EXPLAINING THE DYNAMICS OF THE INDUSTRY LIFE CYCLE: SIGNAL BASED COMPETITION IN MULTI-ATTRIBUTE PRODUCT SPACE

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Abstract
The industry life cycle (ILC) model "is so widely accepted and its basic premises so taken for granted that it has become conventional wisdom" (McGahan, Argyres et al. 2004).

The ILC is a stylised characterization of observed regularities of how industries evolve from the initial development of a particular product, through the development of a mass market to a mature and stable industry. It is a model of industry behavior over time which provides insight to researchers, managers and policy actors. However, the theoretical underpinning for these dynamics is as yet incomplete (McGahan, Argyres et al. 2004), as there currently is neither an explanation of the observed regularities, nor a solid explanation why some industries do not follow the standard ILC model. Why is this so? One reason is that at the heart of the ILC is a focus on products, their development, production and sale (Barras 1986). While this product focus provides a powerful lens allowing empirical reality to be abstracted to a more conceptual level, it may miss the disparate factors that explain how actors coordinate their actions in an evolving, uncertain and dynamic environment. We argue that another more serious issue is that changes in the selection environment have not been fully elaborated. To deal with this, the paper draws on the signaling literature to explain the observed changes in coordination and actions in an ILC over time.

Signals refer to the communication that transmits information between the actors in a particular economic system characterized by information asymmetry allowing for coordination of actions, including competition. Signals are used in neoclassical economics to allow coordination when information is asymmetric among actors (Akerlof 1970; Spence 1973). From this perspective, signals are defined as "a form of credible communication that transmit information from sellers to buyers" (Bergh and Gibbons 2011: 546). This specifies signals, in neoclassical theory, as being useful analytically where a seller can communicate false information (deliberately or unintendedly) to a buyer (Kirmani and Rao 2000) in an attempt to alter the equilibrium situation to their advantage, or the situation is beyond the information processing abilities of the actors involved. However, if we introduce true uncertainty (Knight 1921), that people are not rational decision makers in the economic sense (Loasby 2002), that economic dynamics involve systems of multiple actors (Freeman 1991), and that the economic system is a discovery process (Hayek 1945), characterised by economic experiments (Rosenberg 1992) then we find a different and wider role for signals. Signals then involve communication that transmits information between the actors in a particular economic system. From a heterodox economic perspective, signaling is how a sender, often but not always the seller, tries to influence the decision making of the receiver.

To analyze how signals affect the industry life cycles, we introduce the concept of multi-attribute product space (MAPS), which is the informational space defined by a product’s set of attributes (Lancaster (1966)). Products are viewed as purchased for ‘what they do for customers’ rather than the technology or design that underlies the product. Products constitute an assembly of attributes; such as ability to perform a task, shape, colour, cost and so on. Thus, customers understand
product attributes through signals, and derive the value of the product through comparison with competing products and the social situation via signals from MAPS. Firms interact with a range of actors in developing and producing their products; including suppliers, researchers, competitors, intermediaries and customers. Firms know which attributes to structure in the product because they learn from the signals observed in the industry MAPS. They use this understanding to guide their innovation and interaction with other actors in developing, producing and selling their products. Firms also try to influence the industry MAPS, by sending signals that other actors observe and use to derive their understanding of the MAPS.

The signal literature stresses that the signals that are useful for the sender are the ones that are perceived as reliable by the receiver, and that are costly or hard to imitate. Hard to imitate signals (HIS) include, expensive advertising or brands, track record, reputation, or standards. Actors including the competing firms, suppliers, customers, innovation intermediaries and institutional actors such as government observe the signals in the MAPS. These actors may try to influence the MAPS, or use their understanding of the MAPS to improve their position. For example, a supplier may improve their ability to sell into the industry by understanding what customers value about particular product attributes. Another example is the common action of government in providing rules and regulations about the reduction of hazards to society.

We use signals to account for the observed regularities in the ILC, and to explain why some industries do not follow the ILC. For each of the three phases of the ILC (Abernathy and Utterback 1978; McGahan, Argyres et al. 2004) the paper explains how signaling affects the ILC by discussing why industries may get stuck in certain phases, and why industries move from one phase to another. Our contribution is to provide a signal based lens that explains the observed dynamics in the ILC, and explains why some industries do not follow the ILC.

**Key Words:**
Competition
Evolutionary economics
Signals
Products
Industry life cycles
INTRODUCTION

The industry life cycle (ILC) model “is so widely accepted and its basic premises so taken for granted that it has become conventional wisdom” (McGahan, Argyres et al. 2004).

The ILC is a stylised characterization of observed regularities of how industries evolve from the initial development of a particular product, through the development of a mass market to a mature and stable industry. It is a model of industry behavior over time which provides insight to researchers, managers and policy actors. However, the theoretical underpinning for these dynamics is as yet incomplete (McGahan, Argyres et al. 2004), as there currently is neither an explanation of the observed regularities, nor a solid explanation why some industries do not follow the standard ILC model. Why is this so? One reason is that at the heart of the ILC is a focus on products, their development, production and sale (Barras 1986). While this product focus provides a powerful lens allowing empirical reality to be abstracted to a more conceptual level, it may miss the disparate factors that explain how actors coordinate their actions in an evolving, uncertain and dynamic environment. We argue that another more serious issue is that changes in the selection environment have not been fully elaborated. To deal with this, the paper draws on the signaling literature to explain the observed changes in coordination and actions in an ILC over time.

Signals refer to the communication that transmits information between the actors in a particular economic system characterized by information asymmetry allowing for coordination of actions, including competition. Markets act as communication systems transmitting the information that provides the basis for decision making by all actors (Galtier, Bousquet et al. 2012). Signals are what allows this communication, and so coordination to occur. The concept of signals is used in neoclassical economics to allow coordination when information is asymmetric among actors (Akerlof 1970; Spence 1973). From this perspective, signals are defined as "a form of credible communication that transmit information from sellers to buyers" (Bergh and Gibbons 2011: 546). This specifies signals, in neoclassical theory, as being useful analytically where a seller can communicate false information (deliberately or unintendedly) to a buyer (Kirmani and Rao 2000) in an attempt to alter the equilibrium situation to their advantage, or the situation is beyond the information processing abilities of the actors involved. However, if we introduce true uncertainty
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that economic dynamics involve systems of multiple actors (Freeman 1991), and that the economic
system is a discovery process (Hayek 1945) characterised by economic experiments (Rosenberg
1992) then we find a different and wider role for signals. Signals then involve communication that
transmits information between the actors in a particular economic system that allows coordinated
action. From a heterodox economic perspective, signaling is how a sender, often but not always
the seller, tries to influence the decision making of the receiver. Signals can be deliberate, such as
advertising, or unintentional as when customers prefer one of several competing firms’ products,
thereby sending signals to all firms about the set of product attributes most customers prefer.

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may improve their ability to sell into the industry by understanding what customers value about
particular product attributes and so enhance their input to the industry to improve product
attribute/s valued by final customers. Another example is the common action of government in
providing rules and regulations about the reduction of hazards to society.

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industries do not follow the ILC. For each of the three phases of the ILC (Abernathy and Utterback
1978; McGahan, Argyres et al. 2004) the paper explains how signaling affects the ILC by
discussing why industries may get stuck in certain phases, and why industries move from one
phase to another. Our contribution is to provide a signal based lens that explains the observed
dynamics in the ILC, and explains why some industries do not follow the ILC.

We commonly use the automotive industry as an example following common practice in the ILC
literature (Klepper 1997:147), however other industries are also used as no single industry covers
the range of dynamics found in the ILC literature. Our goal in this paper is to develop a single
conceptual lens on the observed dynamics of the industry life cycle and thus deepen our
understanding of the actual evolution of industry. Explanatory models and theories are useful in
allowing researchers and practitioners to go beyond brute empirical facts and to develop broad
ranging and clear explanations and policies.

In the next section we look at the ILC literature, followed by a discussion of the literature on signals
in economic theory. The next section is the core of the paper using our model to explain the
observed regularities in the ILC. Following that we present a discussion section, then the
conclusion.
INDUSTRY LIFE CYCLES

A large number of detailed empirical studies have shown regularities in the evolution of many industries. Typically ILC work follows industries as they increase in scale, whether of number of products sold or the volume of monetary sales. Over time scale increases and commonly an S shaped curve is seen. Initially sales growth is slow and scale is very low. At some point growth ‘takes off’ and the scale of the industry grows rapidly. Another inflection point is reached and volume growth slows and can tend towards zero or even reduce over time, causing a shakeout in the incumbent firms. These three phases in the standard ILC S curve form the basis for the three phase model we use in this paper, and other ILC researchers use (Utterback and Abernathy 1975; Abernathy and Clark 1985; Klepper and Graddy 1990; Afuah and Utterback 1997; Klepper 1997; McGahan, Argyres et al. 2004). These three phases are the fluid, transition and mature phases.¹

In the fluid phase the industry is fragmented, with uncertainty about how to improve the product and what customers really want (Klepper 1997; McGahan, Argyres et al. 2004). Both firms and users experiment in trying to find ways to develop a more valuable product. As a result, many firms producing different variants of the product enter the market and competition focuses on product innovation. This uncertainty and experimentation leads to many firms having to incorporate the production of inputs by vertical integration using ‘unspecialized machinery’ (Klepper 1997: 148). The end of the fluid phase is when a particular set of technologies in a specific product architecture emerges that many customers find valuable and firms can produce at a profit and scale up – termed the dominant design (Abernathy and Utterback 1978; Saviotti and Metcalfe 1984; Anderson and Tushman 1990; Suarez and Utterback 1995). The start and end of the fluid phase are accordingly nebulous, as it is unclear when a ‘new’ product and a DD actually exist.

The transition phase is a period of growth driven by ongoing increases in demand for the product as defined by the DD (McGahan, Argyres et al. 2004: 3). The DD leads to an increasing number of customers perceiving that the product is legitimately of value and so enter the market, increasing demand. Initially the number of firms increases, then drops as entry decreases and exits increase. Innovation thus moves from a product focus toward a process focus as efficient operations become essential to survival. However, product innovation tends to be within the confines of the DD, and firms not producing the DD either change over or exit. Toward the end of the transition phase market growth slows, or even stalls, and does not recover, leading to a major shakeout. Associated with the stability of the DD, increased legitimacy and increased scale is the emergence of complementary products, such as “gas stations to service gas combustion cars” (Klepper 1997: 150), and specialised suppliers and intermediaries (Johnsen, Phillips et al. 2006).

The mature phase occurs when industry growth ceases or slows dramatically meaning that only the most efficient and best positioned firms survive. Market shares stabilise as the established firms occupy well specified competitive positions and barriers to entry increase (McGahan, Argyres et al. 2004). Innovation moves to being incremental in both product and process, with an focus on productivity improvement (Klepper 1997; McGahan, Argyres et al. 2004). Suppliers become more deeply involved, often taking some of the design and production roles from the central firms (Johnsen, Phillips et al. 2006). Customer preferences are stable and finely detailed regarding the product architecture.

Sometimes the scale of the industry reduces over time during the mature phase, which can be thought of as a decline phase. Alternatively, sometimes an innovative new product that performs much the same functions as the existing product comes into competition, and over time it can disrupt the industry, either taking some of the market or even driving the existing firms out of business (Christensen 1997).

These stages involve quite different competitive and technological dynamics. The same firm organisation can facilitate or hinder innovation at different life cycle stages (Koberg, Detienne et al. 2003). Sometimes even minor changes in the architecture of the product can be difficult for some firms to adapt to, even causing exit from the industry (Henderson and Clark 1990).

Because the ILC model is an empirical derivation from observed behaviour in many industries a theoretical explanation for what is, and is not, observed in those industries does not yet exist (McGahan, Argyres et al. 2004). This explanation needs to be based on a common underlying driver of behaviour in all industries. Common factors discussed in the literature are technological change, scale economies and competition. Technological change is often not industry specific and so is a difficult fit to the ILC for individual industries. Scale economies require an explanation for why they sometimes do not occur, and so rely on a deeper causal logic. Competitive dynamics are industry specific, involve both technological change and scale economies, and are a causal factor in all competitive industries that the ILC is based on. Competition is thus a useful lens to understand why the ILC occurs as it does.

**SIGNALS IN ECONOMIC THEORY**

Signals are used as an important factor across a wide array of economic and business theory. In economics signals and the ability to accurately understand signals is an important issue used to explain why theory and reality fit so poorly so often. The 2001 Nobel Prize was awarded to Akerlof (1970), Spence (1973; 2002), and Stiglitz (Grossman and Stiglitz 1976; Stiglitz 2001) for modelling the effects of not everyone having access to the same information. In general, it is acknowledged that if signals are not available to and easily understood by all then markets will not behave in a ‘pure’ equilibrium manner. Furthermore, issues such as bounded rationality (Simon 1955) and whether a network is fully connected (Potts 2000) influence how markets are understood by the participants. Information gathered from signals, and the desire for information, is not fully rational, but often is symbolic and connected to mental models (Fieldman and March 1981).

Riley (2001) reviews the economic literature on signalling showing that the introduction of this concept in the 1960s and 1970s provided “clear explanations of a wide range of economic phenomena, where formerly there were just puzzles” (op cit: 474). Without the concept of signalling, and the associated theories around asymmetric information, standard economic models simply cannot explain many commonly observed features of the economic world. To introduce signals into economics without destroying the underlying models it was necessary to limit their applicability to the case where agents had differential access to information, that is information is asymmetric between actors. Once information is asymmetric equilibrium can be distorted from a pure marginal cost / marginal price calculation because some actors can present the impression that the marginal situation is other than reality. Thus, theories based on signalling can explain situations unable to be explained by a pure neoclassical economic analysis.

There is a considerable literature looking at signals in regard to specific issues in the economics and business literature, with some studies examined below. The affect of advertising as signals on markets has been investigated in economics (Nelson 1970; Nelson 1974; Kihlstrom and Riordan 1984; Williamson 1985; Milgrom and Roberts 1986). Competitive market signalling, where firms signal to one another in an effort to influence competitor behaviour has also been studied (Heil and Robertson 1991). Another signal based issues is how firms can signal the value of their internal information resources without actually making public this knowledge (Ndofor and Levitas 2004). The valuation of firms is affected by the race and education of senior management (Sauer, Thomas-Hunt et al. 2010). How a product is priced sends signals that affect purchase and use behaviour beyond the specific effect of the price level (Gourville and Soman 2002; Heffetz and Shayo 2009). Several other specific signal based issues have also been investigated in individual studies.
Once the transmission of information becomes important for economic analysis a definition of signal becomes important. Signals are often defined as "a form of credible communication that transmit information from sellers to buyers" (Bergh and Gibbons 2011: 546). In neoclassical theory signals are useful analytically where a seller can communicate false information (deliberately or unintendedly) to a buyer (Kirmani and Rao 2000) in an attempt to alter the equilibrium situation. This implies there is no Knightian uncertainty where people simply cannot put a probability distribution to outcomes that allows mathematical analysis as per the standard models (Knight 1921). Additionally, the standard economic analysis assumes some variant of rational decision making, despite research showing people are not rational decision makers in the economic sense (Loasby 2002). Further complicating the subject of signals in economic analysis is that economic dynamics involve systems of multiple actors (Freeman 1991) involved in an experimental process (Rosenberg 1992) of discovery (Hayek 1945) rather than a process of finding an underlying truth. Signals, in this heterodox view then become the fodder that feeds peoples’ imaginations and sensemaking (Weick 1995) that drives their decision making and so economic dynamics. In our view signals involve communication that transmits information between the actors in a particular economic system, without there necessarily being an underpinning ‘truth’, and the meaning of information is socially embedded (Feldman and March 1981). From a heterodox economic perspective, signaling is how the actions of a sender, often but not always the seller, produce information that may influence the decision making of the receiver.

A MODEL OF SIGNAL BASED THEORY OF COMPETITION IN MULTI ATTRIBUTE PRODUCT SPACE

We focus on signals because signals provide the information from which all actors make decisions, and so are the glue that holds together an industry’s dynamics. Competition in an industry requires that the competing firms, the pool of customers, and other actors all have information about one another to base decisions on. This information results from analysis of the various signals sent by the interacting parties. That is, without signals there is no interaction and thus no competition. Signals are therefore the central feature of a competitive setting, binding the various parties together. By using the lens of signals we intend to get at the heart of industry evolution.

Everything and every action sends out signals of various types, so we must distinguish between what matters and what doesn’t. The signals that matter in competition are those that are hard to imitate because signals that are easy to imitate mean that firms cannot differentiate themselves and so are not the basis for either superior competitive performance in either the short or longer run. Hard to imitate signals (HIS) provide firms with the basis for sales that are more profitable as against competitors. Thus HIS are at the heart of competition. It is the generation, imitation, transmission and understanding of these HIS that is the motive force in competitive dynamics.

Competition occurs in multi attribute product space (MAPS) because people buy products for their attributes (Lancaster 1966), and thus to gain the necessary income to survive a firm must produce product attributes valued by customers relative to competitors’ product attributes. Therefore, we can think of the market at the centre of an industry as being composed of a space defined by the attributes of the product group being produced. On the supply side product attributes are derived from the technical characteristics of the product. On the demand side product attributes are derived from what the product does for the customer. So, the engine, drive train and wheels of a car produce the attribute that the car can move and manoeuvre under its own power. As with most products cars have multiple attributes, and it is on the totality of the product attributes that purchase decisions are made. Customers will have differing preferences for the various attributes. For example, in cars some people will highly value power and handling and give little weight to carrying capacity, whilst others will more highly value carrying capacity and care only that the power and handling of the car are adequate for the intended use. Firms therefore compete in a space characterised by multiple attributes of the product, with differential weight given to the various attributes by customers in their purchase decisions. The core of competition is the sending,
receiving and comprehending of signals, and that these signals are primarily about MAPS and the ability to compete in that space. Simplifying, to producers (firms) and users (customers), the MAPS for a particular product group defines what signals are of value and what configuration of signals provides differentiation between products. Customers use socially mediated mental models of what provides them with value and how much to pay for the product, and thus what variants of the product they would prefer to buy (Devetag 1999; Loasby 2001). We thus model customers as social groupings that have collective, but heterogeneous, preferences for the product and the competing firms’ variants of the product, understood through patterns of signals within MAPS. Similarly, firms develop mental models of what the product is and how to best compete within the MAPS. We know that managers’ mental models affect firm decisions and actions and so the performance of firms (Gary and Wood 2011). Firms thus face the problems of understanding what makes the product saleable, how to best improve the saleability of their product as against their competitors, and how to do this most efficiently. By observing signals from customers, competitors, input suppliers and other pertinent actors firms comprehend the current state of the MAPS, can envisage future MAPS, and discern ways to improve their product value and operational efficiency. Firms therefore have incentives to develop HIS of product value whilst improving operational efficiency. This leads firms to innovate in terms of product, process and organisation.

Customers only receive the signals sent by firms after the signals have moved through various channels; products on store shelves, word of mouth recommendations, advertising and other promotion, and recommendation by independent experts. Firms can thus shape the relativities of product signals through trying to influence the channels signals move through. Once customers, potential and actual, receive the signals they must then interpret them to arrive at an understanding of the product’s relative value. This is done using the customer’s lifestyle as a basis (or operations if the customer is an organisation), and comparing each product to its direct competitors. Decisions tend to be made within mental models influenced by peer groups, thus meaning purchase decisions are often social in nature rather than arrived at by atomistic customers. This allows each customer to place a value on the product in each time and place. Purchase decisions are arrived at through a consideration of the perceived product value versus the customer’s budget constraint. If the products value/price tradeoff is greater than competitors and within the budget constraint then the product will be purchased. Although simplistic, this model captures the core of how purchase decisions are made, and thus what firms have to do to gain income.

Competition in our schema is a dynamic process driving innovation and evolution of the selection environment. The competing firms produce products that they submit to the market. In doing this the MAPS is created. Customers scrutinize the signals from the attributes of the products competing in this market and make purchase decisions. The outcome of this is the dynamics of the selection environment, whereby firms incur costs to produce their products and earn income from product sales. Over time firms will be driven from a market if they cannot make a profit. Thus, once firms get feedback from signals from the selection environment they respond by innovating and/or imitating in some way. Signals derived from competitors’ products are clearly visible, along with customer responses to these products. The processes of competitors are partially visible to each other, because each firm produces an analogous product it has a good ability to understand what competitors are doing. Competitor organisation is more difficult to observe, but firms can gain some insight through industry events, interpersonal networks and people who have worked for competitors. Competing firms observe one another through available signals, and this influences managerial behaviour and how the firms innovate. This then leads to changes in MAPS and the selection environment, and so on in a continuing process of coevolution driven by competition. Throughout this dynamic competitive process firms are sending and receiving signals, acting on their understanding of these signals and developing strategies. It is through HIS that firms develop and retain a competitive advantage; whether derived through product attributes, production processes or organisational structures enabling efficient production and innovation.

Because of the lack of clarity regarding signals and their interpretation, firms only learn the actual meaning and value of their actions after they try out innovations by conducting economic
experiments (Rosenberg 1992; Johansson 2010). Customer understanding of signals coevolves over time with product innovations and social and organisational change, endogenously changing the nature of the MAPS from the demand side. Thus, taking a signal based view we can expect firms to continuously experiment in trying to develop HIS of product value and HIS of operational effectiveness and efficiency.

**THE INDUSTRY LIFE CYCLE AS EXPLAINED BY SIGNAL BASED COMPETITION IN MULTI ATTRIBUTE PRODUCT SPACE**

In this section the three phases of the ILC explicated previously are examined in the light of signal based competition in MAPS. We focus on the competitive dynamics underlying each phase, the transitions between phases and why some industries get stuck in certain phases.

**Fluid phase**

The fluid phase starts when a new product class is established with concomitant producing firms, customers and market. In the fluid phase products are highly differentiated and serve niche markets, and there is uncertainty both about what customers really want and how the product can improve. Both kinds of uncertainty make it hard for firms and customers to definitively say what the best path of development is. That is, in this phase the MAPS is being developed, with conjoint learning by the firms and customers about what attributes make the product valuable, how and why, and how best to produce these attributes. In this fluid phase firms interact with customers to understand their needs and how best to serve them. Concurrently firms develop the product with the aims of 1) having a viable product (a product customers will buy for enough to keep the firm in business), 2) having a path for future development given what is known of the product and technology/ies underlying it and 3) how best to produce the product with the aim of reducing cost and increasing product saleability. In this phase firms are trying to understand the signals in a complex and changeable MAPS, and develop a set of product attributes that meet customer needs and allow profitable operation.

Industries start when some new product is developed, sometimes completely new, sometimes disrupting an existing industry. “In cases of a completely new product, learning-by-doing on the part of the consumer is as important as learning-by doing on the part of producers” (Mokyr 1990: 130). In the case of a new product disrupting an existing industry the new product tends to serve niche interests and slowly improve relative to the existing product (Christensen 1997). Over time a new product can eclipse the old product, or sometimes the products serve related, but different customer groups. An example of the formation of the concept of the product is in the early stage of the automobile when steam powered and internal combustion engines competed. The major advantage the internal combustion engine had was that it had the attribute of starting and stopping rapidly as compared to the slow start up of a steam engine (Mokyr 1990). As products are an assembly of attributes selection occurs on both the individual attribute and the array of attributes as a whole. There is thus a to and fro of firms altering the signals their products produce through the architecture of their product’s attributes. In the fluid stage firms have close interaction with customers, often co-soloving problems. This leads to firms getting robust feedback as to what their product attributes signal to the customer and how the customer understands these signals and their value. That is, the fluid stage is about economic experiments aimed at understanding how to create value for the customer. By observing competitors’ actions firms are able to vicariously learn from others’ economic experiments.

In the fluid phase the focus of competition is about understanding how to create a valued pattern of signals around the product itself. This is essentially a process of understanding what attributes, and in what product architecture, customers gain enough value so that the firm can profitably produce the product. Firm HIS are therefore about the ability to produce a product valued by specific customers, and customer HIS are the willingness to purchase and co-produce the product.
Augmentation of the product (e.g. advertising and branding) and optimising production are secondary issues to finding what sells. At this stage there is no scalability of HIS because interactions are primarily through dyads rather than generally broadcast. Throughout the fluid phase the idiosyncrasy of firm offerings and customer demands means that the focus is on distinctive product variants. Price is an important signal in the fluid phase, but is more negotiable between parties due to the co-production of the product and uncertainty about what product attributes are actually important.

Customers have some need that the product meets, but haven’t yet worked out what is the best package of product attributes to fulfil their needs. Use of the product provides signals as to what the product attributes actually do, and so what is valuable about the product and how best to use the product. Firms need to decipher customer needs from the signals derived from customer use and translate that understanding into product attributes (Afuah and Utterback 1997). This sensemaking process (Weick 1995) from customer feedback is central to learning to compete in the fluid phase. The most important customers are lead users, who actively take a role in developing the product (Von Hippel 1988; Morrison, Roberts et al. 2004). This leads to active user-producer interaction (Lundvall 1988; Fagerberg 1995) and learning by both parties. At this stage many signals are HIS because there is such active learning and little standardisation. Each product is a learning experience for the firm and customer. As the firm and customer learn about how the product attributes provide value, conjectures are developed about how to improve the product’s value. When firms develop products based on these conjectures and customers use the newly changed products all parties learn. Because the product is not yet standardised and so production methods constantly change in the fluid phase the focus is “on those capabilities that allow one to determine what features to include in the product” (Afuah and Utterback 1997: 196). Because of the many experiments in the architecture of the product’s attributes, signals in this stage are often too fluid for stable suppliers, intermediaries or institutions to arise.

Given the uncertainty in the fluid phase about the product’s attributes and how to create value there are strong incentives for entry by new firms. It is extremely difficult for incumbents to erect barriers to entry, because the fluid state makes signals unclear as to their importance. These new entrants may be de novo firms pursuing a novel conjecture about how to compete in the nascent industry. The entrants may be firms diversifying into the industry from a related or unrelated industry. Related diversifiers have established capabilities to produce product attributes and thus specific signals. Unrelated diversifiers may enter the industry because they feel it is potentially an attractive market, and try to build the required capabilities themselves or acquire firms with the required capabilities. These new entrants result in an increased range of product features being developed for the product and thus more economic experiments being conducted.

As the fluid phase continues, the pattern of signals often starts to stabilise and an understanding of the product attributes that are valuable emerges. Some suppliers and intermediaries may start to develop specialised capabilities because they can understand the signals given off by the firms and customers. This leads to increased legitimacy of the product, firm, and industry as a wider audience can perceive the existence of a product valuable to many people.

Certain industries get stuck in the fluid phase because signals do not settle on a stable pattern that is associated with better performance. That is, no DD emerges and so no scalability of HIS in possible. For example, many large construction projects are one offs with a team assembled for each project. The firms involved learn how to assemble the right mix of resources and capabilities for each job. Each product, a large construction, is unique to some extent and firms compete by being able to interpret how best meet the project’s scope in a profitable way. In this sort of industry firms are always reinventing themselves, often using loose coalitions of partners in the case of construction.
Shift from the Fluid to the Transition phase

An industry shifts from the fluid phase to the transition phase when a DD and a growth market emerges allowing increases in scale and routinisation of production. This occur when the pattern of signals stabilise around a product architecture (the DD) that signals to a large group of potential customers enough value that they will buy the product for a high enough price for the firms to be profitable and invest in increasing scale. These signals come from the product itself, marketing and especially word of mouth recommendations by existing customers that the product is fit for the purpose and worth buying. The DD must signal a large potential market, that the product architecture is producible at a profit, and that the product can be developed further to give the firm some advantage. For the firm the signals are thus market, technological and competitive. The DD provides a template for production and product development for firms because the pattern of signals derived from the DD is stable and understandable.

This means the shift from the fluid stage to the transition stage is when the industry’s MAPS is stable and understood by both producers and customers. The MAPS now most likely corresponds to a stable set of technologies and production methods. Firms that do not adapt their mental models to the stable MAPS will continue to invest in experimenting with the product architecture. Firms that succeed in shifting to the transition stage will adjust their sensemaking to be based on the DD and associated MAPS. To survive firms must send out signals that they can profitably produce the DD.

The DD itself constitutes a HIS, as it is the array of product attributes that both fulfils the needs of a large group of customers and is economically viable. Firms that learn to produce the HIS of the DD can viably scale up and compete, those that cannot will not be competitive. Competitors, customers and resource providers will pay attention to the signals of the ability to produce the DD and will perceive the competence of the firm according to this set of signals. When the firms and customers are convinced that the DD signals an increased market both start to increase their scale of activity. This leads to increasing returns and economies of scale.

Transition phase

Once a DD emerges the industry grows until demand is satiated and the industry matures. In this transition phase firms send out HIS of 1) growth in production volume, 2) improvement of the array of product features in the DD, and 3) reduction in the price of the product. From a signals perspective the transition phase is best thought of as having two periods. Initially the stability in the MAPS is associated with market growth as new customers enter to purchase the proven product and so firms learn mental models of growth within a path defined by the evolution of the MAPS. Toward the end of the transition phase market growth tails off as potential new customers grow fewer, whilst firms still perceive overall market growth.

The DD is a stable architecture of product attributes that defines the MAPS and clarifies the situation for producers and customers, and allows others to specialise in aspects surrounding production, marketing, exchange and use of the product. Because increasing purchases of the product are a HIS of customer commitment firms invest in scaling up production. To be an above average performer in the growing sector each firm needs to convince its customers that its product has a better value/cost offering than competitors. This provides incentives for economic experiments by firms to refine the core DD product attributes, and to experiment with introducing new attributes. That is “in the transitional phase attention shifts to how to improve the values of those features” (Afuah and Utterback 1997: 196). Firms also look for ways to improve operational efficiency, developing their internal production operations, distribution and service networks and marketing of their product (Afuah and Utterback 1997). From the signal perspective price reduction is due to both the cost reducing affects of economies of scale and associated learning, and the fact that customers can now more finely judge the relative value of competing product offerings and thus price premiums are reduced. The ongoing increase in demand during the transition phase
allows some firms to survive in niches in the industry MAPS. There are ups and down in the growth of demand in the transition phase, after a cessation in demand growth picks up again. Thus, over this transition phase there will be a winnowing of less competitive firms, whilst some firms can survive in niches.

The nature of the customer base changes through the transition phase, from active and experimental to more detached and conventional. This is due to the signals in the MAPS stabilising and becoming legitimated, supporting the entry of new customers. In the fluid stage customers had a particular need for the product, and so were willing to be active in investigating how the product could be tailored to them. As the DD has emerged and the industry starts to grow rapidly these active customers have their needs satisfied and become less active. New customers enter who have less desire to be actively involved in shaping the product but strongly feel the need for it. Later customer entrants require signals that the product will reliably have certain attributes and that value for money is proven. Thus, by the end of the transition phase customers have transformed in their interaction with MAPS from actively co-producing the product, and thus signals about the product, to relatively passive customers. This stability in the MAPS and the change in customer attitude and interaction with firms leads to a greater emphasis being placed on price as a signal.

The DD and increased market scale signal to investors and new entrants that this is legitimately a potentially lucrative arena for action. Investment in firms in the industry by others signals to potential new entrants, customers, suppliers, intermediaries and other actors such as government that this is a legitimate area of increasing importance. Potential entrants assess the various signals of demand growth and competition and the difficulty in profitably making the product and decide whether to enter or not. Incumbent firms can influence this by sending signals supporting or discouraging entry, for example by whether they license key technology to new entrants (Afuah and Utterback 1997). Firms entering from related areas understand the signals based on their mental models of what they currently do. Unrelated entrants interpret what signals are HIS through their own analysis, and may require the emergence of specialised suppliers and intermediaries to facilitate them gaining suitable capabilities.

With the emergence of a DD, increased scale, and legitimacy specialised suppliers, distributors, retailers and other market intermediaries may emerge or enter the industry. Market growth provides HIS to suppliers that this is a valuable market for them and the DD provides suppliers with clarity as to what technologies and services are required to be a viable supplier to this industry. As specialist suppliers grow and establish themselves they change the pattern of signals in the industry. The existence of specialist suppliers provides HIS to entrants and existing firms that they can purchase inputs to create certain product attributes. Suppliers can, by specialising, reduce the costs and increase the quality of certain final product attributes and so of the entire final product. As the scale and range of specialist suppliers grows through the transition phase they add a new group of signal generating actors. But because suppliers are specialised they increase the stability of the structure of signals. Specialised suppliers may provide HIS to customers, depending on the industry. In the transition phase market intermediaries may replace direct links between firms and customers, acting to filter signals between firms and customers. Market intermediaries, such as distributors and retailers, amplify certain signals and alter the structure the signals to increase their sales and profits as much as possible. New issues of the appropriation of the value the product creates arise between the intermediaries and the producing firms.

After the shift to the transition phase the product the industry is centred on may send HIS that it is a legitimate competitor to certain other products. The competing product classes (e.g. automobiles and horse drawn vehicles) then send out HIS about their respective superiority to potential customers, suppliers and other actors. When the transition phase occurs to its full extent the new product outcompetes the old one/s for many customers.

As the transition phase takes hold various institutional actors (government, standards bodies, regulators, infrastructure providers and others), as well as social groupings, begin to increase their
involvement with the industry because it sends out HIS of increased scale, legitimacy, and importance. The DD can become reinforced by institutions such as regulations, standards and laws. For example, the motor car industry has a wide range of standards and regulations associated with it, along with significant public policy and infrastructure. As the industry grows during the transition phase this institutional framework grows and can restrict the flexibility of the industry to change. Additionally, complementary products can emerge that interface with the DD. For example, gas stations and cars as previously discussed.

During this phase the firms and other actors adapt their strategies and business models to signals of continuing growth in the industry. Because competitors are trying to improve their product’s value within the architecture of the DD the reference signals for customers of product value keeps changing, driving product innovation to sustain sales income. There is thus a greater focus on the specific components (production focus) and attributes (customer focus) of the product than on the product architecture. This can lead to improvements in the performance of individual attributes and of the product as a whole. Also some competitors may innovate to introduce new product attributes. Customers may also start to desire new product attributes, or a different structure of attributes within the DD architecture. This may be due to the new customers entering the market being less experimental than the early adopters. Thus, the transition phase is a period where a set of business models emerge that provide certain ways of competing within the architecture of the DD, with growth as a base assumption underlying these business models.

Some industries get stuck in the transition phase when there is no shakeout as demand plateaus. In these industries there are many players competing within the product architecture of a DD over periods of decades without a shakeout occurring. Such industries as restaurants and hairdressing continue to exist without a few firms dominating production for long periods. In these industries the signals associated with DD’s and the MAPS are stable. However, the generation of signals in these industries is not subject to such increasing returns that small players are driven out of business. This may be due to localisation being a very important signal to customers, or the costs involved in viable production being low enough that this signal encourages new entry.

**Shift from the Transition Phase to the Mature Phase – Shakeout**

The transition phase shifts to the mature phase when the signals given off by the competing firms, customers and the product have reached the entire potential market and so market size stabilises. Firms are likely to rely on their experience to understand the signals they receive, and in past times slowdown in demand was temporary and growth resumed. Additionally, the competing firms are sending out signals of commitment to the market, increasing production volume and investing in product upgrading. As the mismatch between production volume and demand grows some firms simply cannot gain enough sales volume to pay for their costs and they exit. At this point a shakeout occurs and only the largest/best firms survive as mainstream/niche players, increasing pressure on differentiation within a tightly defined set of product attributes in the MAPS. This is because signals are so well structured, understood and ubiquitous that firms can only compete at the margins of signals defined by the DD. Incumbent firms have signal based advantages due to branding, knowledge of customers, distribution and sales channels, and sunk costs signalling commitment. Because the pattern of signals is so well understood and stable, competition increasingly focuses on creating areas of differentiation outside of the core product itself using tactics such as advertising and branding. The surviving firms readjust their mental models to a world of a stable total market size, with durable product architecture and well understood market segments. The firms thus interpret signals from the perspective of continually improving their current product and production processes. This stability in product attributes reflects stability in the underlying technology and customer demand patterns. This leads to the industry developing a settled configuration in supply chains and routes to market.
**Mature Phase**

The ability to produce large volumes of the product at consistently high quality for a low cost is now the key to firm survival. The industry is well established, with manifest legitimacy and path dependent competitive dynamics. The pattern of signals in the industry has now stabilised so that all actors have a clear understanding of their own and others role/s and how value is created and through what channels in the industry. The industry MAPS is well defined, meaning there is a clear understanding of product attribute structure for each market segment. For example, people generally understand the complicated market structure of the automotive industry. The brand names Rolls Royce, Ferrari, Toyota and Jeep, and product types sports, SUV, sedan and people carrier all signify specific patterns of product attributes that are associated with certain socially constructed meanings for the vehicles and their owners. This state of affairs in the mature phase means that firms navigate with firmly established mental models of what the array of signals in an industry means.

In the mature phase customers have a strong understanding of what the product attributes do for them, and understand the differences between variants of the product. One the one hand this limits the innovativeness of firms because customers are locked into the signals from the DD. On the other hand this stability allows a fine level of understanding of the product by customers, and thus differentiation within the DD. Customers learn over time how to value certain product attributes at an ever finer level, allowing greater differentiation and innovation within the DD. In the mature phase firms need to be active innovators and imitators across a range of product attributes to send signals that capture the attention of customers against competitors’ innovations.

In the mature phase competition between firms can involve strategies of defending and enhancing a market position through strategic moves. This strategy arises because of stability in the relative position of competitors in the MAPS in the mature phase. This stability leads to firms turning toward economic experiments and strategies aimed at influencing rivals and potential rivals to perform actions advantageous to the firm. Firms can do things such as “irreversible investments in capacity, brand name, patents, special licenses or contracts and distribution channels; reputation for retaliating” (Afuah and Utterback 1997: 192). These all signal that this is a difficult industry to enter and thus potential new entrants may decide not to enter due to these signals. Existing competitors take note of each other’s strategic moves and act to counter any threats.

Another strategy is that of enhancing the product’s relative value by augmenting existing attributes, or introducing new attributes. Firms thus end in a race to develop better/new product attributes (HIS) as against their competitors. For example, every two or three years each car model has some sort of upgrade aiming to improve the car’s value relative to competitors through improved and or/ new attributes. This strategy commonly relies on a parallel strategy of cost reduction to be successful. Thus, the MAPS evolves toward being more multifaceted and refined. A second approach to improving the product’s relative value against competitors is through economic experiments aimed at developing new variants of the product to develop new niches and/or enter competitors’ niches, producing HIS for specific customer segments. This potentially produces economies of scope, reusing internal resources at low cost to gain sales in related areas. Examples in the automotive industry are the development of the SUV and people carrier segments. This approach involves rearranging the pattern of signals within the DD to be attractive to a specific customer group not currently served. This produces an increasing number of closely related but discrete niches within the MAPS.

These product strategies can rely on internal resources and capabilities, but can also involve the use of external resources such as suppliers and alliances with competitors. These product strategies will tend to be confined within the pattern of signals in the industry, but over time can reshape it. For example, the use of advanced suppliers to develop new and improved product attributes signals to the supplier that it is worthwhile to invest in technology development and to develop a relationship with the end customer themselves. Thus over time, in the mature phase, suppliers can move toward replacing the central firms in the development of certain technologies.
and so certain product attributes. For example, in the automotive industry leading suppliers develop technology that allow new attributes, such as ABS breaking and GPS units.

Another common strategy involves improving efficiency which requires the firm to remove costs from production without losing relative product value. This productivity based strategy may or may not affect product attributes, outside of price. Typical strategies in manufacturing include design for manufacturability, reducing cycle times, process and incremental innovation, and internalising innovations from suppliers (Afuah and Utterback 1997: 198). Improving efficiency allows firms to reduce price, or to keep the price stable whilst introducing new/improved attributes.

Strategies of product improvement and efficiency can be combined, as is clearly shown in the automobile industry where the lean production philosophy developed by Japanese carmakers lowered costs and raised product quality simultaneously (Womack, Jones et al. 1990). Lean production results in products combining signals of higher quality and lower costs, improving the value/price tradeoff facing customers. Over time, as customers perceived the Japanese carmakers as producing better quality cars at the same or less price Japanese cars signalled better value in the segments they competed in. This resulted in the Japanese carmakers increasing their market share. Over time even the world’s largest carmakers (General Motors) went bankrupt.

New entry is typically difficult in the mature phase as established firms have developed positions in the stable industry MAPS, thus creating difficulties in new firms finding viable niches to enter. Additionally, established firms have irreversible investments what signal they will defend their market position vigorously, creating mental obstacles to entrepreneurs considering entry. However, because the established firms see the industry through such well established mental models in the mature phase a different view of the MAPS may perceive a structure of product attributes that serves a new niche. Alternatively a new entrant may see that it can provide the same product attributes in a different way. That established firms are so firmly ensconced in how they interpret signals in the industry means that a novel way of competing may succeed simply because the incumbents find it difficult to understand the world through a different lens (Savion 2009).

Suppliers, market intermediaries and institutional actors will also be involved in the manipulation and interpretation of signals in the mature phase. Suppliers face signals pressuring them to increase productivity and to improve their offerings to make the industry’s products more valued by customers. The specialisation and scale of suppliers usually increases and some suppliers may increase their role in the sector due to their ability to signal their importance and centrality in the sector. Market intermediaries specialise in creating signals to customers that economise on cognition by structuring customer choice between products and providing information on competing products. This promotes specialisation in firms by reducing the range of activities firms are involved in and potentially allowing increased scale. In mature industries there may exist a complex array of distributors, retailers, marketing firms and others whose role is to provide access to the product for customers, including information provision. If these firms, especially distributors and retailers, can get large enough they can start to preferentially support the signalling of certain firm’s products in exchange for a greater appropriation of the value the product creates. Another type of intermediary are those that provide information on the performance and relative value of competing firms’ products (Earl and Potts 2004). In the mature stage these market intermediaries become very important filters as to the quality and value of the product attributes.

The institutional infrastructure in the mature phase is well developed and stable, imposing a particular structure on signals in the industry and often enforcing the DD. Standards, legislation and other hard institutions can enforce certain sets of signals as being legitimate and others as being invalid, confining innovation to certain bounds. Soft institutions like norms can also be quite constraining as to how people think of a product, and how it is made and sold, restricting action in potentially viable alternative ways. As Nelson and Winter (2002: 33) discuss in regard to Polaroid and digital photography, the business model of how the organization works can be more powerful than the underlying basis of competition changing. Thus in the mature phase firms may find it hard
to deal with innovations that require different competitive actions to succeed (Christensen 1997; Chesbrough and Rosenbloom 2002).

In the mature phase a new technology or product architecture may arise that fulfils some market needs better, and this can disrupt the industry. Christensen (1997) found that in general these disruptive products were worse at serving the needs of most customers, but provided signals that attracted niche markets. Over time the disruptive products improve, and the firms producing these products become more efficient and expand into the existing market. By reconfiguring the architecture of signals the new product variant may eventually create a new MAPS, or alter the existing MAPS, so that the disruptive product becomes the standard following a full ILC.

DISCUSSION AND CONCLUSION

The general contribution of this paper is to show that a signal based lens provides a more general and abstract explanation of the ILC than currently exists. Our relatively simple signal based model allows us to explain not only why the observed features of the ILC occur, but why the ILC sometimes fails to describe industry dynamics. This potentially allows more generalisable research from the ILC and the provision of specific advice to managers and policy makers. This can lead to ILC researchers moving into a more general understanding of the industrial dynamics of the economy through an analysis of its constituent industries.

We contribute the concept of MAPS, which has a ‘shape’ that corresponds with the overall architecture of the product as perceived by the various actors. Over the life cycle of an industry the MAPS, and how the various actors deal with it, change. The MAPS is initially fuzzy, which drives economic experimentation into finding the more viable configuration of the product's attributes, and so the DD. The clarity in the MAPS associated with the DD provides lucid guidance to firms as to what signals it needs to generate and to customers as to what configuration of the product is valuable. This clarity in the MAPS becomes more defined and stable over time, leading to the ability to reap increasing returns and so to the dominance of a small number of firms in the mature phase. The clearer and more conventional the MAPS the better attuned and more deeply held the mental models and cognitive frames of all actors becomes. Over time these cognitive frames can become rigid and understanding inflexible. Consequently, we see the concept of MAPS as providing a useful lens on industry dynamics through a signal based lens.

Competitive success requires that the firm be able to produce profitably, which in turn requires some ability to differentiate against competitors whilst reducing competitor advantage through imitation. Doing this effectively necessitates that firms not only have signals of differential value and efficiency, but that these signals are hard to imitate. The ILC clearly demonstrates the race that is competition, where firms attempt to differentiate their products, do so progressively more efficiently, and try to erect carriers to competition. Their success in these strategies is closely linked to how hard to copy they are. The concept of HIS provides a clear and simple construct with which to think about competitive actions, both generating HIS and imitation itself.

That signals provide a powerful, general and flexible lens on competition and both firm and industry dynamics is one implication of this paper. Competition is central to any economics of capitalism, and evolutionary economics does not yet have a fully worked out theory of competition. We suggest that a signal based theory of competition might be one way to take this paper forward. There is a general understanding of markets as communication systems (Galtier, Bousquet et al. 2012). To understand communication in markets you have to understand signals; their generation, transmission, receiving, understanding and the affect this has on actions. Doing this in an evolutionary manner will also contribute to the theory of signals in economics, as it brings signals away from equilibrium into a dynamic environment.

Future research from this paper can explicitly look at the signals in various industries over time to see if signals and product architectures/attributes fit our model. This can include research into
industries that do not fit the ILC to see how the pattern of signals operates in that industry, and thus to deepen our general understanding of industrial dynamics using the ILC as a base case.

**BIBLIOGRAPHY**


