the definition of an organization varies, I use a classic definition from Selznick (1948) which emphasizes *goal* or *purpose* and *functional decomposition* as important aspects. Given this research project's interest in business ecosystems, this would be similar to *firm* (or more colloquially, *company*) using economics terminology.

1.4.1.2.2 Organizational *Set*

Moving up one level of analysis is the organizational set, that is the organizational unit that consists of the focal organization and its interdependent organizations (or stakeholders). Again, using economics terminology, this would be similar to *enterprise* or *extended enterprise.*

> *"A crucial defining characteristic of the concept of **organization set** is that it views the environment from the standpoint of a specific **(focal)** organization."*[125]

The organization set level of analysis is typically used by a variety of disciplines focused on studying organizational-environment interactions, like resource dependence (Pfeffer and Salancik, 1978) and transaction cost economics (Williamson, 1975)

> *"Analysts employing the **resource dependence** approach, typically work at the level of the **organization set** as do many of those utilizing **transaction cost** approaches."*[126]

This research will posit a typology of organizational sets which range from internally competitive to internally cooperative (like an *interorganizational community* – see below).

1.4.1.2.3 Organizational *Population*

> *"[Populations consist of...] all the organizations within a particular boundary that have a **common form**."*[127]

Although population ecologists define a *population* of organizations as those organizations having a common *form*, the precise definition of what constitutes form is rather elusive – sometimes purposefully so.

> *"Hannan & Freeman (1977, 1989) **explicitly refrained** from proposing any fixed rules or typology for identifying organizational forms. They argued that form may be generally inferred from an organization's formal structure or normative order, and that the classification of an*

[124] Selznick, 1949, pg. 114.
[125] Scott, 2003, pg. 126.
[126] Scott, 2003, pg. 127.
[127] Hannan and Freeman, 1977, pg. 936.

> *organization as one form or another may be specified according to the **interests of the investigator.**"*[128]

Having noted the plurality in the current literatures, this research tends to focus on the systemic properties inherent in both architectural as well as biological definitions, namely: goals, boundaries and activities.

> *"Organizational **forms** – the specific configurations of **goals, boundaries, and activities** – are the elements selected by environmental criteria, and change may occur through new forms eliminating old ones or through the modification of existing forms."*[129]

Organizational populations are collections of isomorphic organizations, competing within the same niche. Thus, an economist's "industry" may be comprised of one or more populations.

> *"**Ecologists** define **populations** as organizations exhibiting the same structural form while **economists** define **industries** as including all organizations serving the same **demand** or function, which could include quite diverse types of providers of substitutable products."*[130]

In light of the primary construct of this research – the enterprise architecture – an organizaional population refers to those enterprise architectures (organizational sets) having similar architectural forms, this is modular or integral.

1.4.1.2.4 Organizational *Community/Field*

> *"Interorganizational **communities** and organizational **fields**... focus attention on a collection of **diverse types** of organizations engaged in **competitive and cooperative** relations."*[131]

> *"An organizational **community** is a set of co-evolving organizational populations joined by ties of **commensalism and symbiosis** through their orientation to a common technology, normative order, or legal-regulatory regime."*[132]

An organizational *community* or *field* transcends the level of analysis of an organizational *population* by encompassing both similar and dissimilar organizations, which allows for the potential for birth and death of organizational populations.

> *"A number of advantages are associated with this level of analysis. First, we can examine the **interdependence and coevolution** of organizations of differing types. Organizations that both **compete and cooperate** with **similar and diverse** organizations. Second, a community or field-level perspective allows us to observe not only the **waxing and waning** of a particular type of organization but also the **disappearance** of some types and the **emergence of new forms** (Astley, 1985). Third, the organizational field can be viewed as encompassing the other levels: **the individual organization, the organizational set, and two or more populations of interdependent organizations.** "*[133]

---

[128] Romanelli, E., (1991), pg. 82.
[129] Aldrich, H.E., (2006), pg. 28.
[130] Scott, (2003), pg. 127.
[131] Scott, (2003), pg. 129.
[132] Aldrich, H.E. and Ruef, M, (2006), pg. 243.
[133] Scott, (2003), pp. 130-131.

1.4.1.3 Comparision of Terminologies

Table 7 below summarizes the terminology used for the analyses in both economics and sociological terms.

Table 7: Terminology Comparision in Economics and Sociology

Notes	Economics	Sociology
Focal unit of Enterprise	Firm	*Organization*
Primary construct	Enterprise	Organizational *Set*
Homogenous collection of competing Firms	Industry	Organizational *Population*
Heterogenous collection of competing Firms		Organizational *Community/Field*
Homogeneous collection of competing Enterprises	Ecosystem	*Population* of Organizational *Sets*
Heterogeneous collection of competing Enterprises		*Community/Field* of Organizational *Sets*

Figure 66 below summarizes the definitions in both economics and sociological terms.

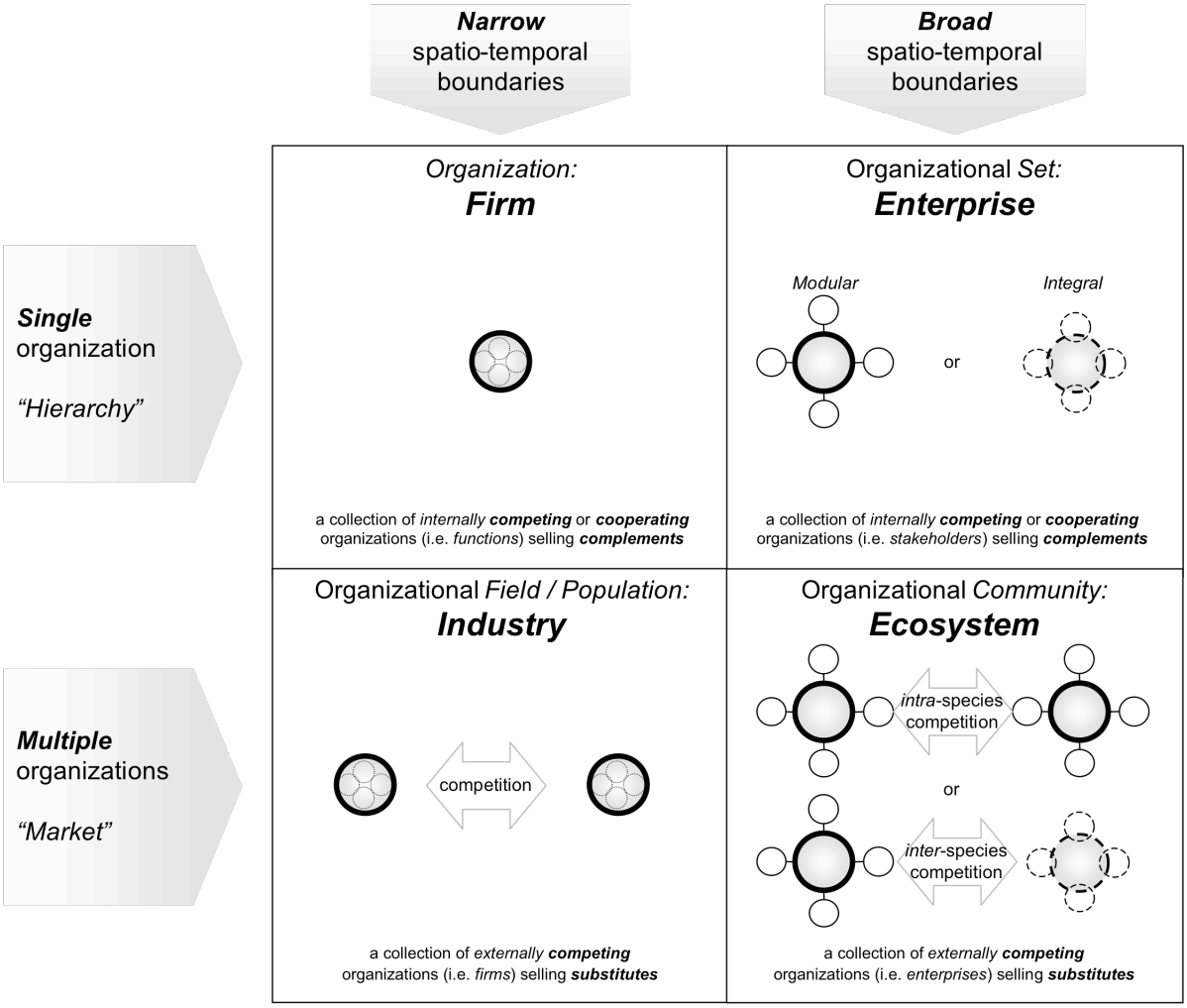


Figure 66: Summary of Working Definitions

Figure 67 below summarizes conceptually the how the unit(s) of analysis are applied to the proposed framework. Note that the primary construct of "enterprise architecture" is at the level of organizational *set*, while the overarching unit of analysis is the level of organizational *community* (of organizational *sets*).

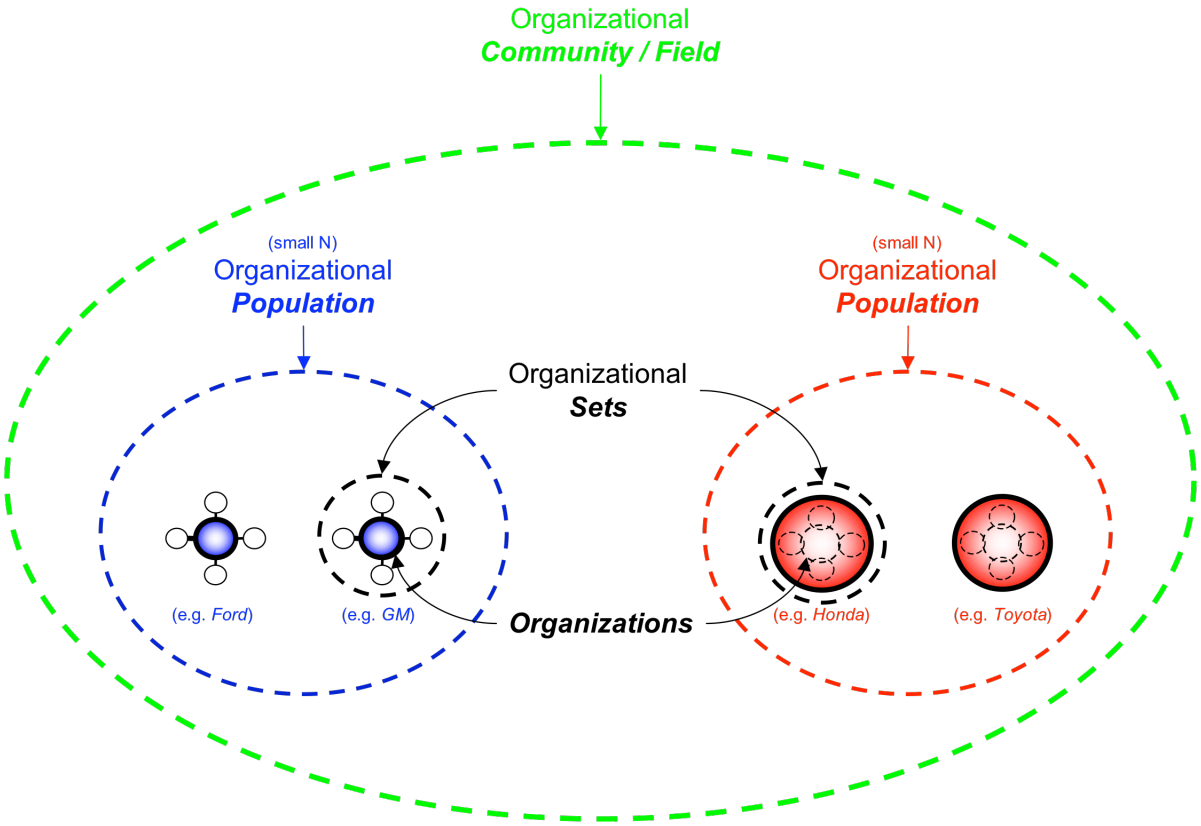


Figure 67: Summary of Units of Analysis in Framework

One final clarification of definitions is needed. This framework holds constant and focuses its investigative lens on the environment or market. For example, this may be "the design and manufacture of large commercial airplanes." This market may evolve over time in both quantity and quality spaces, and it in fact may support differing species of competitors. When one of the propositions states that dominant designs oscillate over time from integral to modular to integral, it is referring to the enterprise architectures of the dominant species, which could theoretically be the same species which evolves, or it could be the emergence and exit of multiple species. This is illustrated in Figure 68 below.

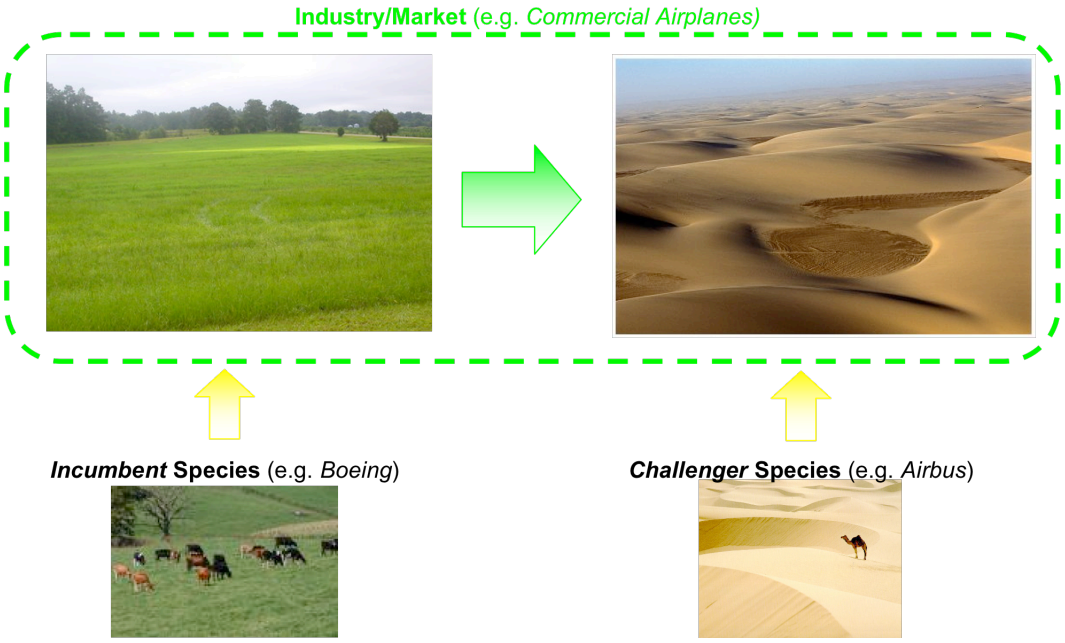


Figure 68: Focus is on the Evolution of Dominant Species within a Fixed Environment

This is in contrast with a body of resesearch (e.g. Fine, 1998) which aims to postulate theories concerning the evolution of market niches within a changing environment as illustrated in Figure 69 below. Here, the firm-supplier make-buy interface is posited to oscillate over time from integral to modular to integral.

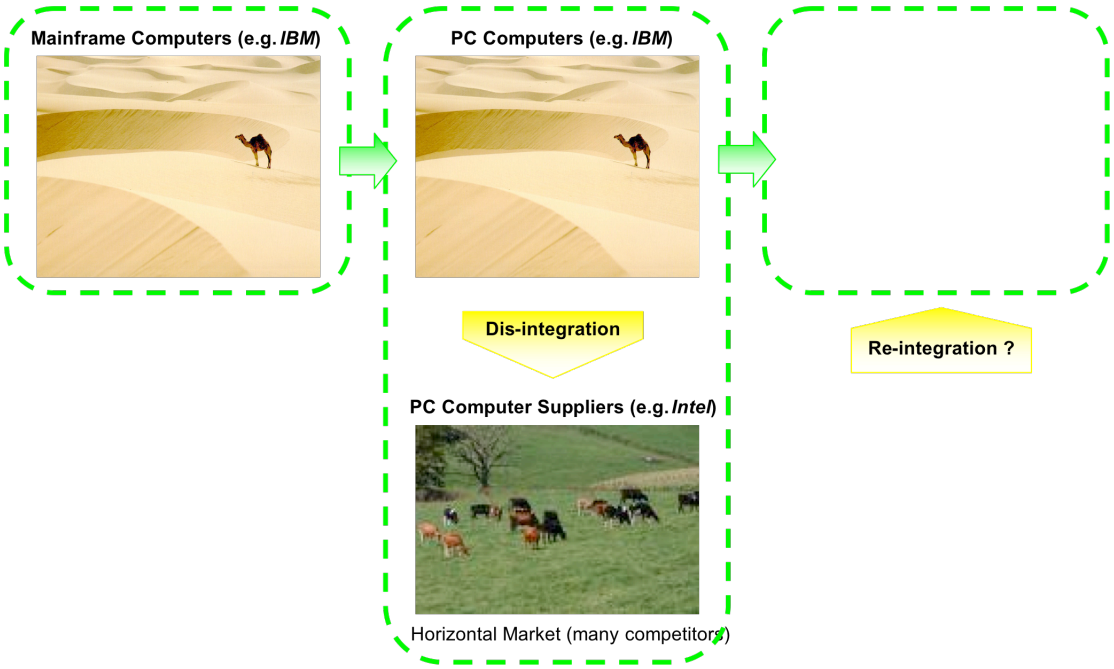


Figure 69: Focus is on the Evolution of Market Niches in a Changing Environment

1.4.2 *Variables*

The following subsections briefly discuss the relevant variables used in the research dissertation. The dissertation is initially introduced in terms of the familiar and traditional correlative terms of *dependent* and *independent* variables.

> *"The **scope of variables** that **basic research** encompasses can be quite legitimate and effective but also rather **narrow**. **Policy researchers** must be more **eclectic** and include at least all the variables that account for a significant degree of variance in the phenomenon that the policy aims to change."*[134]

As the goal of this research is to develop complex causal mechanisms, the dissertation then proceeds to clarify the variables as *interdependent*.

1.4.2.1 *"Dependent"* variable: Long-term Firm Performance[135]

At the highest, most abstract level, this research seeks to explain the variable of performance – and specifically long-term firm performance. The following subsections will decompose this variable into the definitions used for the purpose of the research.

Explanations of sustained superior firm performance in the industrial organization-based "barriers" or resource-based "inimitability" frameworks, tend to focus on cross-sectional distributions either between or within industries. This research however focuses on *longitudinal* data of *intra*-industry sustained long-term firm performance. As such, we are interested in tracking the performance of dominant firms as they grow and die throughout the industry's life-cycle, as illustrated in Figure 70 below.

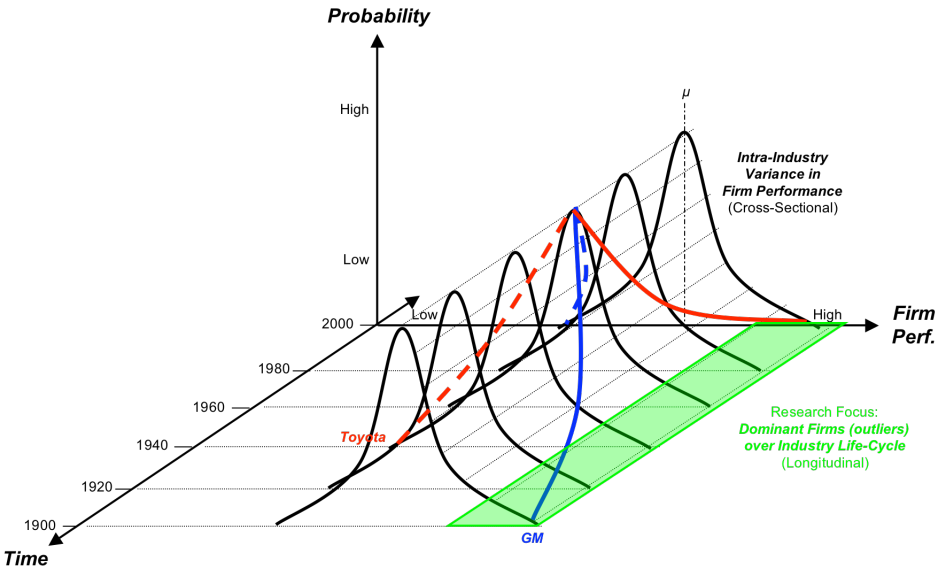


Figure 70: Longitudinal Trajectories of Dominant Firms within an Industry's Evolution

[134] Etzioni, A. (2006), pg. 838-839.
[135] It should be pointed out that this research attempts to explain the circular causal interactions of competence-competition using feedback principles, therefore the explicit acknowledgement of "dependent" and "independent" variables can be misleading.

1.4.2.1.1 Defining "*Long-term*"

As this research seeks underlying mechanisms for how the external competitive environment shapes and is shaped by firms' internal capabilities, long-term trends must be observed. This research therefore seeks systemic "first mode" explanations of long-term trends and performance trajectories. As this research also seeks to explain co-evolution of firm performance with industrial evolution, the definition of "long-term" will correspond to the development of the industrial life-cycle S-curve. While this period will vary from industry to industry, it is observed to take from 10 to 50 years depending on the speed of industrial development.

As shown in Figure 71 below, "long-term" performance will therefore exceed the length of the typical 3-5 year business cycle. In doing so, local "non-systemic" (or higher mode) explanations for firm performance will be "filtered out". Examples of such non-systemic causal explanations include various *endogenous functional* explanations: e.g. a better/worse product design, a more/less effective marketing campaign, a labor strike, or various *exogenous environmental* explanations: e.g. the oil-crisis, 9-11 terrorist attacks, etc. This research is interested in those enabling and constraining "structures" (or enterprise architectures) which consistently and systematically create better product designs, more effective marketing campaigns, no expensive labor strikes or which consistently and systematically control exogenous events .

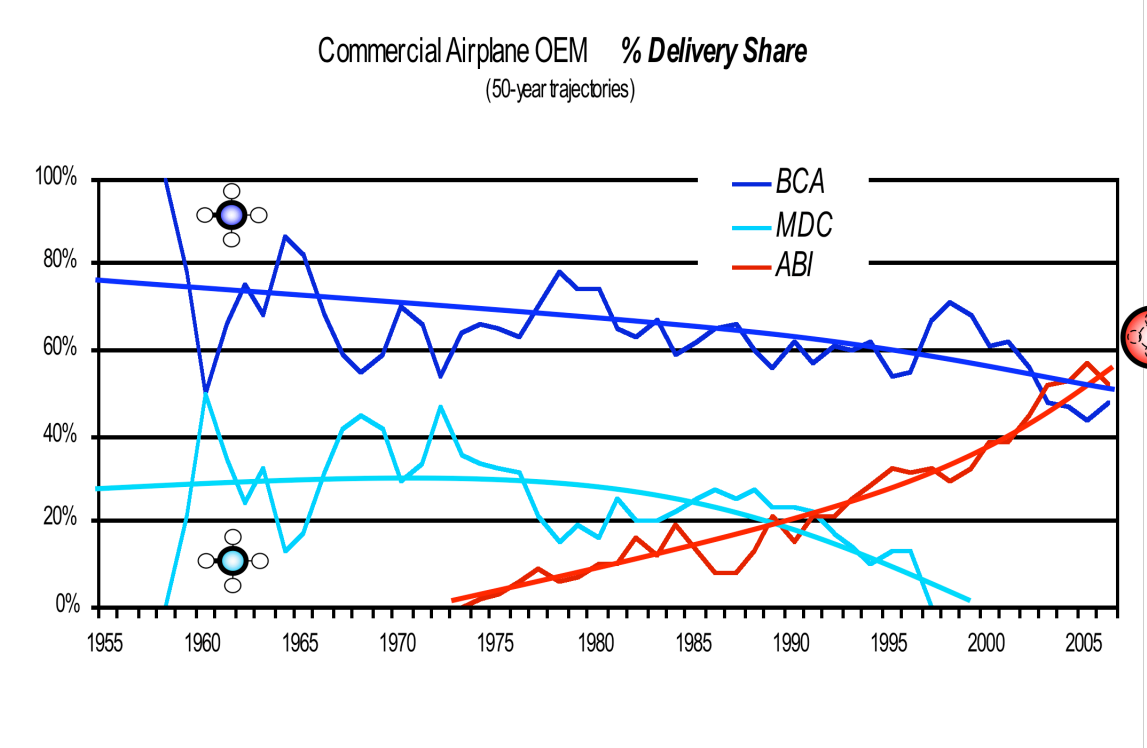


Figure 71: Explaining Long-Term (1st Mode) Trajectories of Firm Performance

1.4.2.1.2 Defining "*Firm Performance*"

Such performance can be measured in a number of ways[136], including survival/longevity, market share or profitability.

> *"Profit is an **opinion**..."*

The continuous dependent variable used in this research (as is typical for most research in competitive strategy) is long-term firm competitive performance, defined specifically as *economic* or *financial* performance.[137] As such, there are a vast number of measures and metrics upon which to base the research.[138] This is made even more complicated given the fact that the theory constructed herein identifies a spectrum of *enterprise architectures* each having diametrically-opposed performance objective functions (as characterized by Penrose's question above). This makes a direct comparison of performance difficult, as each architecture purports to achieve different objectives.

In order to reconcile this dilemma, the common performance metric that will be used for all enterprise architectures will be maximization of shareholder value as represented schematically in Figure 72 below as market capitalization, even though this is the explicit goal of the shareholder-based architecture, while it is an indirect and implicit goal of the stakeholder-based architecture.

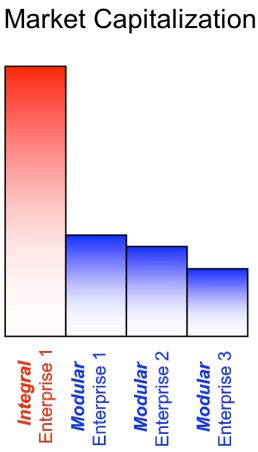


Figure 72: Key "Dependent" Variable: *Shareholder Value*

The research will demonstrate the circumstances under which shareholder value is maximized by those architectures actively attempting to do so, and when it is maximized by those architectures that are not solely focused on this objective.

---

[136] Ford and Schellenberg (1982) identify three different frameworks: the goal approach, the systems recource approach and the constituency approach.
[137] It is well-known in strategic management literature (Powell), that performance based on financial measures is sensitive to the financial measures chosen, and moreover, the notion of performance, is actually a socially-constructed phenomenon (Fligstein).
[138] A common financial performance metric used within the strategic management literature is "accounting profit" (McGrahan and Porter, 1997).

1.4.2.1.2.1 Sub-variables: *profitability* and *growth*

> *"**Growth** might be the **lifeblood** of a business, but it isn't always the best or most **sustainable** way to create **value for shareholders**. Return on invested capital (ROIC) is often just as important a measure of value creation and can be easier to sustain at a high level."*[139]

The notion of shareholder value (or market value) has been demonstrated to be mediated by the effects of *growth* and *profitability*, which have direct linkages to the *exploitation* and *exploration* tendencies of different enterprise architectures (Cho and Pucik, 2005). The firm's growth performance will be measured by the three compound annual growth rates of total assets (inputs), total revenues (outputs) and economic and market value added, EVA & MVA (value).[140] The firm's profitability performance is measured by three profitability ratios of ROA, ROE and ROI.[141]

As will be argued later, the different enterprise architectures tend to have objective functions based on either profitability or growth (Thurow, 1992). For this reason, both will be tracked.

1.4.2.1.2.2 Sub-variables: *past* performance and *future* health

> *"Managing companies for success across a **range of time frames** – a requisite for achieving both performance and health – is one of the **toughest challenges in business**."*[142]

In addition, the notion of shareholder value has been demonstrated to be dependent upon *past* financial performance and *future* growth prospects.[143] These sub-variables will be important in understanding the distinction between enterprise architectures and their underlying mechanics.

> *"It's common corporate-finance knowledge that something on the order of **60 to 80 percent of the value of a business lies in its long-term cash flows**. And if you're investing with a short-term horizon you're giving up the value creation of a business."*[144]

---

[139] Cao, B. Jiang, B. and Koller, T. (2006), pg. 12.

[140] Note that there is an inherent conflict embedded in strategy research between the typical unit of analysis, and the metric used as the dependent variable. Desirable market-based financial variables like MVA are typically reported for the corporate entity in a diversified conglomerate, while those for the disaggregated strategic business unit are more difficult to determine.

[141] It should be noted for the *Boeing–Airbus* duopoly that the notions of returns on assets, equity and investment are difficult to measure and not necessarily reliable measures of profitability (Dess and Robinson, 1984). As each firm embarks on different strategic make-buy paths for example, the boundaries of the firm change, as does the ownership of assets and therefore the meaning of ROA. In addition, each firm is on a different trajectory of equity offerings and ownership, the notion of ROE is difficult to compare. In this instance, a more transparent and meaningful measure in a capital-intensive duopoly with large economies of scale would be used like market share.

[142] Dobbs, Leslie and Mendonca (2005), pg. 63.

[143] Dobbs and Koller (2005).

[144] David Blood, Managing Partner of *Generation Investment Management*, in Mendonca and Oppenheim (2007), pg. 4.

1.4.2.2 "*Independent*" variables

1.4.2.2.1 Primary variable: Enterprise *Architecture*

> *"A proposed theory may posit that construct A leads to outcome B, but since A is a* ***'consruct,'*** *the reader often wonders what A is in real life. How would one measure A? How would one know that the empirical variable that one has obtained really captures A? By* ***seeing a concrete example of every construct*** *that is employed in a conceptual argument, the reader has a much easier time imagining how the conceptual argument might actually be applied to one or more empirical settings."*[145]

The primary construct developed to explain the dependent variable of long-term firm performance is the enterprise architecture, that is the firm and is relationships with its key stakeholders, as is shown in Figure 73 below. As was addressed earlier, this construct attempts to resolve a key debate in the field of strategic management between the source of competitive advantage as residing internally within the firm or externally in the environment.

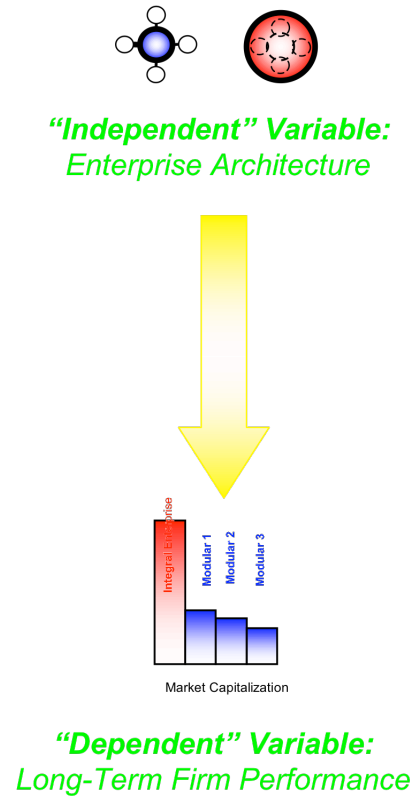


Figure 73: Primary "Independent" Variable: Enterprise *Architecture*

[145] Siggelkow, N. (2007), pg. 22.

1.4.2.2.2 *Intervening* variables: Enterprise *Function* & Environment *Evolution*

> *"The ability to get closer to theoretical constructs is particularly important in the context of **longitudinal research** that tries to **unravel the underlying dynamics of phenomena that play out over time**. As scholars have increasingly begun to appreciate the role of dynamic processes (e.g., path dependency or evolutionary processes), rich longitudinal research is needed to provide the details of **how** these processes actually play out."*[146]

In addition to explaining the source of long-term firm performance, the research seeks to explain where the "independent" variable itself comes from. In order to do this, the research proposes two other mechanisms or variables for this purpose: enterprise function as a *mediating* variable between enterprise architecture and long-term firm performance, and environmental evolution as a *moderating* variable between long-term firm performance and enterprise architectures as shown in Figure 74 below.

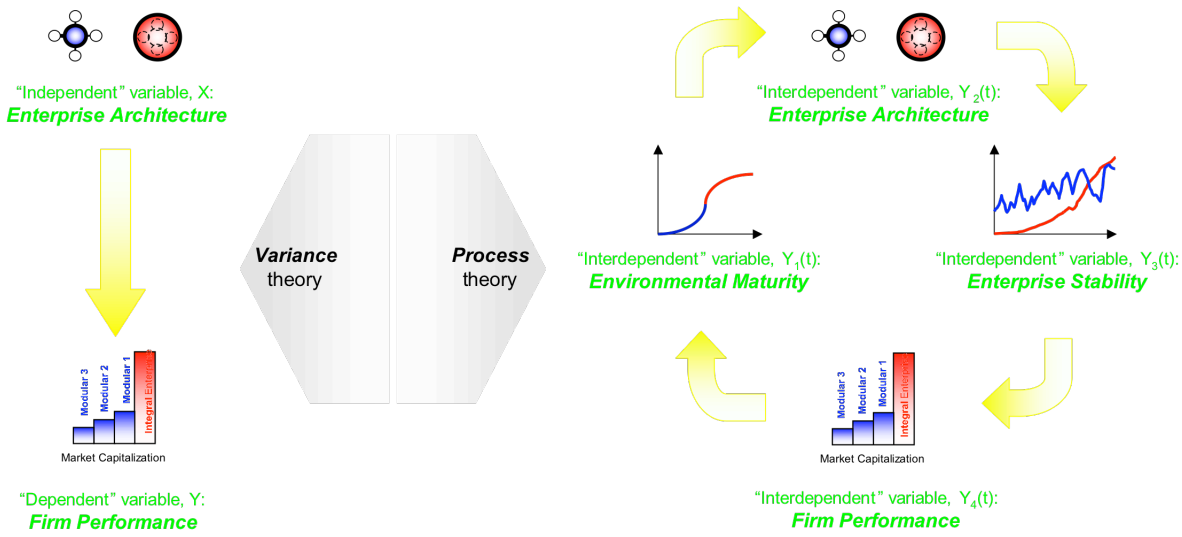


Figure 74: Intervening Variables: Enterprise *Function* & Environment *Evolution*

[146] Siggelkow, N. (2007), pg. 22.

1.4.2.3 *Interdependent* variables

> *"The only meaningful way to study organization is to study it as a system. As Henderson* [1935] *put it, the study of a system must rely on a method of analysis, '...involving the simultaneous variations of* ***mutually dependent variables****.'"*[147]

Modern organizational theory has long recognized the organization as a system of mutually dependent variables (Scott, 1961). Such mutually dependent variables has been referred to by noted organizational studies scholar, Karl Weick (1979) as "interdependent" variables.

> *"The* ***cause-effect relationships*** *that exist in organizations are* ***dense and often circular****."*[148]

Such interdependent variables can be thought of as arranged in a system of causal feedbacks (Forrester, 1961; Weick, 1979) generating both positive and negative feedback loops operating in complex organizations (Richardson, 1991).

> *"Modern organization theory asks a range of interrelated questions: (1) What are the* ***strategic parts*** *of the system? (2) What is the nature of their* ***mutual dependency****? (3) What are the main processes in the system which* ***link*** *the parts together? (4) What are the* ***goals*** *sought by systems?* [5] *What* ***research tools*** *should be used for the study of the system?"*[149]

This research dissertation therefore embraces the underlying systemic nature of the organizational phenomena under consideration and its highly interdependent variables. The operational questions being answered reflect those of a systems-theoretic approach applied to the study of organizations.

> *"The utility of the notions of* ***'mechanistic'*** *and* ***'organic'*** *management systems resides largely in their being related as* ***dependent variables*** *to the rate of environmental change.*
>
> *There are other* ***'independent variables'*** *which directly affect the form taken by any management system (although, even conceptually,* ***their independence from each other as well as from the management system, is not to be insisted upon; causal relationships in this, as in other social fields, are not one-way affairs****)."*[150]

1.4.2.3.1 *Correlative* vs. *Causal* approaches

Although the preceding discussion of the *dependent* and *independent* variables implies that the research dissertation will focus on traditional large sample statistical regression analyses to establish correlation among variables, in fact due to the nature of the question, data and epistemology, a feedback causal approach will be undertaken as shown in Figure 75 below.[151]

---

[147] Scott, W.G. (1961), pg. 15.
[148] Weick, K. (1979), pg. 7.
[149] Scott, W.G. (1961), pg. 16.
[150] Burns, T. and Stalker, G.M.. (1961), pp. vii and 96.
[151] Sterman (2000), pg. 141 warns about the importance and difficulty in establishing causal not correlative relationships between variables in system dynamics.

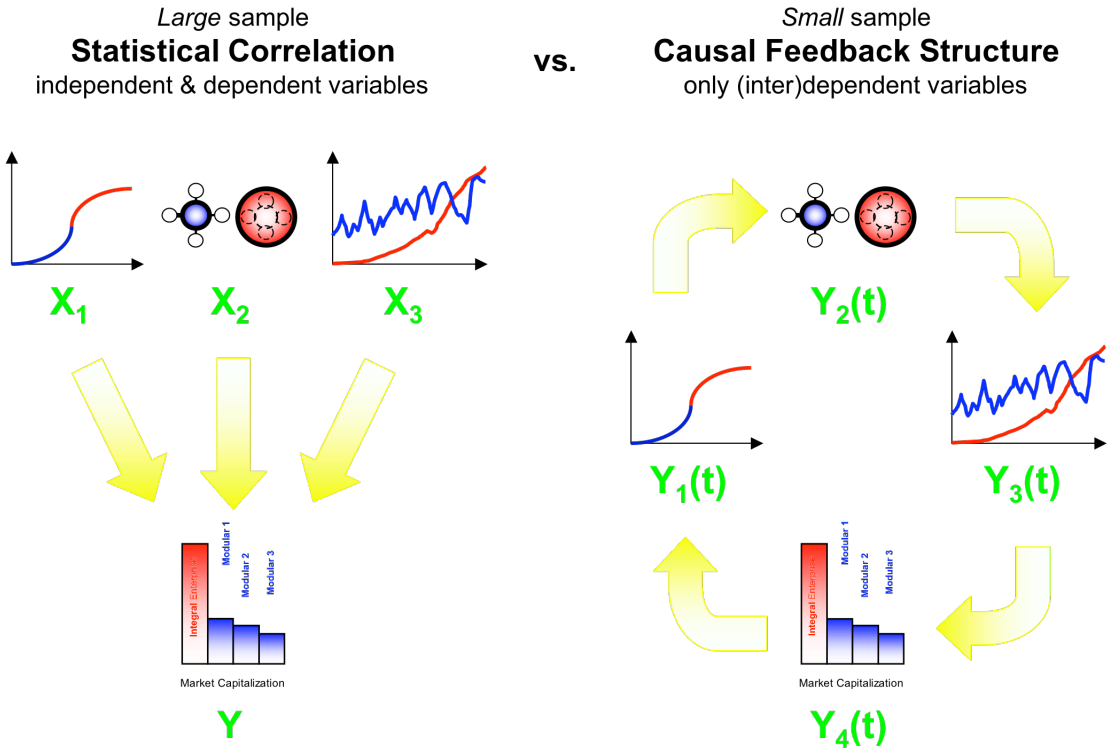


Figure 75: *Correlative* vs. *Causal* approaches

> *"**We must wait until theories have been much better developed** before we can highlight the relatively few variables which can be measured and rigorously examined statistically."*[152]

As mentioned earlier, the theory generated from this research intends to identify the fundamental macro-variables that drive long-term trends and trajectories in firm performance. It is hoped that further future theory development and refinement will lead to the justification for the use of more rigorous statistical methods needed to fully validate and extend the theory. For the purposes of this research program, the establishment of underlying causality takes precedence over correlation. This focus on seeking underlying causality takes its queue from the pragmatic design-oriented tradition of architectural theory, upon which much of the grounded theory of this research is based:

> *"Instead of just looking for statistical connections between variables, we may try to **find causal relations** between them… The search for causal relations of this sort cannot be mechanically experimental or statistical; it **requires interpretation**: to practice it we must adopt the same kind of common sense that we have to make use of all the time in the inductive part of science. The data of scientific method never go further than to display irregularities. We put structure in them only by inference and interpretation. In just the same way, the structural facts about a system of variables in an ensemble will come only from the thoughtful interpretation of observations. We shall say that two variables interact if and only if the **designer can find some reason** (or conceptual model) which makes sense to him and tells him why they should do so."*[153]

[152] Porter, M. E. (1991).
[153] Alexander, C. (1964), pp. 108-109.

1.4.2.3.2 *Variance* vs. *Process* approaches

> *"Process research is concerned with **understanding how things evolve over time and why** they evolve in this way. Whereas variance theories provide explanations for phenomena in terms of **dependent and independent variables**, process theories provide explanations in terms of the sequence of events leading to an outcome."*[154]

Variance theories attempt to point toward correlation in the constructs. They are concerned with *what* the relative explanatory power of different constructs are (e.g. external competition vs. internal capability in determining firm performance).

Process theories, conversely attempt to uncover plausible causality in the system. They are concerned with *how* the constructs are formed (Van de Ven, 1992).

As will be described in more detail in chapter 2, this research dissertation will attempt to build theory primarily from *process* data, although the aim of using *variance* data is recognized and will ultimately be recommended (Markus and Robey, 1988; Langley, 1999).

> *"Although **process explanations** featuring the role of history and learning were central in the **founding of the main** [strategy] **theories** (e.g. Selznick, 1957; Penrose, 1959; Chandler, 1962), they have been **largely neglected** by subsequent research."*[155]

Over the past 40 years since the establishment of some of the most significant strategic management theories, much research in the strategic management field has drifted away from a *process* approach towards a *variance* approach, as would be expected. This research dissertation however attempts to join the recent calls in the strategic management literature to restart the cycle of knowledge creation by focusing again on *process* explanations, due to the observation that over the past 40 years there have been significantly new phenomena which need to be understood and explained. In this research, it is the nature of competition between two radically different architectural forms or "species", which heretofore have not come into "contact" that is unique and therefore requires a new approach.

[154] Langley, A. (1999).
[155] Farjoun, M. (2002), pg. 565.

1.4.2.3.3 Randomness and Indeterminacy

> *"The model suggests that the relationship between environments and organizations is* ***not random but is indeterminate,*** *and that the very indeterminacy of environmental effects on organizations is* ***potentially explainable****."*[156]

The emphasis of this research on *process* theory, with *interdependent* variables attempts to reveal that the firm's relationship with its environment is not fully random, yet neither is it fully determinate. The same situation of theory drove the research agendas of other scholars (Pfeffer and Salancik, 1978).

> *"Given this* ***causal sequence****, one may not observe a perfect relationship between organizational actions and structures and the environment for several reasons. First, since each intermediate variable undoubtedly has* ***other causes*** *besides those specified, the relationship between between environments and organizational actions and structures may be attenuated by these other factors. Second, because of the* ***linked nature of the causal process****, any indeterminacy or error in the process will be magnified because of the intermediate steps that link environments with organizations. For instance, even if each of the causal links were as strong as a .8 correlation, the overall correlation between environmental dimensions and organizational characteristics would be only .51. It is not surprising, therefore, that* ***researchers often fail to find strong relationships between environmental characteristics and organizational outcomes****."*[157]

[156] Pfeffer, J. and Salancik, G.R. (1978), pg. 228.
[157] Pfeffer, J. and Salancik, G.R. (1978), pg. 229.

1.4.3 *Boundary Assumptions*

1.4.3.1 Spatial

The framework developed herein has boundaries of application, and assumptions embedded in the boundaries. They will be addressed in terms of the market (demand) environment and the technological (supply) environment.

1.4.3.1.1 Market

The product and service offerings of the firms and industries studied are relatively homogeneous and stable. That is, competitors in the automobile industry are largely competing on the production of cars and competitors in the airline industry are largely competing on the delivery of seat miles. The complex fracturing and fragmentation of markets into niches or the evolution into services is not the primary focus of the research.[158]

1.4.3.1.2 Technological

Technological development is assumed to progress smoothly between discontinuities.

[158] I am indebted to Prof. Mari Sako for helping to identify this, and for challenging my thinking in this set of assumptions.

1.4.3.2 Temporal

This dissertation aims to develop a theory of the evolution of business ecosystems. By definition therefore, it aims to analyze the evolution temporally (that is diachronically) from the "birth" to "death" of an industry (and its associated ecosystem), as well as between "life-spans" of successive industries.

1.4.3.2.1 Long-term Trends

> *"The model is **not intended to account for short-run changes**, which are **temporary** responses to **local** conditions, but rather for **long-run transformations** in the **form** of social organization."*[159]

1.4.3.2.2 Truncated Life-Cycle

In order to bound the analysis and more importantly to bring parsimony to the developed theory, this dissertation will focus on a truncated version of the classical industry lifecycle (Porter, 1980, pg. 158.), namely from the *introduction* phase through the *growth* phase, and finally through the *maturity* phase. This research will therefore give less emphasis to the *decline* phase. As shown in Figure 76 below, the dissertation therefore effectively maps out the classic "S-curve". An implicit assumption is that the evolution of a new industry will occur near the peak of industry sales.

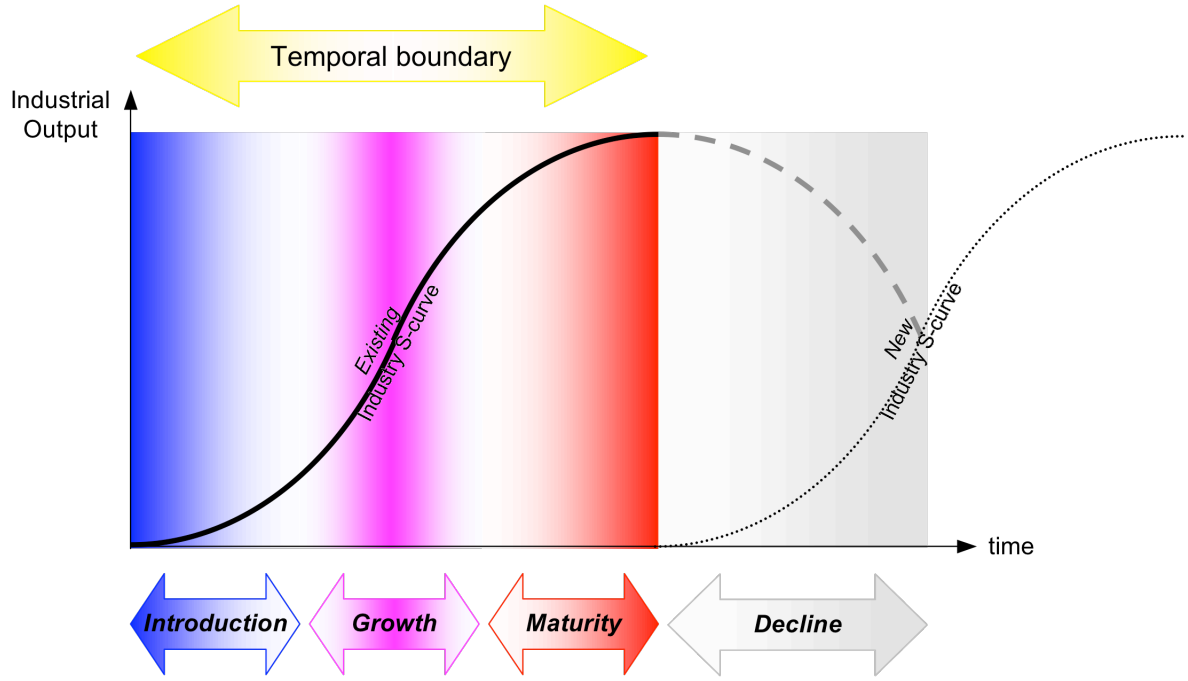


Figure 76: Temporal Boundary of the Framework

[159] Aldrich, H.E. (2006), pg. 27.

1.4.3.2.3 *Bi*- vs. *Tri*-phase Industry S-Curve

Finally, this dissertation initially sets out to describe a theory of the evolution of business ecosystems in terms of a *bi*-phase temporal discretization of the industrial S-curve. This is done to present the competing generic environmental regimes of *exponential growth* vs. that of *goal-seeking stability* characterized by *emerging* and *maturing* markets respectively.

Once simplification is established, then a further refinement is made in which the environment is characterized into a *tri*-phase temporal discretization of the industrial S-curve as shown in Figure 11 below.

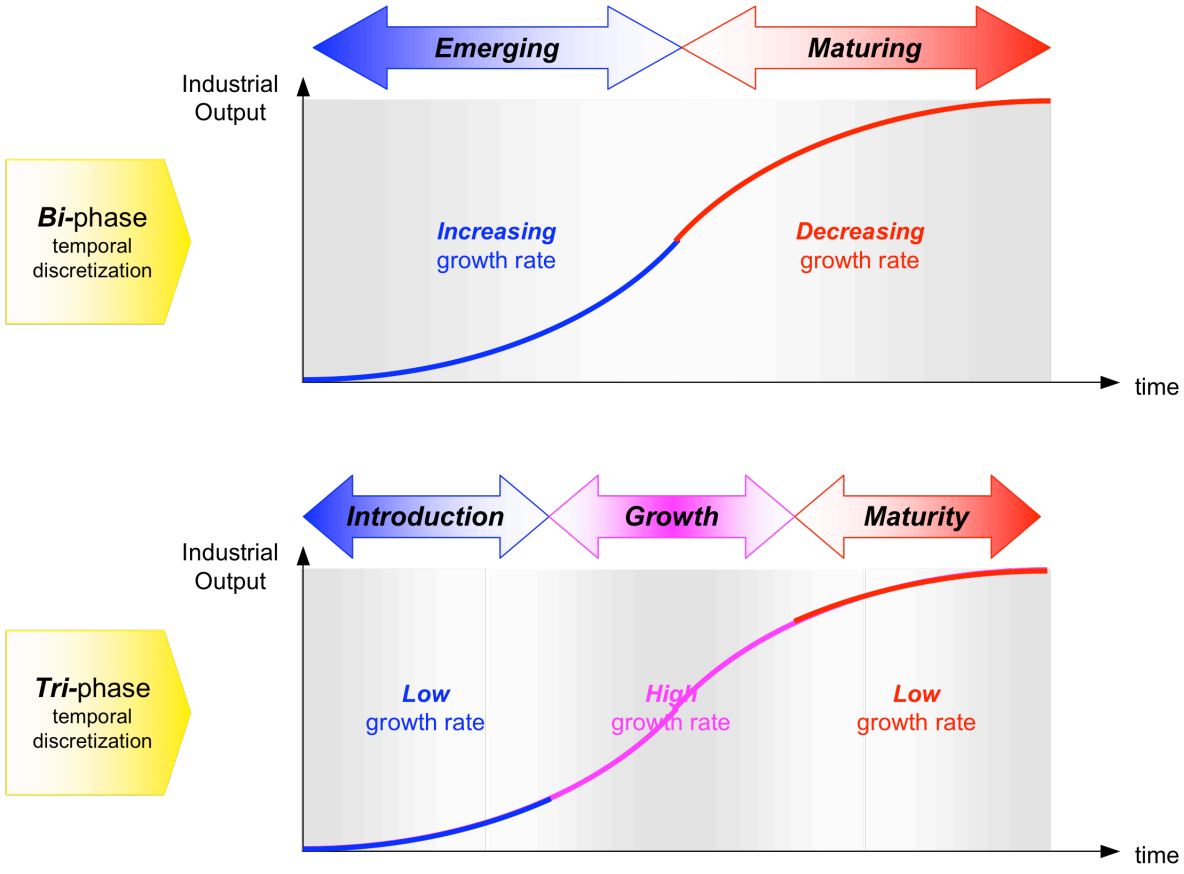


Figure 77: *Bi*- vs. *Tri*-phase Temporal Discretization of the Industrial S-Curve

1.4.4 *Summary of Research Framework*

The following section briefly summarizes the three main a priori constructs used for the research. In addition, some of the fundamental propositions are developed. The mid-range theory that is derived from these constructs and propositions, can be seen as an *architectural* design *heuristic*.

As the research develops, the intent is the development of testable proposition-derived hypotheses that are based on measurable data. The low-level substantive theory that is derived from these hypotheses and data can be seen as an *engineering* design *law*. The structure of the mid-range theory is illustrated below in Figure 78.

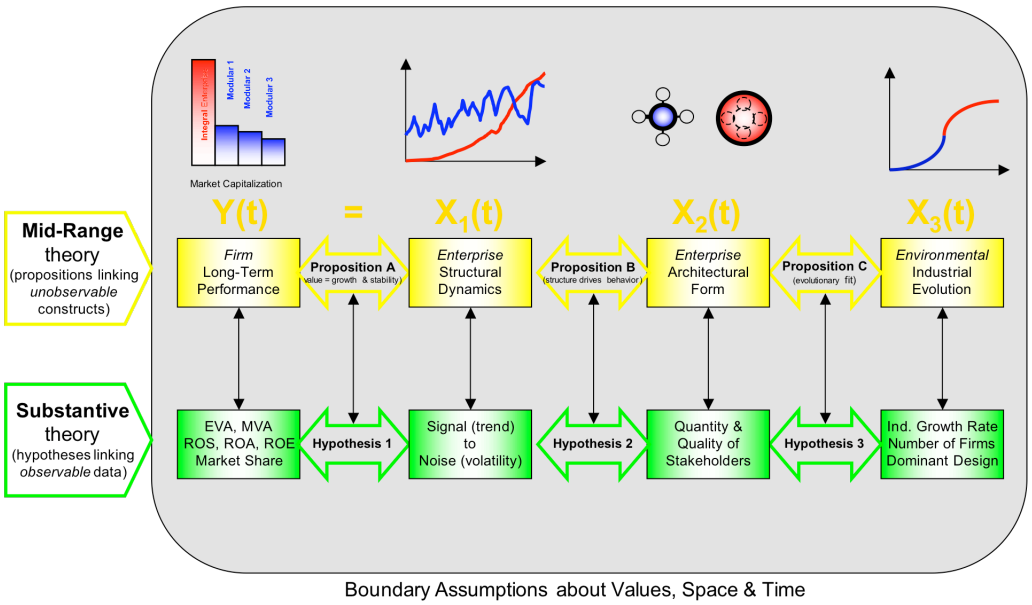


Figure 78: Structure of Proposed Mid-Range Theory

The theory attempts to show how long-term firm performance is ultimately caused by enterprise architectural form, and how it causes the evolutionary environmental conditions which create the architectural forms. Given the unit of analysis, the dependent and independent variables, the equation that this research will attempt to derive, constrain (bound), and ultimately prove is the following:

$$Performance = f(form, structure, environment)$$

or more explicitly:

Long-Term Firm Performance = f(enterprise architectural form, input-output structural dynamics, industrial evolutionary dynamics)[160]

[160] I am indebted to Prof. Charlie Fine for clarifying these relationships. Note that over the long term, each "independent" variable is itself time-dependent, as well as dependent upon the other "independent" variables.

1.4.4.1 Framework *Summary*

1.4.4.1.1 High Level Summary

The primary "independent" variables are derived from the propositions and constructs developed in this research and are summarized in Part II. These include the construct of an *enterprise architecture*, and the proposition that it drives the enterprise's *structural dynamic* behavior, (i.e. its growth and profitability*),* which ultimately drives the *industrial evolution.* These constructs and their propositional relationships are briefly summarized in Figure 79 below:

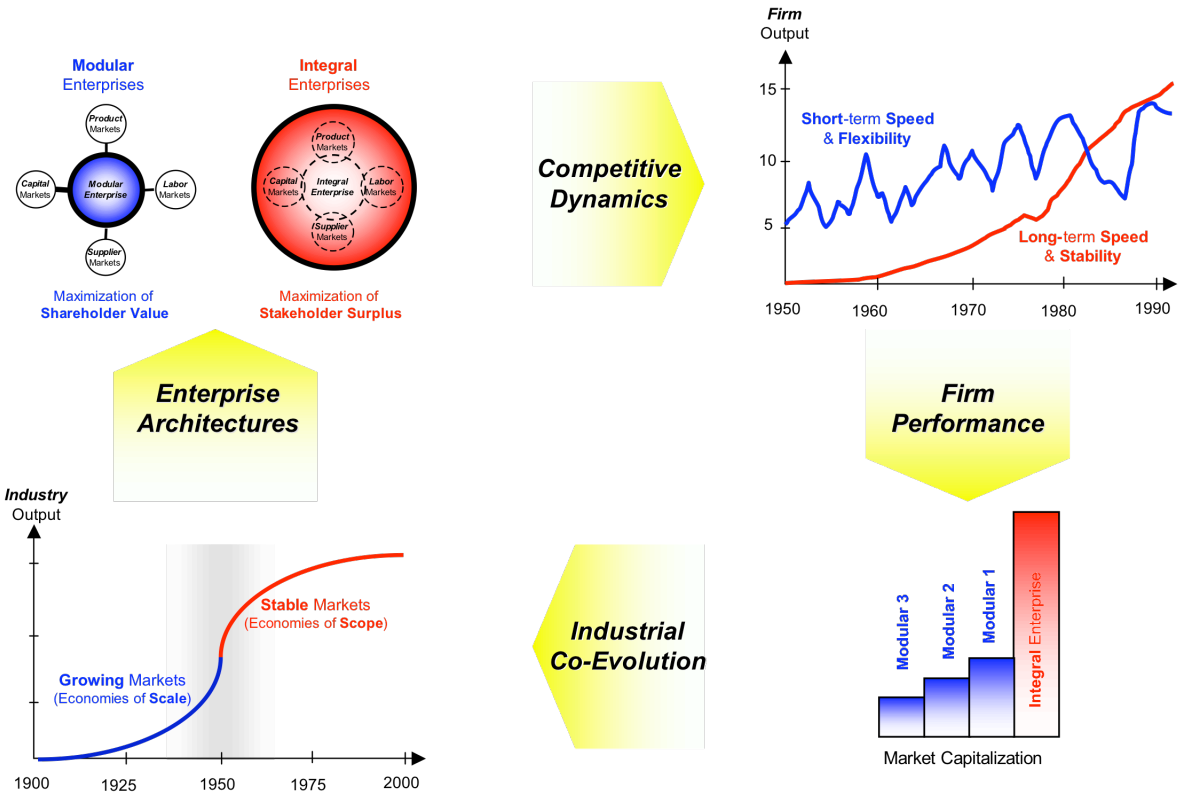


Figure 79: Summary of Proposed Co-Evolutionary, Meta-Strategic Framework

*"Key dimensions at **the firm and environmental levels** have **reciprocal relationships** so that firms develop capabilities either through **choice or selection**, that then shape the environment which, in turn, further shapes capabilities. Thus firm strategy and performance fundamentally arise from interactions between organizational and competitive factors at **several levels of analysis**."*[161]

[161] Henderson, R. and Mitchell, W. (1997), pg. 12.

1.4.4.1.2 Detailed Summary

> *"Critical to understanding contemporary differences in market share and profitability among firms within an industry is **systematic knowledge** of how those differences arose in the first place. Understanding the **structural evolution of industries** – the rate of change in output and prices, the rates of entry and exit (turnover), and the growth and decline of individual firms (mobility) and industry participation – is widely recognized as **fundamental to identifyling the origins of profitable market leaders who can sustain performance over time**. Industry evolution provides important important **contingencies** that affect the viability of various firm strategies. Without a keen grasp of the underlying mechanisms driving industry evolution and the resulting changes that occur at the industry level over time, we are less able to identify why certain firms in an industry are the **winners** and other **losers** (Agarwal and Gort 2002)."*[162]

As shown in Figure 80 below, the aforementioned high-level summary will be further developed into a more detailed framework consisting of an endogenous causal model.

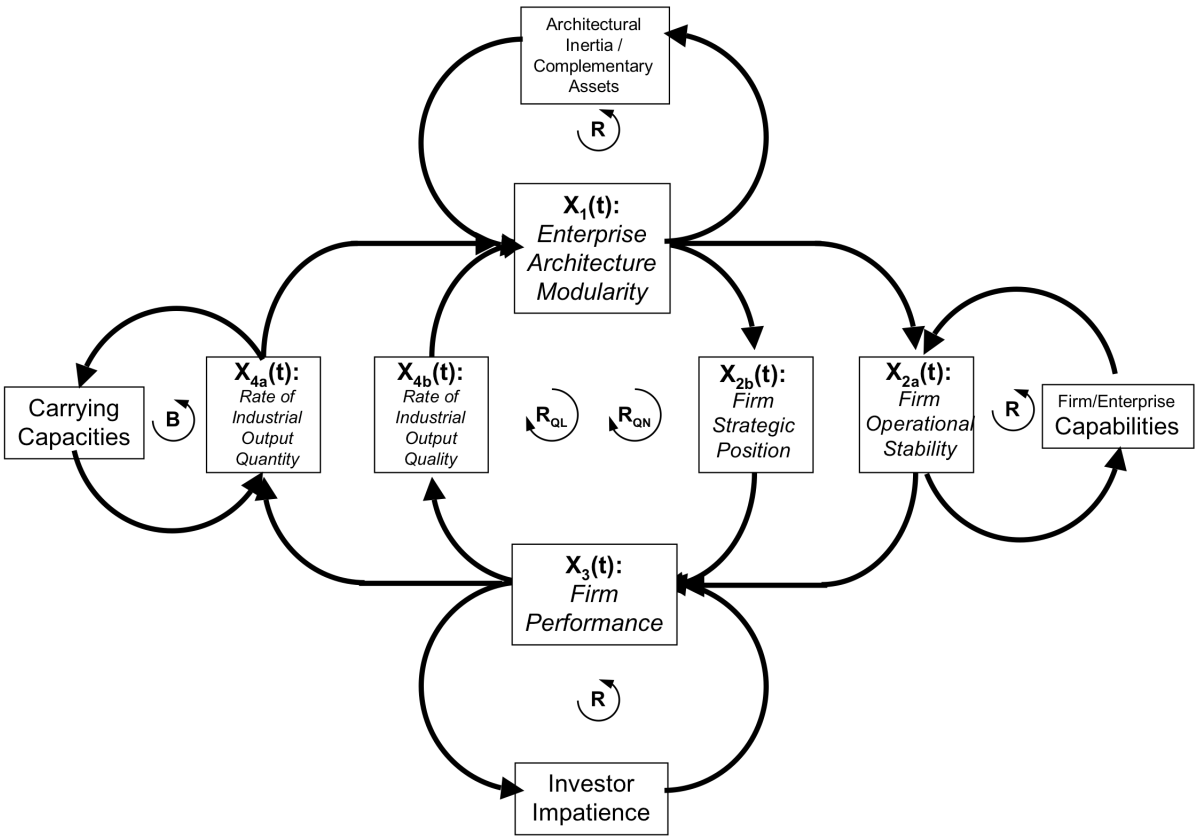


Figure 80: Detailed Causal Model

[162] Lenox, M.J., Rockart, S.F. and Lewin, A.Y. (2007), pg. 599.

1.4.4.2 Framework as *Strategic Management* Theory

The framework can be summarized as shown in Figure 81 below in terms of the classic industrial organization / strategic management paradigms of "structure-conduct-performance" (Mason, 1939; Bain, 1956) and "the resource-based view" (Penrose, 1959; Wernerfelt, 1984).

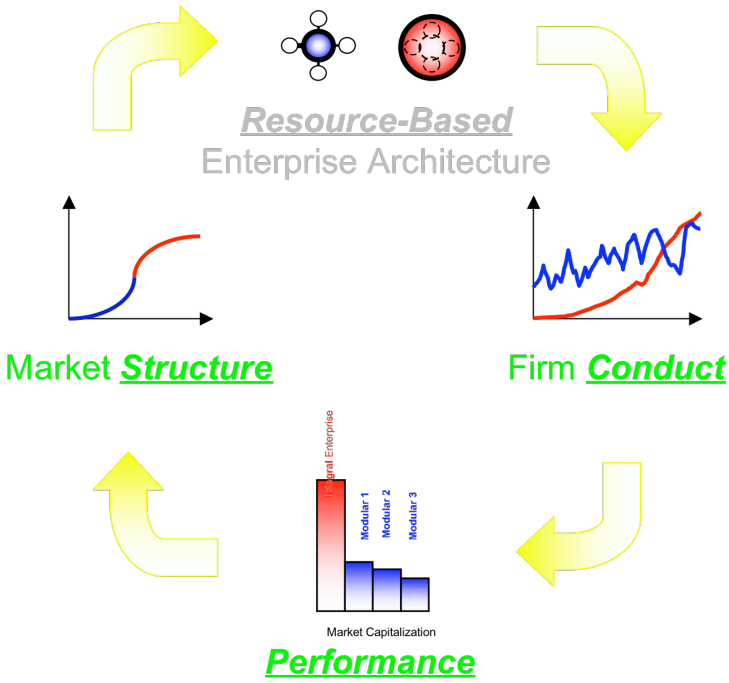


Figure 81: Framework as *Strategic Management* Theory

1.4.4.2.1 Market *Structure*

> *"The **rate of growth of the market** can serve as an **important trait of market structure**. Fast growth, for instance, reduces the payout of short-run collusive strategies relative to strategies aimed at raising the firm's sustainable market share."*[163]

1.4.4.2.2 Firm *Conduct*

> *"Market **conduct** comprises the processes whereby **firms choose their preferred price and product outcomes** and reconcile their divergent offers in the market place. It also covers predatory or exclusionary conduct."*[164]

1.4.4.2.3 *Performance*

> *"A chief test of market **performance** is the **rate of return**."*[165]

[163] McGugan, V.J. and Caves, R.E. (1974), pg. 391.
[164] McGugan, V.J. and Caves, R.E. (1974), pg. 392.
[165] McGugan, V.J. and Caves, R.E. (1974), pg. 394.

1.4.4.3 Framework as *Social System* Theory

Much of the early work on social systems in the 1950s and 1960s can be discussed within two influential paradigms, *structural functionalism* and *general system theory* (Burrell and Morgan, 1979).[166] Later, social system theory "evolved" into an evolutionary theory as put forth by the organizational ecologists (Hannan & Freeman, 1977) among others. The following three subsections briefly discuss the proposed framework within these paradigms.

1.4.4.3.1 Framework as *Structural Functionalist* Theory

> *"The concept of **function** as defined thus involves the notion of **structure** consisting of a set of **relations** amongst unit entities, the continuity of the structure being maintained by a **life-process** made up of the activities of the constituent units."*[167]

Each of the three independent variables of the framework corresponds with the structural functionalist problems of: *social morphology* (i.e. what kinds of social structure are there?), *social physiology* (i.e. how do social structures function?) and *social development* (i.e. how do new types of social structure come into existence?). As shown in Figure 82 below, the theory presented within this dissertation can be expressed within the structural functionalist paradigm.[168]

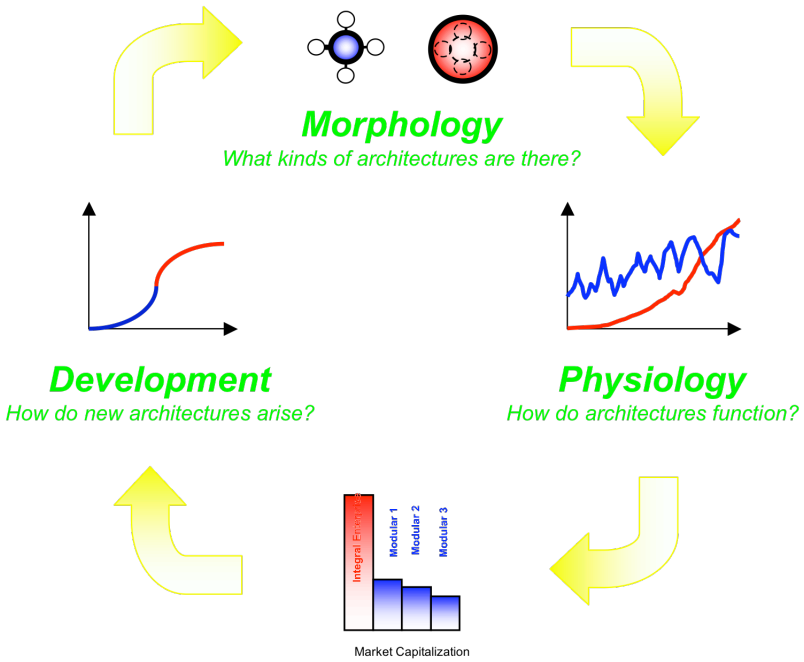


Figure 82: Toward a *Structural Functionalist* approach to the Framework

[166] Note that *structural functionalism* makes explicit use of a biological metaphor, while *systems theory* does not (Burrell and Morgan, 1979, pg. 49).
[167] Radcliffe-Brown (1952), pg. 180. Note that Radcliffe-Brown cautions that social structures can only be observed through their function.
[168] As will be discussed later in this chapter, a "structural functional" explanation differs from the "causal" explanation.

1.4.4.3.1.1 Social *Morphology*

> *"**Morphology**: The branch of biology that deals with the **form and structure** of organisms without consideration of **function**."*[169]

> *"**Anatomy**: The science of the **shape and structure** of organisms and their parts."*[170]

To begin with, the architecture (i.e. form and structure) of the enterprise will be defined independent of the strategic and operational functions they fulfill.

1.4.4.3.1.2 Social *Physiology*

> *"**Physiology**: The biological study of the **functions** of living organisms and their parts."*[171]

In particular, having defined the architecture (i.e. the form and structure) of the enterprise, the framework will attempt to tie causal arguments to the strategic position (i.e. physiological function) of the architecture. Specifically that integral enterprise architectures, born into mature industries tend to have a cost-leadership posture or strategic function.

1.4.4.3.1.3 Social *Development*

Finally, having defined the architectural form, structure and strategic function of the enterprise, the framework will endeavor to explain how these structures and functions evolve over time, for example, how integral enterprise architectures, born into mature industries begin with a cost-leadership posture or strategic function and later evolve into a differentiated strategic function.

[169] From "*Dictionary.com*".
[170] From "*Dictionary.com*".
[171] From "*Dictionary.com*".

1.4.4.3.2 Framework as *General System* Theory

> *"Certain methods of studying **behavior** apply to all organized systems, namely **structure, function and evolution**. Any organized system can be seen from these three perspectives which encompass the broadest scope of a **general system theory**."*[172]

In addition, each of the four interdependent variables of the framework corresponds with the system concepts of *General System Theory* (Rapoport, 1968): *evolution, function, structure* and *behavior* (or performance - to use a variable pertinent to strategic management) as shown in Figure 83 below.

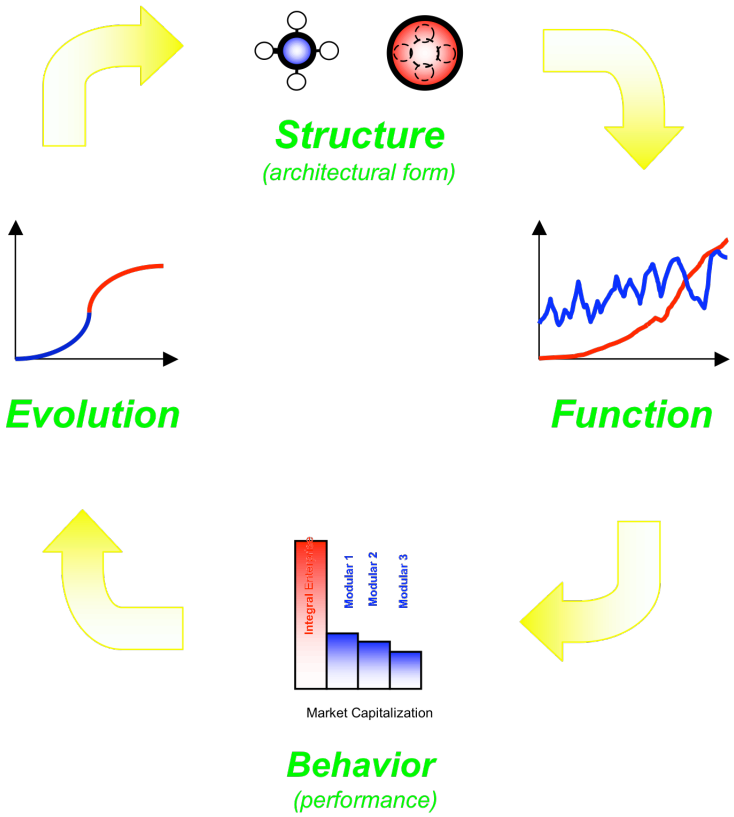


Figure 83: Toward a *General System Theory* approach to the Framework

1.4.4.3.2.1 System Goals: *Stability, Growth* and *Interaction*

Unlike traditional research in the strategic management literature which focuses on the isolation of a few isolated low-level variables to explain firm performance, this work attempts to aggregate many confounded variables into three high-level, aggregate, system variables.

In Essays #1 and #2, we will discuss the enterprise objective functions or goals, which in terms of general systems theory, can be stated as *stability, growth* and *interaction* (Henderson, 1935, pg. 86).

[172] Rapoport, A. (1968), pg. xx.

1.4.4.3.3 Framework as *Evolutionary* Theory

> *"**Evolutionary** theory explains how particular **forms of organizations** come to exist in specific **kinds of environments**. Variation, selection, retention and struggle occur **simultaneously** rather than sequentially. Analytically, the process may be separated into discrete phases, but in practice they are **linked in continuous feedback loops and cycles**."*[173]

Each of the four proposition sets of the framework corresponds with the evolutionary mechanisms of: *variation* (i.e. how do new types of social structure come into being?), *selection* (i.e. how do social structures compete successfully?) and *retention* (i.e. how do new types of social structure become perpetuated?). Note that the *variation* mechanism is further subdivided into "blind" or Darwinian variation, whereby the environment dictates organizational form, and "semi-blind" or Lamarckian variation, whereby management dictates organizational activities like market and production strategy. As shown in Figure 84 below, the theory presented within this dissertation can be expressed within the evolutionary paradigm, with the proposition sets shown below as the connecting yellow arrows.

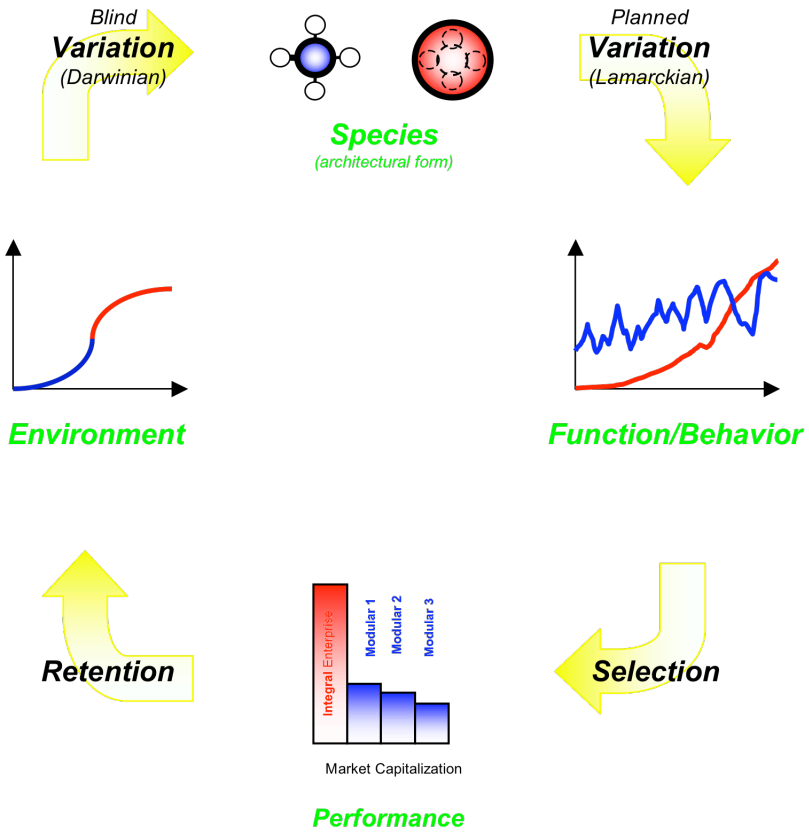


Figure 84: Toward an *Evolutionary* approach to the Framework

[173] Aldrich, H.E. and Ruef, M. (2006), pg. 26.

1.4.4.4 Framework as Temporal Theory

The independent variables associated with function, structure and evolution each take on a different *temporal* perspective as shown in Figure 85 below. The function-related variable takes a (small dt) "*static*" view, defining the properties and characteristics of the architectures. The structure-related variable takes a (medium dt) "*dynamic*" view of how the static structures interact to drive dynamic behavior. Finally, the evolution-related variable takes a (large dt) "*evolutionary*" view of how the environment evolves dominant architectural "species" which oscillate nonlinearly. The evolutionary trajectories of enterprise architectures are seen from the lenses of *adaptation* and *selection*.

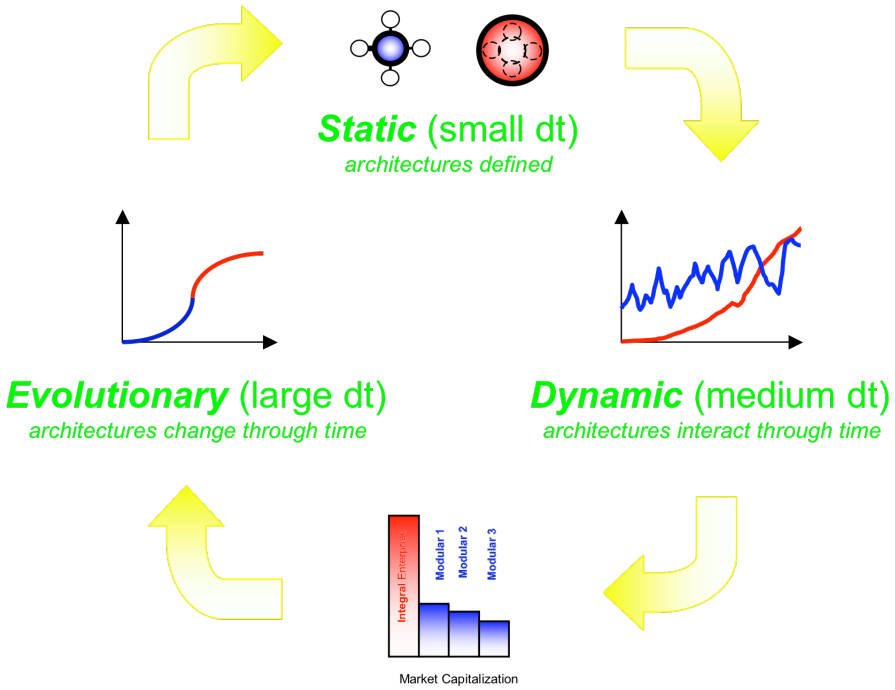


Figure 85: The Framework viewed through a *Temporal* perspective

Note that for *very* large dt, that is, after firms and industries cycle around the above loop numerous times, the random processes of variation, selection and retention begin to take hold and evolve the architectural characteristics of species. The scope of this research does excludes such long-term evolutionary pressures.

1.4.4.5 Framework as *Architectural Design* Theory

> *"A quest for **field-tested and grounded** technological rules, which in the field of management will be predominantly **qualitative** and **heuristic** by nature, means trading the priestly beauty of **truth** for the soldiery glory of **performance**."*[174]

The objective of building a rigorous and relevant conceptual framework, which aims to contribute to the explanation and delivery of long-term firm performance, will be met using a high level of abstraction. As such, the conceptual *form* of the firm and its relationship with its environment will provide fundamental answers to the question of performance, whereas more detailed, operational explanations using a lower level of abstraction will provide more precise explanations, *given* an architectural-level explanation. In this sense, the architectural form is a solution-neutral restatement of the problem[175], and as such the architecture enables and constrains (but does not determine) what the enterprise can do.

> *"**Architectural insights** are worth far more that ill-structured **engineering analyses**."*[176]

As shown in Figure 86 below, the framework can be demonstrated to follow the architectural design process, as in the process used to design and build artifacts of civil architecture.

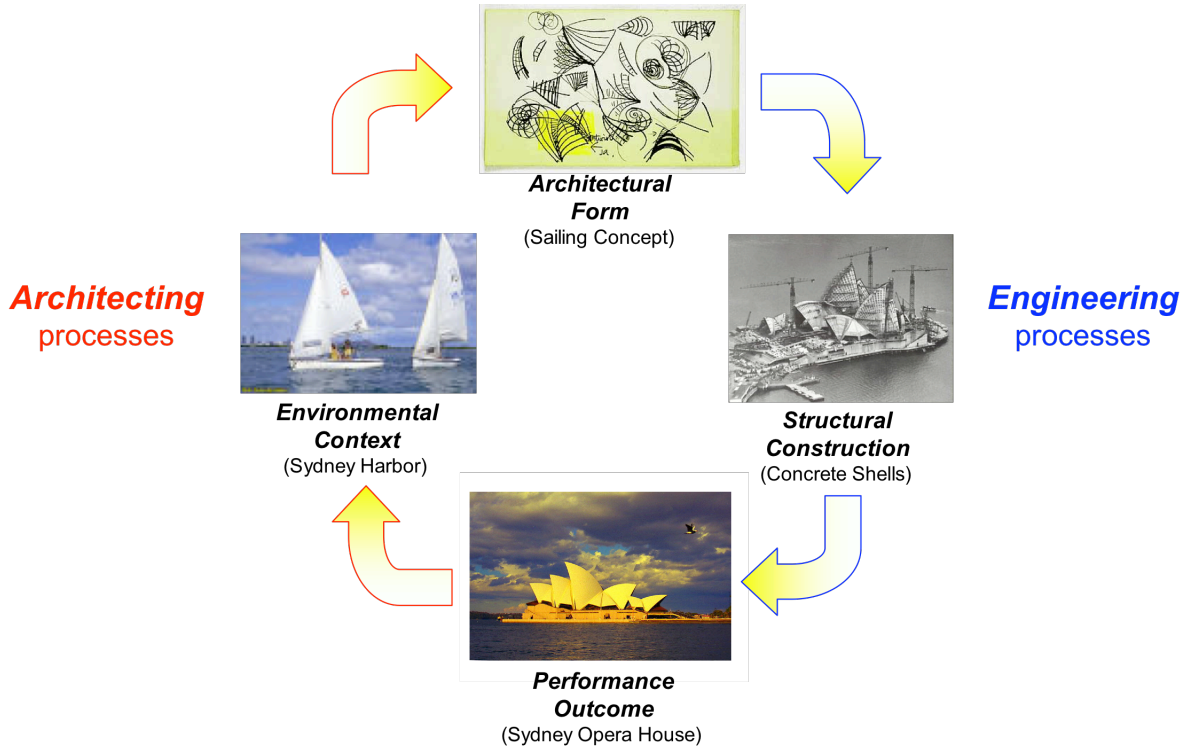


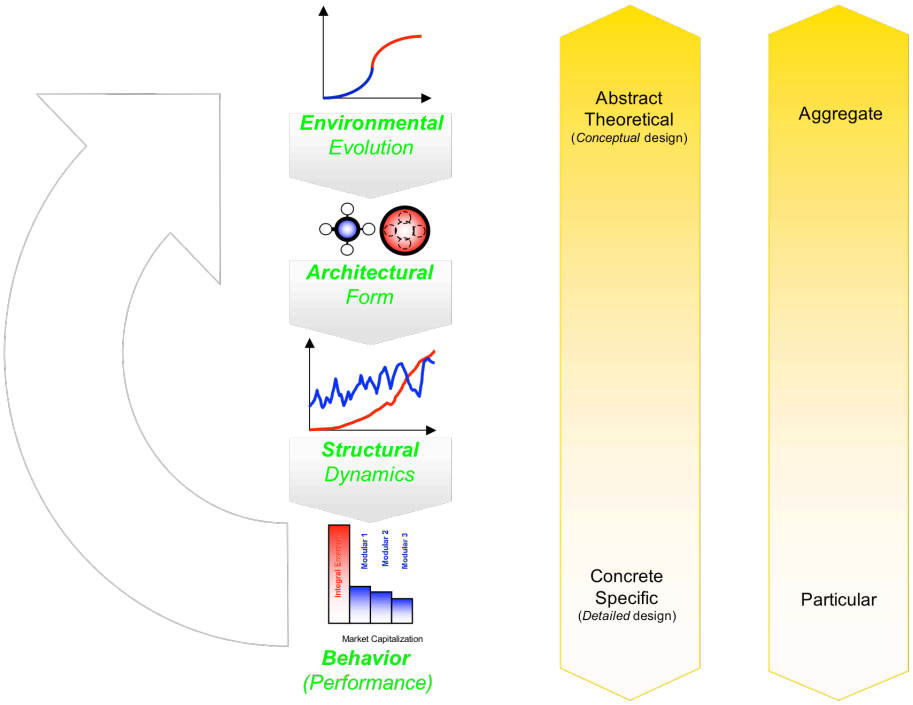
Figure 86: Framework as *Architectural Design* Theory

[174] van Aken (2004), pg. 242.
[175] From MIT Prof. Ed Crawley.
[176] Rechtin, E. (1991) and Rechtin, E. (2000), pg. x.

1.4.4.5.1 *Trends & Trajectories* via Architectural *Abstraction & Aggregation*

Although the proposed framework is being derived empirically from the field-based data of observing and developing the phenomena of business competition, it also (upon reflection) can be seen to have its roots in the abstractions and aggregations of architectural design theory. The act of architecting a social structure progresses (both linearly as well as iteratively) from the intense study of the environment in the abstract, to the induction of a high-level form or concept, to the deduction of lower-level structures (from well-tested laws), finally to the creation or delivery of a high-performing entity (Piepenbrock, 2004).

As shown in Figure 87 below, this research will therefore attempt to explain the high-level *abstract* architectural forms and their *aggregate* behaviors that firms and their extended enterprises will need to exhibit long-term high-performance in different environmental conditions. In this sense, this research dissertation is seeking underlying long-term *trends* and performance *trajectories* – the "signals" through the "noise" of lower levels of



abstraction.

Figure 87: Framework presented as "Ladder of Abstraction/Aggregation"

Of more relevance to the performance objectives as stated in this research dissertation, another analogy of the framework can be developed as shown in Figure 88 below. An analogy of architectural abstraction might be to explain or design a high-performance solution in a motor sport race. Instead of immediately launching into low-level detailed explanations of engine power and torque or design for aerodynamics, an architectural approach would ensure the high-level abstract *form* achieves *fit* with its environmental demands and its overall *function*. Therefore observing that the race will take place in a mud

bog as opposed to a slick racetrack gives the abstract solution that a crude “tractor” form will dominate any race car, now matter how powerful its engine or low its drag coefficients.

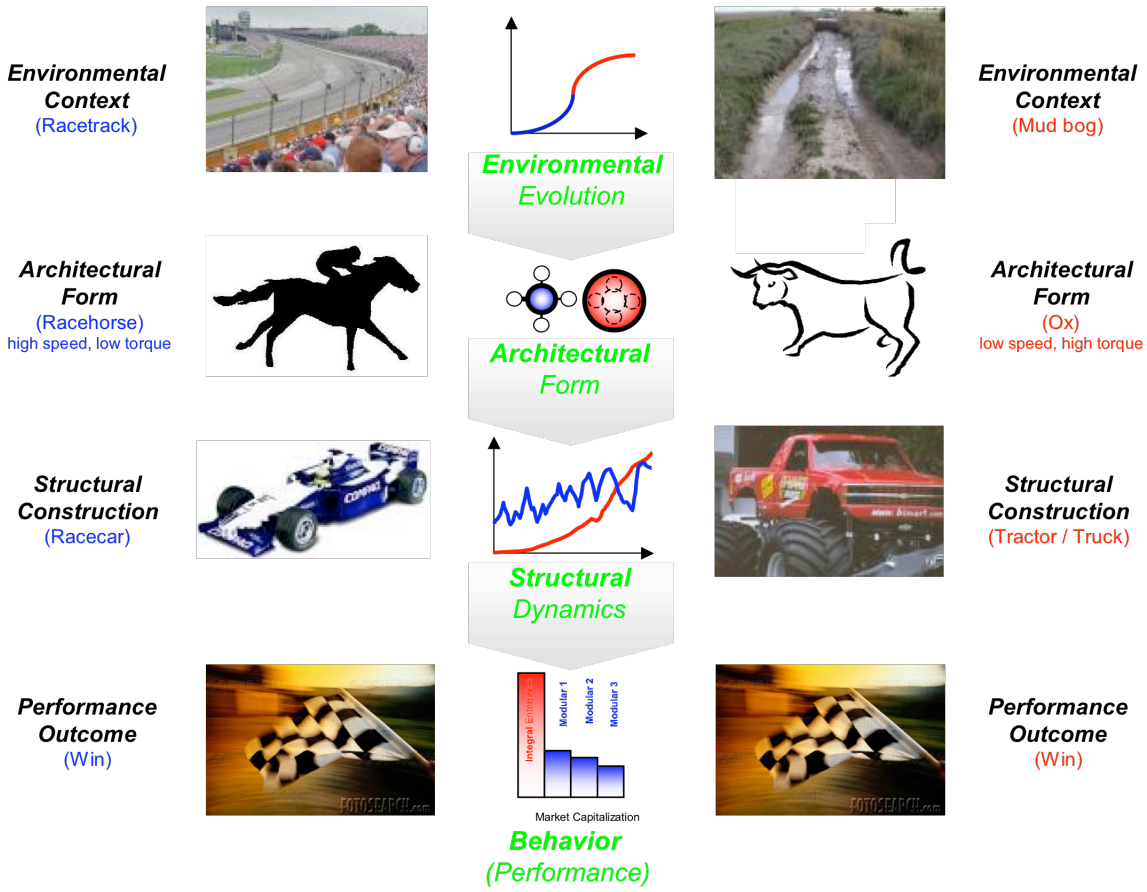


Figure 88: Proposed Framework expressed as a *Motorsport Race*

1.4.4.5.2 "Resolution" Limitations of an *Architecture*-based Framework

The framework presented herein attempts to contribute towards a general theory of the evolution of business ecosystems, which in the process explains long-term firm performance. It is however, by its very design, a conceptual framework with a low degree of "resolution". That is, it predicts *generally* under which *aggregate* conditions, a firm *should* outperform its rivals over the *long term*. For example: "the greater the maturity of the market, the more enterprise architectures with greater integrality should dominate."

As such, it will be demonstrated that the high-level enterprise architecture transcends the firm's strategy and its operational efficiency. Due to its low resolution, there will be "noisy" exceptions, which will play out over the short term, where for example, excellent strategy coupled with excellent execution trumps poor architecture in a near-transition environment.