INNOVATION, INSTITUTIONS AND INDUSTRY EVOLUTION: HISTORICAL LESSONS FOR A MULTI-DIRECTIONAL WORLD

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SUBMITTED TO:

21ST ANNUAL CONFERENCE OF
THE SOCIETY FOR INSTITUTIONAL & ORGANIZATIONAL ECONOMICS
JUNE 23–25, 2017
VENUE: COLUMBIA UNIVERSITY, NEW YORK CITY, NY, USA

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ABSTRACT

In this study, we develop and empirically test the theory that new industry entrants hold advantages over incumbents in the shift from unidirectional to multi-directional revenue streams. Using a Cobb-Douglas production function, modified to isolate returns to innovation, we examine data from three separate contexts: steamships on western U.S. rivers (1810-1860), satellite-based Internet services (1962–2010), and food waste recycling (1995-2015). The results reveal that while incumbents often attempt to stretch existing technologies to fit emerging circumstances, entrepreneurial innovators achieve greater success by approaching multi-directional value creation as a distinct challenge, one requiring new technologies, organizational forms and business models. While existing theories have primarily attributed incumbent inertia to a firm's inability perceive and pursue radical innovations, our results also suggest that existing firms are simply unwilling to pursue innovations that are likely to erode the marginal profitability of their respective business models. Ironically, rather than protecting incumbents' financial interests, we find that "marginal reasoning" can lead to diminished performance and even extinction. Our proposed framework and empirical findings have implications for a diverse array of multi-directional frontiers, including: social networking, commercial space travel, distance education, and medical treatments using nanoscale technologies.

KEY WORDS: Innovation, Disruption, Entrepreneurship, Historical Analysis, Economic History

1. INTRODUCTION

Multi-directional value creation has emerged as one of the defining characteristics of novel activity systems (Porter 2002), profitable business models (Zott, Amit & Massa 2011) and key sources of sustainable competitive advantage (Dierickx & Cool 1989). Sometimes called "round tripping" in supply-chain research (Carter & Rogers 2008; Chen & Paulraj 2004; Ketchen & Hult 2007), multi-directionality occurs when revenues are generated through the development of solution sets that allow commercializable goods and services to flow in more than one direction (Beamon 1999), such as: distance education, transportation and communication networks, cloud computing, multi-party licensing arrangements, proprietary knowledge exchange, and even nanoscale therapies using the human circulatory system. Despite its growing prominence, multi-

directionality remains ill-defined and underexplored. As such, the phenomenon falls outside the explanatory range of existing frameworks. This study aims to address this notable gap.

With few exceptions, multi-directionality is typically preceded by and evolves from simpler unidirectional business models (Sendall & Küster 2004). Unidirectionality involves the creation and capture of value from transactions that transfer the benefits of goods and services from a producer to a consumer. For example, early personal computers consisted of discrete hardware produced and sold by PC manufacturers for purchase and use by individuals who wanted computers for basic desktop applications such as word processing and spread sheeting. The purchase of a PC thus constituted unidirectional creation and capture of value. Conversely, an individual buying a web-enabled personal computing device today harvests value from the hardware, software, and cloud capabilities while also creating value for friends, family members and countless companies that track his or her "footprints" across the internet through big data analysis and micro-marketing. Access to hardware has become simply one facet of what is now a vast, inter-related network of multi-directional value creation.

From the perspective of both incumbent firms and new ventures, a pressing challenge is how to best capitalize on the shift from unidirectionality to multi-directionality. Extant theory offers conflicting predictions about how these transformations are likely to play out. On the one hand, existing theories related to incremental innovation suggest that large-scale incumbents hold an advantage over smaller, newer firms in extracting value from dominant designs (Tushman & Murmann 1998) through efficient-scale replication of existing technologies, particularly when extant solution sets can be extended into new profit opportunities with minimal modification. (Abernathy & Utterback 1978; Baumol 2004; Utterback, 1994). Accordingly, it may seem

logical that incumbents would make the necessary technological and organizational adjustments to dominate migrations from unidirectional to multi-directional value creation.

On the other hand, despite the proven ability of incumbent firms to draw considerable value from existing technologies through incremental innovation (Utterback 1994), their dominance is far from a foregone conclusion (Hunt 2013; Tushman & Murmann 1998). Existing literature has taken ample note of how ascendant start-ups may challenge incumbents through the rollout of destabilizing technological alternatives (e.g. Dosi 1982; Nelson & Winter 2009; Teece 1986; Schumpeter 1934). For example, Tripsas and Gavetti (2000) examined how digitization fundamentally altered the landscape of the imaging industry, hastening the demise of selected incumbents who failed to embrace emerging technologies. The failure of established firms due to technological disruptions (Christensen 1997) often occurs when the central design logics of a technology's core architecture are reconfigured (Henderson & Clark 1990) in ways that change how value is created and captured (Tushman & Murmann 1998). Accordingly, technological change appears to be both a driver of industry evolution and a key determinant of firm survival (e.g. Agarwal & Gort 2002; Audretsch 1995; Klepper 1997).

From a theoretical perspective, the central role of disruptive technologies in explaining variances in firm performance and survival seems secure (Benner & Tushman 2003; Christensen 1997; Henderson 1993). In actuality, however, the focus on technological disruptions has had the consequence of limiting scholars' consideration of other strategic factors, most notably firms' financial objectives (Beaver 2005). Oftentimes, incumbents sift, sort and select the commercialization of technological alternatives based on the perceived financial impact, not the innovativeness of a given solution set (Agarwal & Gort 2002; Rogers 2010). The reason for this stems from marginal reasoning (Dixit & Stiglitz 1977). Once firms achieve efficient returns to

scale, decision-making logics shift from a focus on aggregate profit to marginal profit, which involves the attempt to fully leverage existing technologies (Coelli, et al. 2005) rather than spawn new ones. The drive to preserve margins leads to restrictive conceptions of opportunities and conservative strategic actions, even when firms possess the wherewithal to dominate new technological paradigms. We have labeled this phenomenon "*the tyranny of marginal analysi*s." Despite a superior capacity to harvest higher aggregate profits through multi-directional value creation, efficient scale firms become "locked into" existing technologies in path dependent fashion (Arthur 2007; Teece et al. 1997) due to self-imposed, self-limiting margin requirements. Under this set of assumptions, the logic supporting incumbent supremacy is inverted, so that smallness and newness are assets rather than liabilities in extracting value from round tripping.

The focal point of our investigation centers on the paradox of incumbency in multi-directionality: that despite possessing insider knowledge, efficient scale and superior resources, incumbents often fail to develop the leading solution sets for multi-directional flows. We pose the following question: Under what conditions would new firms outperform existing firms in developing and monetizing multi-directional solution sets? We address this question using novel datasets drawn from three contexts: (i.) Steamships designed for the U.S. western waterways (1810–1860), which allowed bi-directional portage from New Orleans to Pittsburgh; (ii.) Two-way, satellite-based internet services (1965–2010), which allowed bidirectional flow of broadband content; (iii.) Food waste recycling from restaurants and stores (1995–2015), which is collected for compost to grow local produce that is delivered for sale by the disposal customers.

The findings contribute important insights to the ongoing efforts to understand value creation and appropriation within complex, multi-directional systems, including emerging commercial frontiers in social networking, commercial space travel, distance education, and

medical treatments using nanoscale technologies. Prior scholarship has noted the problems incumbents face in ambidextrously achieving profitable efficient scale at the same time as they seek to develop novel breakthroughs and innovations (e.g. Benner & Tushman 2003; Christensen 1997; Hudson 1997; Tushman & O'Reilly 1996); however, the underlying cause of incumbents' inability or unwillingness to capitalize upon near-certain profits has remained largely unanswered until this paper. By combining studies in economics, strategic management, innovation, entrepreneurship and history, we have developed a novel and potent concept of "the tyranny of marginal reasoning" to explain why and how incumbents are eventually supplanted by newcomers even when incumbents appear well-positioned to dominate.

In the following section, we provide additional context regarding extant theory while developing two hypotheses. After detailing the three novel contexts, our datasets and the methods used in this study, we present the results and conclude by reflecting on the implications for practitioners and the many opportunities our findings hold for future research.

2. THEORETICAL DEVELOPMENT

The theoretical perspective that we develop in this study has roots extending to the work of Schumpeter (1934), Penrose (1959), and Baumol (1968), who variously noted that while the improvements derived from innovation are indispensible to economic growth, innovation is not the same as entrepreneurship, nor does innovation in and of itself generate profits. Rather, profitability arises through efficient returns to increasing scale for firms that have ascended an experience curve (Henderson 1974). Incumbents safeguard extant technologies because it is generally profitable to do so. However, this protective orientation makes incumbents susceptible to two forces that are relevant to round tripping: business model disruptions and the errant use of marginal reasoning.

The Disruptiveness of Multi-Directional Value Creation

An extensive body of scholarship has examined the tendency of incumbent firms to focus on incremental improvements to existing technology once they have achieved high profitability through efficient returns to scale (e.g. Abernathy & Utterback 1978; Baumol 2004; Methe, et al. 1996). Over short periods of time, this approach can be highly effective in harvesting profits from existing innovations (Benner & Tushman 2003). Over longer spans of time, as competing technologies arise, the adverse consequence of incrementalism is that incumbents may be rendered ill equipped to survive the emergence of disruptive technologies (e.g. Christensen 1997). As Danneels (2004) noted, disruptive technologies are often associated with the replacement of incumbents by new entrants. Nonetheless, firms are often unwilling to risk near-term profitability by investing in disruptive activities (Benner & Tushman, 2003; Christensen, 1997). "The short-term certainty of exploitation crowds out exploratory learning and innovation," noted Levinthal and March (1993:682).

The reluctance of incumbents to depart from profitable existing technologies and business models also impacts how they frame their respective responses to multi-directional value creation. Under circumstances in which multi-directionality is merely additive – for example, bus, train and airline passenger travel – then incumbents should thrive because round-tripping enables them to further leverage existing technologies and thereby gain even greater economies of scale. The exact same technology, and approximately the same cost structure, can transport passengers by bus from Chicago to Los Angeles, and from Los Angeles to Chicago. New entrants would be hard-pressed to change the basic calculus other than competing on cost.

However, multi-directionality is often quite disruptive when it requires the development of technologies, organizations and business models than differ markedly from those used to

exploit unidirectional revenue flows. For example, prior to the advent of river-faring steamships, trading companies would use simple barges to drift downstream with the current. Upon arriving at the appointed destination, barges were often disassembled for the lumber or burned since porting an empty craft upstream required up to forty men and three to six months of arduous labor (Hunter 1949). This is a clear example of a unidirectional business model with no future in a multi-directional world since the floatable asset was destroyed after a single use. Companies that excelled in travelling with the current faced entirely new technological and organizational demands in order to profit by moving both with the current and against it (Kane 2004).

Regardless of whether the inability of incumbent firms to thrive or even survive stems from underinvestment and incompetence (Henderson 1990) or novel breakthroughs in the governing technology's dominant design through architectural innovation (Henderson & Clark 1990; Rogers 2010), it is common for extant business models to suffer or even fail when confronted with radical changes in how value is created and captured (Zott, Amit & Massa 2011). For example, the business model underlying the downstream barge industry bore little resemblance to the technologies and organizations that would eventually supplant it through entrepreneurial innovations that exploited multi-directional value creation.

The Henderson and Clark model of architectural innovation attributes the inability of incumbents to heed the warnings of an impending shift in the core technology to "information filters and communication channels that embody old architectural knowledge" (1990:28). In numerous contexts, such as photo imaging (Tripsas & Gavetti 2000), photolithography (Henderson 1993), automobiles (Klepper 1997), and televisions (Klepper & Simons 2000), the central premise of Henderson and Clark (1990) appears to be sound: in each case, incumbent firms screened out vital indicators of a fundamental shift. However, this is not a robust

explanation for the behavior of incumbents facing the migration from unidirectional to multi-directional value creation, wherein the multi-directional opportunity is well-understood and publicly acknowledged by both existing firms and emerging new ventures (Hunter 1943; Kane 2004). The Henderson-Clark formulation appears to be most relevant when emerging alternatives to a dominant design are unknown, unclear, ambiguous or equivocal. The existence of multi-directional opportunities, however, is rarely a matter of debate. Rather, the commercial potential is typically well-understood, even while there may be considerable disagreement about whether profitably scaled, unidirectional incumbent solution sets will be viable in addressing the multi-directional context (Benner & Tushman 2003; Dosi 1982).

Therefore, even when incumbent firms clearly understand the commercial potential of multi-directional value creation, they may be reluctant to act if the opportunity requires incumbents to change technologies or organizational forms. This is not the case for small and new firms (Christensen 1997; Hunt 2013), who are able to address the multi-directional opportunities with few, if any, pre-existing commitments to the dominant design. The classic view of new ventures is that they suffer from two inherent liabilities: smallness and newness (Hannan & Freeman, 1984; Stinchcombe, 1965). The liability of smallness refers to the fact that small firms are resource-poor actors, lacking financial (capital), technological (e.g., research and development [R&D] knowledge), physical (e.g., products, components), and intangible (e.g., market information, new inventions) resources (Hoang & Antoncic 2003; Morris, 2001). The liability of newness refers to the lack of reputation, network ties and legitimacy of the firm (Stinchcombe 1965; Stuart, 2000). Early-stage firms often struggle to attain and maintain credibility in the marketplace (Starr & Macmillan, 1990). These liabilities constitute a significant handicap when multi-directional value creation is largely replicative; that is,

circumstances in which the migration from unidirectionality does not require changes in the core technologies. For example, a newcomer would face formidable barriers in industries geared towards the scaled exploitation of massive infrastructure, such railroads. In addition to the significant capital investment required, new entrants offer no revenue enhancements or cost savings that cannot be exploited more ably by incumbent firms (Benner & Tushman 2003).

Conversely, small and new firms may find themselves on equal, or even preferential footing when the migration from unidirectionality favors significant changes, because they are comparatively unencumbered by allegiances to existing technologies, organizational forms and business models (Christensen 1997; Henderson and Clark 1990). When multi-directionality requires changes in both the dominant technological design and the dominant organizational form, newness and smallness mat become assets rather than liabilities because new entrants are better positioned to develop and market solution sets that embrace new approaches rather than aiming to forestall organizational and technological changes (Benner & Tushman, 2003; Christensen 1997; Danneels 2004; Rogers 2010). In this vein, we predict:

> H1: *Entrepreneurial innovators will outperform incumbent firms in multi-directional value creation when new technologies and organizational forms are required to exploit the multi-directional opportunity.*

The Tyranny of Marginal Reasoning

Round tripping that requires incumbents to invest in novel technologies and organizations runs aground when firms encounter marginal profits stemming from multi-directionality that are lower than the existing marginal productivity of unidirectionality (Sendall & Küster 2004). Margin erosion of this nature can be extremely problematic for incumbent firms. Optimal returns to a production process are most frequently derived using marginal analysis (Baumol & Hall

1977; Beamon 1999; Machlup 1946). Once a firm has achieved efficient returns to scale, diminishing margins typically signify erosion in the efficiency of productive processes (Coelli et al. 2005). Therefore, scaling is a critical facet of shareholder return maximization (Machlup 1946), but more fundamentally, it is also the goal of innovation and R&D investments. Without the prospect of efficient returns to scale, outlays to support innovation are non-rational because it is only through the scaled production of new products and services that innovation serves any profitable purpose (Dosi 1982). For example, even though Apple is widely regarded as one of the premier, design-driven manufacturers of consumer electronics, its gross margins rather than its creativity, are often a central preoccupation of both sell-side and buy-side analysts covering the stock (GuruFocus 2016; Malkiel 1999). Innovative firms are only rewarded for novel breakthroughs to the extent that they can achieve efficient scale production at prices the market will ultimately assign (Coelli, et al. 2005).

It is both understandable and problematic that large-scale incumbents focus on robust margins (Benner & Tushman 2003; Levinthal and March 1993). It is understandable because, *ceteris paribus*, a margin-based focus is consistent with profitability aims. However, technology and organizational forms rarely persist in an unadulterated, unchallenged state for an extended period of time, especially when multi-directionality changes the value-creation, value-capture calculus (Benner & Tushman 2003; Danneels 2004). Applying marginal reasoning frameworks (e.g. Guilding, Cravens, & Tayles 2000), incumbent firms that are faced with the challenges of multi-directional value creation will often seek to implement some permutation of the existing solution sets, rather than venturing into novel alternatives. We call this margin-focused strategic direction-setting "the tyranny of marginal reasoning." Even though aggregate returns may be enhanced through multi-directional models, it is not uncommon for business processes that are

optimized for unidirectionality to exhibit lower marginal returns in a multi-directional context. That is: even though aggregate welfare may be greatly enhanced, incremental returns to scale are diminished relative to the rates of return derived from unidirectional models. For this reason, incumbents may be unwilling or unable to develop and implement innovative solution sets for multi-directional value capture. Instead, innovating entrepreneurs may be the key to facilitating this important source of sustainable development.

H2: *Entrepreneurial innovators will outperform incumbent firms in multi-directional value creation when the marginal returns to multi-directionality are lower than the existing marginal returns to unidirectionality*.

3. MULTI-DIRECTIONAL VALUE OPPORTUNITIES

Up to this point, we have large discussed unidirectionality and multi-directionality in the abstract. We have asserted that newness and smallness may be assets rather than liabilities when the migration from unidirectionality involves significant changes to the dominant technological design, organizational forms or governing business model. Small changes should favor incumbents, while large changes should favor newcomers, but this begs the question: what constitutes small and large changes? Based on the theory we have advanced above, large changes necessitate both technological and organizational changes. Smaller changes should involve either technological change or organizational change or neither. Since some multi-directional conditions may require new technologies but not new organizational forms, while other conditions may require new organizational forms but not new technologies, it is necessary to examine all the possible permutations of technological and organizational disruption. Table 1 provides a roadmap for our proposed rubric.

*****INSERT TABLE 1 ABOUT HERE*****

Scenario 1 involves unidirectional migrations that do not necessitate changes in either the dominant technology or organizational form. This scenario is included for control purposes and is represented by use of the inter-state railway freight industry. Scenarios 2, 3 and 4, each change one or both of these dimensions. Consistent with H1 and H2 above, our proposed theory posits circumstances in which greater change is associated with an increasing presence and success of new ventures. To illustrate the spectrum of potential changes associated with the migration from unidirectionality to multi-directionality, we have gathered data for three distinct contexts: steamships on western U.S. rivers (1810-1860), satellite-based Internet services (1962–2010), and food waste recycling (1995-2015). As indicated in Table 1, each of these three involved different degrees of change.

Steamships on the Western Waterways

Prior to the invention of the steamship, only about 5% of the American population lived west of the Appalachian Mountains, and the mighty western rivers remained an under-utilized resource. Keelboats and flatboats could easily carry goods downstream, but could only travel upstream by tedious, burdensome, and costly methods. The low-grade lumber from flatboats was more often than not simply burned. Keelboats were pulled back upstream, with slaves and immigrants performing this backbreaking work through poling, bushwhacking, cordelling, or warping (Hunter 1943; Kane 2004). A good rate of progress was 12 miles per day (Taylor & David 1951). Fulton and other ocean-faring steamship operators realized the potential commercial opportunity in river-based commerce. However, incumbents were apprehensive of any design that would reduce the compartment space for goods (Haites & Mak 1971; Mak & Walton 1972; Taylor & David 1951), despite facing dramatically different conditions on the rivers. Ocean steamers were substantial crafts that carried large, immensely profitable loads, but

they were perilously underpowered and over-sized for the requirements of river navigation. Instead, new investors and firms emerged that sought to address the round-tripping problem from a fresh perspective.

Two-Way Satellite Internet Service

Early pioneers in communications satellites, who made spectacular profits broadcasting a fixed array of content choices, labored for decades to find ways to stretch the existing business model to incorporate high-speed internet access (Hu & Li 2001). Unidirectional delivery of content optimizes a satellite's marginal revenue generation (Linder, Clausen & Collini-Nocker 2000; Metz 2000). In comparison, the economics of multi-directionality appear at the margin to be unattractive since it involves individual users tying up satellite capacity for idiosyncratic purposes (McKinion,, Turner, Willers, Read, Jenkins, & McDade 2004). There are also critical issues pertaining to contention and traffic monitoring, for which bi-directionality creates exponentially greater technical challenges as well as far higher costs (Obata, Takeuchi & Ishida 2005). Similar to bi-directional river travel, new firms produced novel technologies that were instrumental in making satellite-based broadband financially viable, such as Ka-band spot beams, "bent-pipe" signal reflection architecture, signal amplifiers, attenuation and latency remediators, and ultra-light atmospheric aircraft with onboard solar-charged batteries (Hu & Li 2001; Kuran & Tugcu 2007).

Food Waste Recycling

On average, Americans each annually generate 475 lbs of food waste. In aggregate, this is 70MM tons, nearly 1/3 of the weight-volume in landfills (Council & Hedges 2007; Ghosh et al. 2007). Many states, and most municipalities, favor steps taken to turn food waste into productive compost. Doing so would alleviate landfill space constraints and reduce vermin concerns (Lang 2014). The problem is that for firms that have invested heavily in optimizing the

collection and disposal of unsorted residential and commercial waste, bi-directional value creation looks unattractive. Instead, start-up firms have developed novel process flows that involve collecting food waste, transforming into compost, using that compost to grow local produce, and then selling the produce back to the waste disposal customers (Fehr, Calcado & Romao 2002; Refsgaard & Magnussen 2009). The model has required new organizational structures and the use of aggregate rather than marginal reasoning (Kim & Kim 2010; Parfitt, Barthel, & Macnaughton 2010). New firms have sought to make recycled food waste services the primary service offering, to which the disposal of other refuse has been added, versus the existing model that treated food waste as a disruptive inconvenience.

Control Industry: Inter-State Railway Freight

Freight hauling via inter-state railway systems began in the 1830s, primarily as a supplement to inexpensive hauling via the country's extensive system of canals and by-ways. In unidirectional fashion, downstream shipping via canals was paired with upstream shipping via railroads. Typically, the hauling was supported by separate companies, one for canal portage and other for railroad service. By the 1850s, railway systems were multi-directional, hauling finished goods to the West and returning with raw materials to the East. The multi-directionality was a boon to incumbent railroads, who enjoyed vastly more effective and efficient use of the fixed assets in the migration from unidirectionality. This context, in which neither the technologies nor the organizational forms significantly changed in the migration from unidirectionality, is an ideal industry to use as a control in this study.

4. DATA, METHOD AND MODEL

The centerpiece of our inquiry involves a head-to-head comparison between incumbent firms and new entrants across varying degrees of technological and organizational disruption,

asking: when and how do new and small firms hold an advantage in the migration from unidirectional to multidirectional value creation? Our ability to credibly address our central research question required the use of multiple datasets from contrasting time periods and industry contexts, comprised of technical, operational and financial data. This allowed us to avoid the risk that the social-contextual factors predominating at any given point in time may themselves be the primary driver of observed effects and outcomes. For each of the three contexts, we followed established conventions for differentiating between incumbent firms and new entrants (Evans, 1987; Fritsch and Mueller, 2004; McDougall, Oviatt, and Shrader, 2003; Reynolds, 1987; Reynolds and Curtin, 2009, 2010) by stipulating that new firms needed to be less than five years old and must not have had a major market presence in any other industry prior to commencement of operations in each focal industry. Since our investigation examines antecedents and outcomes surrounding the transformation of unidirectional to multidirectional value streams, the pool of incumbents is generally comprised of firms that were actively engaged in a unidirectional business model.

Data

For steamboat data (1810 – 1860), we drew upon government documents and privately sourced records (Haites & Mak 1971; Hunter 1949; Kane 2004; Mak & Walton 1972) for 510 steamships, owned and operated by 203 different companies. Comprehensive compilations of steamboat economics for the period 1807 – 1868 provide a remarkably detailed accounting of both revenue and costs (Haites & Mak 1971; Hunter 1949; Lytle1952). Costs include craft size, average running time per year, price of wood, daily fuel consumption, labor costs, repairs, wharfage charges and insurance. Revenue data are equally detailed as a consequence of state and federal reporting requirements; these include: shipment manifests, total tonnage, passenger fares

and the value of transported cargo. Wages and fuel constituted approximately 70% of the operating costs, with provisions and administrative outlays making up the remainder. Importantly, detailed estimates have been developed separately for both upstream and downstream travel (e.g. Haites & Mak 1971; Kane 2004; Taylor & David 1951), particularly for companies operating between New Orleans and Louisville.

For two-way satellite interconnectivity (1962-2010), we used data from internet service providers (ISP) and satellite operators (SO), obtained through USPTO, SEC and Dun & Bradstreet databases. The first commercial broadcast satellite was Telstar, developed by AT&T, which went live in 1962. The first residential ISP, The World, was launched in 1989, using wired telephony. From 1962 to 2010 various combinations of satellite technologies and internet service were patented (Hu & Li 2001; Kuran, M., & Tugcu, T. 2007; Metz 2000), involving primarily 168 firms, which were using industry directories and incorporation documents, consistent with prior examinations of market entry and case histories of firm survival (e.g. Baum and Singh, 1994; Caroll and Hannan, 2000; Chen et al., 2011). Financial and operational data for 64 publicly traded firms were obtained through mandatory periodic filings through the SEC. Data for 104 private ISPs were obtained through D&B. Exhaustive documentation on patents granted for military and civilian satellite technologies was extracted through USPTO search engines. From an initial pool of 26,440 patents, 3,418 were identified that are relevant to the confluence of satellite and internet technologies.

The most recent context, involving food waste recycling (1995 – 2015), we gathered data using a survey that was sent to 155 firms operating in the food waste disposal/recycling segment, since only 7 of the firms are publicly traded and there is no effective way to disaggregate food waste costs and revenues from the overall waste handling financials. Definitions and descriptions

included in the survey used taxonomies for food waste and food waste recycling developed through recent studies on environmental management and policy (Fehr, Calcado & Romao 2002; Ghosh, et al. 2015; Refsgaard & Magnussen 2009) Of the 155 firms that were contacted, 117 responded with data that was utilizable in our study. 83 of the firms were classified as incumbents, having participated in waste hauling for an average of 35 years. Only three of these incumbents engaged in food waste recycling. Of the remaining 34 firms, 24 engaged exclusively in food waste recycling, eight handled conventional waste as well as food waste recycling and two disposed of food waste in landfills along with all other refuse. Each firm provided separate, detailed revenue and cost models for food and non-food waste disposal and recycling, where applicable.

The data for our control industry, inter-state railway freight, was drawn from extensive online databases maintained by the U.S. Department of Transportation, Department of Commerce and Department of Agriculture. 134 firms, covering the period from 1835 – 2015, were included in the sample.

Analytical Design

Our analytical design employs a Cobb-Douglass aggregate production function (CDF), modified to take into account returns to innovation (e.g. Dixit & Stiglitz 1977; Kortum 1997; Solow 1957). Through this function, we fully derived the component sources of long-term economic gains, which were regressed in an econometric model that was structured as a head-to-head comparison between entrepreneurs and incumbents. The basic form of CDF is: $Q = AL^{\alpha}K^{\beta}$, where Q is total output, L is the quantity of labor, K is the quantity of capital, and α and β are output elasticities, such that $0 < \alpha, \beta < 1$, and $\alpha + \beta = 1$. While retaining the core CDF structure, we decomposed the capital service function, consistent with Dixit-Stiglitz, to account for the

component contribution of innovations to the productive process. This was done because conventional CDF treats technologies as perfect substitutes, but we placed no bounds on the variety or incremental productive capacity of new innovations in our analysis (Peeters & de la Potterie 2006). The final form of our model (for which the detailed derivation can be provided) is:

$$(1 - I_i) = a + b(k_i - l_i) + cl_i + dT_i + fD_i + gC + e_i \quad \textbf{(1)}$$

In our model, $(1 - I)$ is the log of incremental production attributable to firm-level innovation; $(k - l)$ is the log of physical capital per unit of labor; l is the log of labor units; T is an orthogonal set of codes representing industry-level technological variety across unidirectional and multi-directional contexts; D is an orthogonal set of codes representing the market opportunities for unidirectional and multi-directional value creation; C is a dummy coded variable for firm type (incumbents: 0; new entrants: 1) i represents the ith company for each of the three datasets; e_i represents error terms; and, a, b, c, d, f and g are parameter estimates. Since the sum of the output elasticities always equals 1 in CDF, our model captures the residual component of production (I) that is attributable to innovations that may or may not be operationalized at the firm level.

Predictors

As indicated above, the dependent variable in our investigation is Returns to Innovation (RTI), which is a continuous value for firm-specific productivity calculated as the logged partial derivative of the innovation component from the decomposed capital service function of our CDF. The two focal predictors are (i.) Firm Type, a discrete dichotomous variable for incumbents and new entrants; and, (ii.) Firm versus Industry Margins, a continuous variable represented by the difference of firm margins less average industry margins.

Controls

As indicated in Equation 1, the model also estimates values for labor, industry technology, unidirectional and multi-directional market opportunities. Additionally, we control for known covariates of productivity: time-series data for macro-economic factors (GDP growth), demographics (aggregate population and income per capita); industry population, industry size and industry cohort controls drawn from population ecology (Hannan & Freeman 1977); and, firm-specific effects related to age, size, intellectual capital (patents and citations), executive management experience (years).

5. RESULTS

Table 2 reports the descriptive statistics and correlations among the model variables. Small-to-moderate correlations among the main independent variables in the study suggest that multicollinearity might be an issue in the empirical models. To address these concerns, before estimating the statistical models, we centered all continuous, independent variables. We then calculated the variance inflation factors (VIFs) with the full model reported in Model 6 and all VIFs were below the standard threshold of 10 suggesting that any concerns multicollinearity are resolved. Without exception, the correlation coefficients are consistent with the relationships we have predicted through our theoretical conception of the migration from unidirectional to multi-directional value creation.

*****INSERT TABLE 2 ABOUT HERE*****

The central proposition of our framework is that under certain conditions newness and smallness are assets rather than liabilities in multi-directional value creation. To test the theory, we predicted that new firms would outperform incumbents under two conditions: (i.) when the

shift from unidirectional to multi-directional revenue requires new technologies, organizations or business models; and, (ii.) when analysis suggests that the marginal rates of return for multi-directional profits were less than unidirectional rates of return. The rationale for each prediction is derived from the theory-based assertion that greater levels of technological and organizational change will improve the prospects of small and new ventures vis a vis incumbents. This is expected to occur because incumbents will tend to seek to apply solution sets that leverage existing capabilities, routines and business models (Benner & Tushman 2003; Danneels 2004; Zott et al. 2011). When the changes required to create and capture value from multi-directionality relatively modest, then incumbents will possess the capacity to make small, incremental tweaks to existing systems (Hunt 2013) and thereby stretch existing solution sets to maintain efficient returns to scale. Conversely, substantial changes to the technological and organizational paradigms will make tweaking ineffective and stretching impossible. A summary of the regression results provides strong confirmation of these core assertions (Figure 3).

*****INSERT TABLE 3 ABOUT HERE*****

For each of the three historical contexts and the control scenario both Firm Type and Marginal Returns were significant predictors of the dependent variable, Returns to Innovation. The results provide strong support for H1 and H2, as well as the degree of change predicted by the four scenarios in Table 1. The positive coefficients for steamships, satellite internet and food waste each indicate that new and small firms are situated more favorably within the industry as the greater and greater changes befall a given industry in the migration from unidirectionality to multi-directionality. Importantly, the control scenario using the inter-state railroad freight industry is a negative coefficient. This is precisely as the proposed framework predicts. When incumbents are not required to material alter technologies and organizational forms to capture

multi-directional value, then newness and smallness become significant liabilities. Hence, the negative coefficients. The complete regression results are displayed in Table 4 below:

*****INSERT TABLE 4 ABOUT HERE*****

As the regression results indicate for each of industry contexts, firm type and margin effects are both significant predictors of returns to innovation. Over and above well-established macro, industry and firm-level controls, new market entrants enjoy increasing returns to innovation. Moreover, these returns become more pronounced when the migration from unidirectional to multi-directional value creation and capture is technologically and organizationally disruptive. The comparative ability to harvest returns from multi-directionality is presented in Figure 1.

*****INSERT FIGURE 4 ABOUT HERE*****

This figure demonstrates two stark realities: (i.) incumbents will prevail when they can adapt existing solution sets to new circumstances; and, (ii.) incumbents will, to varying degrees, capitulate when multi-directionality requires significant change. For all except the railroad freight context, returns to innovation – calculated as the partial derivative attributable to firm-level innovation in a multi-directional context -- are, on average, significantly negative for incumbents, indicating existing sources of capital resources are favored to the extent that they extend the marginal returns captured under unidirectional conditions. Meanwhile, new firms derive significant incremental benefit from the technological and organizational innovations they have developed to exploit multi-directional value creation.

It is also evident from Figure 1 that the greater the change, the greater favorable impact on new ventures. Steamships on the western waterways (indicated by the red dotted line) represented the most disruptive scenario, fundamentally impacting core business model elements

involving the dominant technologies and organizational forms. Consistent with our theory, new firms in this industry held a massive advantage over incumbents in harvesting returns to innovation. More modest disruptions to the food waste and satellite industries favored new ventures but in a less pronounced fashion than witnessed in the steam ship context. This "laddered" effect arises as a function of the magnitude of disruption experienced in each industry as a consequence of the migration from unidirectionality.

Meanwhile, in the railroad freight context (indicated by the red line), where the conditions allowed large, efficient-scale incumbents to migrate seamlessly to multi-directionality, there is -- as the proposed model predicted -- a substantial liability to being a small or new venture.

DISCUSSION

Multi-directional value creation is a defining feature of profitable activity systems (Porter 2002) across service and manufacturing sectors. Mega-trend developments, such as those related to globalization, big data analytics, social networking and the monetization of knowledge assets, are continually spawning opportunities for existing firms and new entrants (Agarwal & Gort 2002; Christensen 1997; Klepper 1997). Strategic management scholars have sought to anticipate these developments through frameworks that describe and predict the role of dynamic capabilities (e.g. Helfat et al. 2009; Teece, Pisano & Shuen 1997), ambidexterity (e.g. Tushman & O'Reilly 2006) and technological paradigms (e.g. Henderson & Clark 1990). What is conspicuously missing from extant models, however, are the tools needed to explain why multi-directionality can be a dream come true for incumbent firms, or it can be their worst nightmare. Only by looking at data-rich historical contexts can booms be constructively and reliably separated from the busts.

As the foregoing results suggest, when confronted with disruptive challenges, incumbents will often attempt to stretch existing technologies, organizational forms and business models from unidirectional to multi-directional contexts. In each of the three contexts examined in this study, incumbent firms run the risk of rendering themselves extinct by failing to adapt to the technological and organizational demands associated with the migration from unidirectional to multi-directional value creation In the first two incases – steamships and satellite-based internet services – large-scale, well-resourced incumbents gave way to new and small firms that chose to approach multidirectional value creation as a unique challenge, one requiring novel solution sets that were quite distinct form the systems and capabilities used to derive unidirectional profits. In the third case – food waste recycling – we examined an emerging context in which it is still to be determined as to whether incumbents will adapt and evolve to meet the challenges of multi-directionality.

What makes these three instances particularly illuminating is that in each case the opportunities for multi-directional value creation were well known to the incumbents. However, existing firms attempted to repurpose, retrofit and force-fit extant technologies and organizational forms to the evolving set of circumstances. This was not done out of ignorance of the opportunity. Rather, incumbents relied upon well-proven solution sets in an attempt to preserve the attractive margins that are accrued through efficient returns to scale. Ironically, the marginal reasoning that discourages incumbents from leading multi-directional value creation is a key element in their eventual demise. This is the essence of what we have coined the "Tyranny of Marginal Reasoning." Despite enjoying a significant head start, incumbent firms appear to eschew the enhanced aggregate profitability that accrues to multi-directional value creators. Meanwhile, entrepreneurs, who are comparatively unencumbered by such biases, develop viable

solution sets that endow them with a leadership position in the generation of multi-directional revenue streams.

Limitations and Opportunities

As with all retrospective analyses, this study involves design elements that require careful assessment with respect to robustness. While the three contexts that were selected as the focus of our inquiry are temporally and spatially varied, we knew when we undertook the analysis that each of the three had a rich mixture of incumbents and newcomers. With the benefit of history, we also knew that each involved unidirectional to multi-directional migrations that were turbulent technological transformations, involving expensive decisions that would dictate the long-term fate of each industry. Not all migrations to multi-directionality will be as colorful as theses three, nor will they always favor new, small firms. There are many instances in which incumbents dominated both unidirectionality and multi-directionality. Without apparent exception, these instances involve migrations in which the underlying technology and governing solution sets remain intact, such as inter-state shipping, bus and train travel, and the dissemination of traditional print media. In each of these cases, incumbents were well-served by simply stretching extant solutions to ne circumstances and opportunities. Opportunities abound for follow-on empirical studies that delve into new industries, sectors and technologies to develop increasingly nuanced tests of our theory of multi-directional creation and the strategic impact of marginal reasoning.

From the stand-point of statistical robustness, studies such as the one we have conducted in this paper are prone to the effects of endogeneity. As a safeguard, robustness tests were performed to insure that the results were not subject to the potentially confounding effects of endogeneity and right-side truncation. As with most studies in which both the business strategies

and the outcomes of those strategies are included in the analysis, our research design is susceptible to endogeneity on three fronts: omitted variables, reverse causality, and errors-in-variables bias. To assess the possible presence of omitted variables, we used the Heckman two-step procedure (Heckman 1979). Applying Heckman, we generated an inverse Mills ratio, which was found to be not statistically significant. As for reverse causality, we used lagged time-series variables to confirm the directionality of focal effects (Davidson & MacKinnon 1992). We also performed a Hausman test (1978), which confirmed that the model predictors are not subject to a simultaneity bias.

Conclusion

An unending assortment of sectors and technologies continue to emerge that are typified by multi-directionality: social networking, commercial space travel, distance education, and medical treatments using nanoscale technologies. Although it often seems logical that incumbent will dominate these domains, the odds seem to be against them doing so. As Henderson and Clark (1990) noted, "An architectural innovation's effect depends in a direct way on the nature of organizational learning." It is not uncommon for new opportunities to emerge from reconfiguring technologies within the framework of existing architectures. When this can be accomplished, incumbents will realize a handsome payoff (Henderson 1973). However, when this is not tenable, incumbents who stretch existing solution sets to meet the demands of multi-directional conditions will find themselves ill-equipped to survive entrepreneurial round-tripping, while new and small firms appear likely to flourish.

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Table 1: Predictive Framework for Migration from Unidirectional to Multi-Directional Value Creation

Scenario	Technology for Multi-Directional Value Creation	Organizational Form for Multi-Directional Value Creation	Impact on Marginal Returns versus Unidirectionality	Prediction	Context in this Study
1	=	=	Better margins	Incumbent Firm Domination	*Control Industry*. Inter-State Railway Freight
2	Δ	=	Mixed margins	Mixed. No clear winners	Satellite-based Internet Service
3	=	Δ	Worse margins	New & Small Firm Domination	Food Waste Recycling
4	Δ	Δ	Worse margins	New & Small Firm Domination	River-faring Steamships

Table 2: Correlation Coefficients

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Returns to Innovaiton											
2	Existing margins	*-0.36*										
3	Firm Type	*0.21*	*-0.24*									
4	Tech Embeddedness	-0.03	0.03	0.08								
5	Organizationla Embeddedness	0.02	-0.02	0.10	0.13							
6	Firm size	0.11	0.11	0.11	*0.17*	*0.13*						
7	Firm age	-0.09	-0.06	-0.05	-0.02	0.10	0.4					
8	Macro-Econmic Matrix	*-0.18*	*-0.17*	-0.07	0.01	0.06	0.09	0.02				
9	Socio-Educational Matrix	*-0.16*	*-0.17*	-0.03	0.00	0.04	-0.10	0.01	*0.22*			
10	Industry Pop at Entry	*0.19*	*0.15*	*0.24*	0.09	0.06	0.03	-0.03	-0.10	-0.04		
11	Cohort Population	*-0.17*	*-0.19*	*-0.15*	0.08	0.12	0.11	0.12	*0.14*	*0.22*	-0.09	
12	Governmental Policy Environment	*0.15*	0.11	0.08	0.04	-0.07	0.08	*-0.16*	0.02	0.07	*0.17*	0.05

Italics indicate correlation with p < .01.

Table 3: Summary Regression Results

Context	H1: New Tech & Org Required				H2: Unfavorable Margins			
	Correlation Coeff. for "Firm Type"	p-value	Model F-test	Adj. R^2	Correlation Coeff. for "Margin Δ"	p-value	Model F-test	Adj. R^2
Western Rivers	0.84	< .001	87.4	.71	1.07	< .001	64.1	.55
2-Way Satellites	0.25	< .01	49.3	.50	0.58	< .01	38.8	.41
Food Waste Recycling	0.43	< .01	56.0	.55	1.01	< .001	69.2	.62
R.R. Freight (control)	-0.77	< .01	61.2	.64	-0.98	< .001	74.1	.67

Table 4: Complete Regression Results for Four Migrations to Multi-Directionality

DV: (Returns to Innovation)	Hypothesis	Model 1 Controls Only	Model 2 R.R. Freight	Model 3 Steamships	Model 4 Food Waste	Model 5 Sat. Internet	Model 6 All 4 Industries
Independent Variables							
Firm Type (1 = New Venture)	H1		-0.77**	0.84***	0.43**	0.25**	0.47***
			0.40	*0.31*	*0.28*	*0.16*	*0.22*
Firm vs. Industry Margins	H2		-0.98***	1.07***	1.01***	0.58**	0.56***
			0.45	*0.42*	*0.63*	*0.32*	*0.29*
Firm - Intellectual capital (Patent cit.)		0.38**	0.31**	0.35**	0.27**	0.20*	0.27**
		0.20	*0.11*	*0.19*	*0.16*	*0.11*	*0.12*
Firm - Key Officer Experience (yrs)		0.12*	0.09*	-0.11*	-0.09	-0.09	-0.03
		0.07	*0.04*	*0.07*	*0.05*	*0.05*	*0.01*
Firm Age (yrs)		0.26*	0.33*	-0.23**	-0.15*	-0.13*	-0.17*
		0.16	*0.17*	*0.16*	*0.08*	*0.07*	*0.11*
Firm Size (% of industry presence)		-0.18	0.15*	-0.32**	-0.19*	-0.14**	-0.19**
		0.09	*0.05*	*0.22*	*0.12*	*0.11*	*0.13*
Entry Cohort (avg lifespan)		-0.09	-0.03	-0.05	0.07	-0.13*	0.03
		0.06	*0.02*	*0.03*	*0.04*	*0.07*	*0.01*
Industry Growth Rate (%)		0.11	0.10*	0.21**	0.19*	0.23**	0.17*
		0.07	*0.05*	*0.08*	*0.06*	*0.12*	*0.12*
Indus Size / Indus Pop (Avg presence)		-0.17*	-0.22**	-0.17*	-0.15*	-0.27	-0.20
		0.12	*0.08*	*0.13*	*0.09*	*0.18*	*0.13*
Indus Population at Entry (#)		0.15	-0.22**	0.25	0.28**	0.22	0.23
		0.08	*0.12*	*0.08*	*0.14*	*0.16*	*0.18*
Industry Size ($ Revenue)		-0.14*	-0.18*	0.13*	0.09	-0.03	-0.04
		0.09	*0.12*	*0.08*	*0.04*	*0.01*	*0.01*
GDP Growth Rate (%)		0.13*	0.11	0.24**	0.16*	0.18*	0.19*
		0.03	*0.03*	*0.09*	*0.04*	*0.04*	*0.05*
Year Dummies		Incl	Incl	Incl	Incl	Incl	Incl
(Constant)		Incl	Incl	Incl	Incl	Incl	Incl
Adjusted R^2		0.35	0.64	0.71	0.55	0.50	0.64
ΔR^2 (vs. Controls only)		-*-	0.29	0.36	0.2	0.15	0.29
F-Value* - Full Model		128.7	149.1	137.5	158.8	161.0	146.3
*D.V. is Returns to Innovation *** p < 0.001, ** p < .01, * p < .05*							

Figure 1: Comparative Returns to Innovation – New Firms versus Incumbents