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Entry Diversion and Submarket Industry Evolution: Dominance of Incumbents, Disruption, or Isolation?

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Abstract

In this paper, we offer entry diversion as a new mechanism to explain dynamics that cannot be explained by the existing industry life cycle (ILC) theories where no shakeout occurs or where one group of incumbents does not become dominant after a shakeout (e.g., disruption by an entrant). Entry diversion happens when entrants observe that expected future profits from a target submarket are decreased by the presence of cost-efficient incumbents down to a level that the entrant chooses to ?open/enter into? another submarket. Contingent on where entrants are diverted submarkets might over time 1) reinforce incumbents? dominance and faster shakeouts, 2) grow to be disruptive leading to change in industrial leadership and latent shakeouts, or 3) result in isolation and no shakeout. We formulate hypotheses based on the degree of technology and market overlap between submarkets. We test and find evidence to our entry diversion framework using a unique submarket and firm level panel data in global semiconductor manufacturing industry between 1995-2012.

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ABSTRACT

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Keywords: ILC, Submarkets, Entry Diversion, Entry Deterrence, Shakeout, Semiconductor Manufacturing Industry

INTRODUCTION

'The evolution of market structure is a complex phenomenon and the quest for any single model that encompasses all the statistical regularities observed is probably not an appropriate goal. Yet there remain phenomena which may well be worth encompassing in a more general theory than is currently available, and which are still poorly understood. Most notable among these are questions of the industry-specific determinants of firm turnover (turbulence) and the volatility of *market shares.'(John Sutton, 1997, p. 57 in 'Gibrat's Legacy')*

The industry life cycle (ILC) has been one of the most influential models of industry evolution literature (Gort and Klepper, 1982, see Peltoniemi (2011) for a recent review). ILC attained this reputation thanks to its great explanatory power to account for most of the empirical regularities found in industries with many differences in production technology, market structures, and regulations (Klepper and Graddy, 1990; Klepper, 1997). These regularities include stylized facts such as firm entry reaches a peak, followed by a takeoff in sales (Agarwal and Bayus, 2002), and then industry stabilizes to an oligopolistic structure as a shakeout renders industry's early leaders to dominate the market while the nature of innovation evolves from product to process innovation (Klepper, 1996). Klepper and Simons (1997)'s analysis of four US industries; automobiles, tires, televisions and penicillin, that experienced sharp shakeouts and dominance of incumbent leaders, all follow ILC.

However, these efforts also brought with it an attention on irregularities. Irregularities are patterns that do not follow the ILC (Nelson; 1999). They include no shakeout industries such as lasers and semiconductors with a steady increase (at least with no sharp decline) in number of firms (Dibiaggio, 2001; Bhaskarabhatla and Klepper, 2012), and industries where no stable dominance of incumbents (e.g., disruption) is observed, like disk drives or computers with continuous change in industrial leadership (Christensen, 1997). Recently, with the increase in availability of large-scale detailed data, a stream of literature that focuses on heterogeneity among firms (Thompson, 2005; Lenox, Rockart, and Lewin, 2007) and heterogeneity of the landscape within an industry (de Figueiredo and Silverman, 2007) started to emerge as an attractive way to explain these irregularities. Yet, it is still too early to say that we can explain all the determinants of these observed anomalies (Klepper and Thompson, 2006).

One area that these efforts will benefit most, however underexplored, is the role of 'change in firm numbers due to entry and exit', i.e., firm turnover, turbulence or industry churn (Caves, 1998).[1] On average 60% of all firms that enter an industry exit within the first five years (and 80% exit within the first 10 years) while new ones replace them (Dunne et al., 1988). However, the persistence of high firm turnover and its contribution to industry evolution stands in stark contrast to many entry deterrence theories and leaves them incomplete by failing to find empirical support for their arguments (Wilson, 1992; Dafny, 2005; Ellison and Ellison, 2011; Seamans, 2012). The clear-cut reason for this conflict is that 'there is too much entry' (Mankiw and Whinston, 1986). Traditional entry barriers such as limit pricing, excess capacity, minimum efficient scale, and absolute capital costs might all pose a hurdle to some entrants, but this does not prevent others to find it profitable and enter (Caves, 1998). Indeed, entry barriers can even end up being entry gateways for lucky entrants (Caves, 1998, p.1976). The resulting picture of current theorizing about entry deterrence is that; despite the significant degree of effort that has been put into their deterrent forces, traditional entry barriers don't really seem to discourage entry, resulting in high firm turnover (Wilson, 1992; Geroski, 1995, p. 430; Caves 1998). We attempt to reconcile this theoretical and empirical inconsistency between the two giant streams of literature (industry evolution and entry deterrence) by exploring the following research question: If there are high entry barriers for attractive high profit markets, why do we still see high firm

[1] Caves (1998, p.1948) tackles the term 'turnover' from three different angles saying that 'We use 'turnover' as a general term to embrace three processes: the births and deaths of business units ('entry' and 'exit'), variations in sizes and market shares of continuing units ('mobility'), and shifts between enterprises in the control of continuing business units ('changes in control'). Our focus is on the first two ones; we look at turnover due to entry and exit while taking into account output capacities (sizes) of firms.

turnover due to entry and exit as the driving mechanism of most if not all industry evolution regularities?

Our approach to solve this puzzle lies in reconfiguring our understanding of entry barriers from the viewpoint of a 'wall' or 'fortress' against potential entrants[2], to a viewpoint of 'levee' or 'dike' for channeling or diverting them to enter into other/new submarkets[3] in an industry. Adapting this type of an entry barrier view would match theory with empirics that while a surge in entry and exit, thus firm turnover persists (thus, entry does not necessarily stop behind a high barrier); incumbents also protect their high profits in their turf. We call this process entry diversion. In this paper, we offer entry diversion as a new mechanism to account for ILC irregularities of no shakeout and no dominance of a firm or group of firms (e.g., disruption).

The main idea behind our theory is as follows. Occupancy by cost-efficient incumbents[4] in main submarkets ex ante (Dafny, 2005; Seamans, 2012) conditions entrants' incentives from imitating the incumbent to finding new sources of growth; i.e., opening/entering into other submarkets (Kessides, 1990; Geroski, 1991). Since product innovation is required to open (or enter into) new submarkets (Mitchell and Skrzypacz, 2011), it can be argued that one way the incentives of entrants to do product innovation originate from entry diversion. In this sense, entry diversion adds the missing initial link to ILC so that that the determinants of 'why firms do product innovation in the first place, and open/enter into new submarkets' are endogenized in a more general ILC theory (Geroski, 1991).[5]

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[2] This view of entry barriers is especially evident in strategic groups (Caves and Porter, 1977) where strategic groups are portrayed as medieval fortress cities.

[3] Submarkets are defined as differentiated niches which are segregated from the rest of an industry on both demand and supply side (Sutton, 1998; Bhaskarabhatla and Klepper, 2012).

[4] Cost-efficiency of incumbents will be measured by output levels of firms, which will be captured in a way similar to Dixit (1980) where threat of output expansion signals about firms' scale economies levels.

[5] Sources of product innovation and submarket formation are usually treated as exogenously given in the literature. For example, Klepper (1996, p.565) randomly assigns product innovation capabilities to firms; Jovanovic and MacDonald (1994) states that an exogenous radical innovation disturbs the balance of the industry and opens new opportunities for growth, and Klepper and

Contingent on where entrants are diverted, these submarkets might 1) render leading incumbents to reinforce their dominance and faster and sharper shakeouts (Buenstorf and Klepper, 2010), 2) grow to be disruptive leading to change in industrial leadership and latent and smoother shakeouts (Adner and Zemsky, 2005), or 3) result in isolation and coexistence of both submarkets where there is no dominance of one submarket over another, thus, no shakeouts (Bonaccorsi and Giuri, 2000; Dibiaggio, 2001; Thompson, 2005). We predict which one of these different patterns will be observed using both demand (market cannibalization) and supply (technological firm-capabilities) conditions of 'where entrants are diverted'. Which submarket will appropriate more value depends on how much technology and market overlap between submarkets there is (Sutton, 1998). Industry shakeouts occur, sooner or later, depending on whether this appropriability condition favors one submarket over another (Klepper, 1997).

In sum, our main argument is that 'entry diversion adds the missing initial link to ILC which resolves the clash with entry deterrence, encompassing different patterns of evolution in a more general ILC theory'. The rest of this paper is structured as follows: We first put forward the theoretical background through the recent irregularities found in the ILC literature and theories that try to explain them. Second, we propose our entry diversion framework using the submarket phenomenon and show how it can account for these irregularities. Third, we test our theory on a unique dataset from the semiconductor manufacturing industry. We finalize with a discussion of the generalizability of our findings and conclusion.

Thompson (2006) and Sutton (1998) treat arrivals of new submarkets and Tong (2009) treats activation of initially inactive submarkets as exogenous drivers of industry evolution.

INDUSTRY EVOLUTION IRREGULARITIES: SHAKEOUTS AND CHANGE IN INDUSTRIAL LEADERSHIP

A long-standing interest in industrial organization is a broader question about market structure, specifically about shakeouts and change in industrial leadership (Klepper and Miller, 1995: Klepper and Simons, 1997, 2005; Sutton, 1997; Nelson 1999; Tong, 2009). A shakeout is a non-monotonic drop-off pattern in the number of firms after achieving an initial buildup and a peak during ILC (Klepper, 1997). The likelihood, magnitude and timing of shakeouts show substantial variations among industries such that while shakeouts are faster and sharper in some cases, e.g., TV receivers, automobiles, and tires, they are slower and smoother in others, e.g., lasers and disk drives (Gort and Klepper, 1982). Regularities involving shakeouts in some industries might happen to behave more like irregularities in others, i.e., not all industries fit well to ILC pattern of shakeout industries (Klepper, 1997).

A number of models have been developed to explain shakeouts. Comparing earlier efforts with more recent ones, one can easily realize the progression from models of exogenous changes (Gort and Klepper, 1982; Utterback and Suarez, 1993) to those that deal with endogenously driven change (Klepper, 1996; Klepper and Thompson, 2006). ILC theories either focus on the importance of exogenous shocks, such as major innovations (Jovanovic and MacDonald, 1994) and the dominant designs (Utterback and Suarez, 1993), or they focus on scale-appropriability relationship (Klepper, 1996; Cabral 2012) leading to shakeouts. While the former is referred to as 'extinct' because their predictions do not match data (Klepper and Simons, 2005), [6] the latter struggles from the assumption of random assignment of product innovation capabilities. Dominant design view lies at the center of the shakeout phenomenon; however where it is

[6] Exit rates do not necessarily increase when industries experience shakeouts; instead, entry stops and the remaining companies are wiped out at a constant rate as a result of competitive pressure created by technological progress (Klepper and Miller, 1995).

positioned exactly in the ILC is less clear. Some take it as the ‘reason’ of the shakeout (Tushman and Anderson, 1986; Utterback and Suarez, 1993; Suarez and Utterback, 1995), while others see dominant design as the ‘result’ of the shakeout (Klepper, 1996; Buenstorf and Klepper, 2010).

In addition to the presence or absence of the shakeout phenomenon, we also observe differences in patterns of industrial leadership between incumbents and entrants, such as how much industry growth is driven by earlier entry into the industry. (Lenox et al., 2007). Faster shakeouts are followed by incumbents’ long-term market dominance. The first cohort grows larger, focuses on more efficiency-increasing (process) innovation, and threshold for profitable entry rises. Eventually entry stops and competition via process innovation drives non-efficient firms out, i.e., sharp shakeouts occur (Klepper, 1996). General Motors, Ford, and Chrysler were all early entrants and jointly dominated 80% of the U.S. automobile industry output by leading the major innovations and a subsequent shakeout.

However, product innovation might also grow to be disruptive for incumbents (Christensen, 1997), which is not covered in these models. In Klepper (1996), product innovations open up new submarkets, but they are instantaneously imitated one period later and new demand is added to mainstream submarket’s total demand. While full appropriation of returns to innovation by incumbents provides a coherent explanation for ‘why shakeouts occur’; it also restricts the model’s ability to account for disruption by new submarkets, slower shakeouts and changes in industrial leadership. When the new submarket offers a radical change in technology that obsoletes incumbents’ competences (Franco et al., 2009), indeed, new firms, not the incumbents, are the ones to capture most of the value (Nelson, 1999).

What we see common among all these theories is that ‘a shakeout occurs when an oligopoly (in a submarket) begins capturing most of the value’ (Dibiaggio, 2001). We can say that ‘a shakeout is a direct outcome of value appropriation'. Basically, for the shakeout to occur, incumbents in the focal submarket should dominate the new submarket and fuse the new and existing ones into one big submarket (Adner and Zemsky, 2005).[7] Buenstorf and Klepper (2010, p.1584) state that this is the case in US tire industry where Ford's Model T fused both rural and urban user submarkets. Guenther (2009) found similar results in German machine tool industry where new multi-functional machining concepts fused traditional submarkets of boring and milling, and lately Bhaskarabhatla and Klepper (2012) studied US laser industry where diode-pumped solid state laser initiated a phase of a 'dominant submarket' which resulted in different submarkets to fuse and create a latent shakeout (after 35 years from industry's inception) which is still ongoing. Therefore, sooner or later a shakeout might occur unless submarkets happen to stay in isolation and coexistence where there is no dominance or disruption of one submarket over another (Klepper, 1997). However, if this 'coexistence balance' between submarkets is disrupted, either by technologies or markets overlapping each other, industries will experience fierce competition due to cannibalization by other submarkets (Adner and Zemsky, 2005) and this would result in a shakeout.

In sum, ILC theories fail to tell us that there can be actually more than one outcome in industry structure (Windrum and Birchenhall, 1998): 1) Dominance of industry leaders and faster shakeouts, 2) Disruption and change in industry leaders and latent shakeouts, and 3) Isolation of submarkets and no-shakeouts. ILC studies cover the first result and explain away the rest as 'irregularities'. In the next section, we introduce our entry diversion framework as a more general theory of ILC to account for these outcomes.

[7] Submarkets include by their nature a very limited group of customers and for incumbents to obtain a size big enough to start a shakeout and dominate the new submarket requires collapsing submarkets to one.

ENTRY DIVERSION: HOW DOES IT OPERATE?

In order to come up with a more general theory of ILC, we start by taking every submarket attracting a stock or queue of potential entrants (what Bain(1956) termed the 'general condition of entry'). Entry typically entails an investment decision with some sunk value (Cabral, 2012). Entrants first scan their options, and then consider the incumbent firms that occupy their target ex ante (Dafny, 2005; Ellison and Ellison, 2011; Seamans, 2012).[8] Occupancy by cost-efficient incumbents[9] in main submarket of interest conditions entrants' incentives from imitating the incumbent to finding new sources of growth, i.e., opening /entering into other submarkets (Kessides, 1990; Geroski, 1991). We call this process '*entry diversion'*.

Entry diversion operates as follows. Take two submarkets; i and j. Potential entrants to submarket i are diverted to submarket j through the presence of a cost-efficient incumbent in submarket i. Incumbents expand, spend more cost-saving R&D, and become more efficient (Gort and Klepper, 1982). Price falls (Klepper and Graddy, 1990), less innovative incumbents exit and threshold for profitable entry rises (Klepper, 1996, Suarez and Utterback, 1995). Entry diversion starts when process innovation by incumbents leads to creation of entry levees and a decrease in entry in submarket i. Without any friction, all the entry that finds it unprofitable to enter submarket i, is diverted to find a submarket j to enter. Eventually, continuous process innovation by incumbents in submarket i increases the threshold for profitable entry up to a point that entry eventually ceases to submarket i (Klepper, 1996). This is the point where entry diversion is at its maximum (all possible entry is diverted towards another one with lesser barriers). Therefore, an increase in entry threshold by incumbents' process innovation will cause a decrease in entry rates

[8] In entry deterrence literature, limit pricing, excess capacity, and early technology adoption are examples of ex ante entry deterrence (Dafny, 2005; Ellison and Ellison, 2011; Seamans, 2012).
[9] Cost-efficient incumbents, in the Klepperian sense, are firms that focus on process innovation and increase the profitable entry threshold with their large scale up to a level so that entry eventually stops (Klepper, 1996).

into the mainstream submarket (submarket i) which will in turn result in an increase in entry into other submarkets (submarket j).

Why would firms do product innovation in the first place when imitating the incumbent is less risky and less costly? Since product innovation is required to create (or enter into) new submarkets (Mitchell and Skrzypacz, 2011), we can say that one way the incentives of entrants to do product innovation originate from entry diversion. Entry diversion, thus, requires a complete change in our strategic thinking; from submarkets exogenously emerging as opportunities, to submarkets endogenously being created by diverted entrants. In this sense, entry diversion provides the initial missing link of ILC. In contrast to current theorizing, we argue that it is not because arrivals of exogenous submarkets (Klepper and Thompson, 2006) or activation of initially inactive submarkets (Tong, 2009), but it is the entry diversion process that results in product innovation and opening of new submarkets.

In operationalizing entry diversion, we need a measure for in capturing the ex ante investment of the incumbent on entry levees; i.e., the incumbent should have invested credibly against entry into submarket i, so that, due to this occupancy, entrants will be diverted to enter/open submarket j. This unobserved credibility of the investment can be proxied by some measure of probability (or threat) of entry. The test for presence of entry diversion, then, should look for the effect of increased probability of investment on entry levees in a focal submarket on 1) increased entry/output/number of firms in other submarkets and on 2) opening/number of new submarkets. As it will be explained in the following sections, our test combines two distinct variables used in common entry deterrence literature, 1) incumbents’ capacity investments as entry levees together with 2) the credibility of this investment, as the independent variable.

Hypothesis 1: An increase in probability of entry into one submarket by cost-efficient large incumbents causes an increase a) in entry into other submarkets, b) in number of submarkets opened by diverted entrants, c) in capacity in other submarkets, and d) in number of firms in other submarkets.

How can entry diversion incorporate the irregularities of ILC to make it a more general theory? Entrants might end up being diverted in close fringe submarkets and eventually fall prey to a shakeout; or we can also expect them to disrupt incumbents' dominant submarkets if they are diverted far enough to grow. We discuss and build upon this issue in the next section.

DOMINANCE, DISRUPTION, OR ISOLATION? WHERE ENTRANTS ARE DIVERTED IS DECISIVE

Following entry diversion; in a Schumpeterian sense, innovation determines the rules of competition, causes entry/exit of firms, and changes relative position of submarkets and firms which are active in them (Utterback and Suarez, 1993; Christensen, 1997). Process innovation takes over to increase efficiency, to decrease costs and hence prices so that more efficient submarkets start attracting demand from less efficient ones (Adner and Levinthal, 2001).

On aggregate, rate of opening new submarkets die out over time (Jovanovic and MacDonald, 1994) and process innovation takes over (Klepper and Thompson, 2006). Entry diversion declines as players take their positions and selection process starts taking place between submarkets. Our main argument regarding this phase is; whether the industry will experience a dominance of leaders and faster shakeouts, disruption (change in leadership) and slower shakeouts, or isolation between submarkets and no shakeouts depends on 'where entrants are diverted', both demand- and supply-wise. The probability that submarket j grows to be disruptive for submarket i is a function of how far entry is diverted (or how far submarket j is located).

To define 'how far', we would need a closeness measure. We argue that the benefits of developing technological (or market) capabilities in one submarket will help an incumbent gain advantages in another, if two submarkets are technology-wise (or market-wise) 'close' to each other. We look at the degree of overlap between submarkets when we talk about 'closeness' or 'substitutability'. Whereas closeness in terms of technologies and markets between submarkets will favor incumbents against entrants, distance in any of these dimensions will give entrants enough room to disrupt incumbents' submarkets (Olleros, 1986, p.13).

Two conditions are needed for an incumbent to dominate a new submarket: First it should be aware of and motivated to act on the threat from the demand side; second it should be capable to respond to the threat from the supply side (Chen, 1996).[10] While demand side of closeness speaks how much do submarkets cannibalize each other; supply side of closeness speaks whether incumbents in the focal submarket are able to exploit their existing abilities to dominate the new submarket.

Hence, 'how far entry is diverted' is a function of both market and technology overlap (Griffin and Hauser, 1996; Franco et al., 2009). Market overlap is related to business-stealing effect of new submarkets from existing ones. The ability and motivation of incumbents to recognize the opportunity will be influenced by the relative size of the market overlap (or closeness). If there is too little overlap, i.e., demand-wise distance is high, sales of a new submarket will come from market expansion in total industry sales via new demand addressing different user characteristics (Adner and Levinthal, 2001).

[10] Whereas competitive dynamics literature focuses on individual firm competition with pairwise comparison between a focal firm and its rivals, we argue that the awareness-motivation-capability (AMC) perspective can be extended to submarket level where awareness and motivation depend mainly on market overlap and capability is largely conditioned by technology overlap between submarkets.

On the other hand, technology overlap is related to the degree of discontinuity in technological development which affects the ability of incumbents to act upon an opportunity.[11] It will be easier (harder) for incumbents to respond when technology overlap is high (low) with the emerging submarkets. Incumbents with their submarkets high in technology and in market overlap with emerging submarkets occupied by diverted entrants will adapt to new submarket needs easily and will not fall victim to selection processes of industry evolution (Agarwal and Helfat, 2009). Table 1 indicates how ILC will evolve (i.e., dominance, disruption, or isolation) with different degrees of overlap among submarkets.

---------- Insert Table 1 here ----------

The upper left quadrant is the part that traditional ILC perfectly explains as regularities. When the new submarket has high overlap in both market and technology, incumbents can use their current technological and marketing capabilities as value creation and value appropriation mechanisms (Griffin and Hauser, 1996; Franco et al., 2009) to recognize and respond the new submarket, and reinforce their industrial leadership. Klepper (1996)'s ILC model and Klepper and Simons (1997)'s analysis of four US industries, automobiles, tires, televisions and penicillin, that experienced sharp shakeouts and dominance of incumbent leaders all fall into this first quadrant.

Second is technology disruption with low technology overlap and high market overlap. This is the case observed mostly in the context of high-technology industries where multiple product generations, or technological trajectories exist. A good example of this is the rise of the digital imaging submarket. High market overlap between digital and analog imaging submarkets

[11] High vs low technology overlap is related to competence enhancing vs competence destroying (Tushman and Anderson, 1986), incremental vs radical (Dewar and Dutton, 1986), sustaining vs disruptive (Christensen, 1997), minor vs major (Gort and Klepper, 1982), or re-formed vs breakthrough innovations (Day et al., 2003).

rendered incumbents such as Kodak[12] aware of the threat from the new submarket; however the low technology overlap represented very different trajectories of technological knowledge and as a result, resources and capabilities of incumbents were more prone to becoming obsolete.

Third is market disruption. In this case, the incumbent's submarket is not cannibalized by the new submarket, thus market overlap is low. Therefore, even though technology overlap is high, the incumbent does not respond to the new submarket, since there is no market cannibalization. Nevertheless, over time the new submarket becomes disruptive (from the demand side) and starts invading the established submarket from the lower end and eventually the industrial leadership changes. This is the case of 'innovator's dilemma' as depicted by Christensen (1997) where incumbents do not recognize developing submarkets since there is no market cannibalization and tend to focus on their current markets. In hard disk drive industry, the uncertainty in smaller disk drive submarkets rendered the cannibalization effect of these submarkets on established ones unforeseen. Even though the improvements such as 3.5-inch hard drives utilized similar technology with their 5.25-inch counterparts, the disruptive submarket created new and distant markets with new, very different user characteristics (e.g., portable computer users) which, over time, replaced the older submarket and rendered redundant market assets that were effective in personal computers (Christensen 1997).

The last quadrant is isolation of submarkets. In some cases, paradoxical to the shakeout phenomenon, submarkets, and firms with heterogeneous size, age, and capabilities within them, survive together in the long run. Having low overlap in technology and market domain, submarkets stay isolated from each other, as Sutton (1998; p.233) calls them 'a set of isolated

[12] A clarification is needed about the difference between entry diversion and market-pioneering/responding (Franco et al., 2009). We are not necessarily interested in first or late mover (dis)advantages. Our interest is more on eventual submarket dominance (or dominant submarket as in Bhaskarabhatla and Klepper, (2012)). For example, Kodak actually pioneered the digital imaging industry; however did not continue on investing in that submarket. Eventually, other firms, being diverted from Kodak's cost-efficient presence in analog imaging submarket, entered and dominated digital imaging submarket and created a disruption.

islands'. The isolation and coexistence of submarkets is observed in turboprop engine industry (Bonaccorsi and Giuri, 2000) and shipbuilding industry (Thompson, 2005). Among turboprop engine firms (Bonaccorsi and Giuri, 2000), even if there was high concentration resulting in an oligopolistic structure, it did not result in a shakeout because two submarkets, generalists and specialists, happen to coexist without disruption because they were distant both demand and supply-wise. Thompson (2005) uses data from U.S. iron and steel merchant shipbuilding industry and the no-shakeout reasoning is based on geographical conditions that large vessels employed in Great Lake couldn't enter into western rivers. Shipbuilding firms had to choose their locations as they would be mostly immobile and be able to serve only surrounding areas where the ships can be used. Use of different technologies for ships (large and small) also lessened technology overlap, resulting in isolation and a no-shakeout pattern.

> Hypothesis 2: Depending on where entry is diverted in market and technology distance, the submarkets will experience a) dominance of leaders and faster shakeouts, b) disruption (change in leadership) and slower shakeouts, or c) isolation between submarkets and no shakeout patterns posited by the ILC.

EMPIRICAL CONTEXT AND DATA

Our theory is well motivated by the evolution of the semiconductor industry. Due to its fragmented structure and fast pace of innovation, the industry is famous among many researchers as a fruitful context to study many different aspects of strategic management, innovation and economics. It was born in 1950 when the first integrated circuit (IC) was developed to replace the bulky and fragile vacuum tubes. With the IC, it was possible to combine multiple transistors[13] on a single silicon chip. Today, each IC might contain over billions of transistors in areas smaller than the surface of a dime.[14] ICs opened a new age of specialization in both technology and market side, and different chip families with different attributes and various end-use applications have been developed. Current advances in chip production necessitate incorporation of more transistors per chip to improve productivity and performance while decreasing cost per transistor.

Manufacturing semiconductors is possibly one of the most technologically complex and capital intensive processes the industrial world has encountered. It comprises hundreds of operations of processing silicon wafers into semiconductor chips.[15] Depending on the size of the wafer and the chip geometry, any number from tens to tens of thousands of dies can be processed on a wafer. As a result of the increasing complexity, the industry correspondingly necessitated higher wafer sizes and smaller technology nodes (geometries). Typically the transition from one node to the next is costly, however this cost is exceedingly compensated by the increase in how many transistors can be fit on a given die, i.e., cost per transistor falls substantively. Moore's law[16] is based on this economic progression and it is this exact process which rendered today's small mobile devices that cost only couple of hundred dollars deliver more computing power than the mainframes of 1980s which cost millions of dollars. These requirements continuously force semiconductor fabrication facilities, i.e., fabs, to give priority to efficiency by increasing their capacities continuously; failing to do which would result in loss of market share.

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[13] Transistor was invented in 1948 by Bell Labs in order to perform switching and amplifying the current flow better than vacuum tubes.

[14] For example, the state-of-the-art Intel chip, i.e., the Sandy Bridge, employs a fabrication method to put together 2.3 billion transistors, each one only 32 nanometers away from each other.

[15] Wafers are silicon substrates produced in disc shape on which a number of ICs is processed, tested, cut into individual dies. They can be of diameter sizes of 76.2mm (3"), 100mm (4"), 125mm (5"), 150mm (6"), 200mm (8"), 300mm (12"), and 450mm (18"). Larger wafer diameters come with costly equipment and facilities for fabs, but they also permit firms to produce more chips per wafer, i.e., higher economies of scale is obtained.

[16] Moore's law states that number of transistors on ICs doubles approximately every two years.

Three main features of semiconductor manufacturing industry make it fit well with our theory. First of all, semiconductors can be easily divided into submarkets (Sutton, 1998, p. 358). Semiconductor products may be thought of as a compressed group of electrical functions, where a function could be a memory bit or a logic gate (Leachman and Leachman, 1999). This way, we can distinguish between main submarkets such as analog, discrete, MEMS,[17] memory, and logic chips etc. which can be further fragmented into a huge array of specialized 'secondary' submarkets such as mixed signal and linear chips for analog; light-emitting diodes (LEDs), [18] thyristors and transistors for discrete; DRAMs and Flash chips for memory; and digital signal processing (DSP) chips, microprocessors (MPUs), and microcontrollers (MCUs) for logic product families etc. The nature of the function determines which application spaces the chip will serve, so the technologies required for producing, say, MEMS chips and memory chips are completely different from each other. They differ as of end uses, too. For example, data processing devices (PCs, notebooks, servers etc.) typically use MPUs, DRAM, SRAM, and more recently NAND Flash memory chips, whereas sensors (MEMS), MCUs, DSPs, power, and analog chips can be found in modern automobiles. The hierarchical structure of submarkets in the industry can be seen in Figure 1.

---------- Insert Figure 1 here ----------

Second, new product cycles emerge between the semiconductor submarkets and that provides important drivers of the industry's evolution. While aggregate trends in the semiconductor manufacturing industry show signs of maturity stage and a shortening and flattening ILC; a closer look into the semiconductor submarkets shows different growth patterns about the ups and

[17] MEMS stand for Microelectromechanical systems. They are miniaturized sensors with extreme reliability such as accelerometers and pressure sensors that have applications in smartphones, inkjet printers, automobiles, projectors, microphones. They can be camera parts, such as movement and direction sensors, which go in mobile phones, or accelerometers that go into airbags.

[18] LEDs are used for lighting homes and offices. Compared to incandescent bulbs which normally last 750 to 1,000 hours, LEDs last around 12,500 hours while they use 75 percent less energy.

downs of the ILC between submarkets. For example, recently the DRAM memory submarket whose products are mainly used in data processing applications (such as PCs, notebooks, servers) has stagnated and started flattening in growth, while flash memory submarket whose products are mainly used mobile and embedded applications including smart phones, tablets etc. started taking off.[19] By the end of 2009, total flash memory capacity installed in fabs has surpassed DRAM memory capacity, and number of DRAM producers also decreased from 98 in 1999 to 19 in 2013 (see Figure 2). Furthermore, these submarkets might fuse in the future as a hybrid submarket between these two is emerging (DRAM&Flash) (e.g., Guenther; 2009; Bhaskarabhatla and Klepper, 2012).

---------- Insert Figure 2 here ----------

Third, focusing on Moore's law, efficient incumbents deploy their resources on producing chips more efficiently, and this efficiency orientation does not necessarily require visions of future markets and applications, leaving ample room for disruptive innovations that are not based on mere production scaling. For example, digital chips (memory and logic submarkets) follow Moore's law whereas analog and discrete submarkets do not follow it precisely. Devices made by digital submarkets increasingly face the need to integrate with the analog domain where they interface with sensors and control elements (e.g., MEMS). This need is more pronounced as silicon technology approaches its limits. Therefore, incumbents focused and dominant on digital submarkets are prone to possible disruption that might come from non-digital submarkets. For example, a new trend called 'More than Moore' begun affecting the industry where value is created not by scaling production but by incorporating different functionalities of digital and analog chips that do not necessarily follow Moore's law.

[19] According to Gartner's market research, PC submarket shrank by 2.7% while tablet submarket doubled its size, reaching 116 million units in 2011. DisplaySearch reported that tablet submarket is expected to reach $78.7 billion and are cannibalizing PC sales more every day.

Data

Our core source of data comes from the Semiconductor Equipment and Materials International ($SEMI^{TM}$)'s World Fab Watch (WFW) data for years 1995-2013. These panel data consist of many variables such as product/class (e.g., Analog, Discrete, Logic, MEMS, Memory etc.), geometries, wafer sizes, fab capacities, equipment and construction costs of more than 1,000 fabs per year worldwide. The size of the initial data was 20,991 fab-year observations.

One of the biggest challenges was to decide on submarkets. After comprehensive research, reading about the industry and conversations we had with industry experts, we agreed on using the product/class variable as it includes the major product categories of a fab. Since it is practically impossible following all product categories within a fab over time reliably, $SEMI^{TM}$ focuses on the two major product types of a fab. This variable initially comprised 37 product classes for the last year of the dataset (see Table 2). There is also a secondary product class variable which classifies a fab by higher level. From these, we allocated foundries, to their corresponding submarkets, because a foundry is not a distinct submarket, but rather a separate business model.[20] For example, as made-to-order chip-producers, foundries might produce memory chips or logic chips; therefore we allocated them accordingly to these submarkets.

We also decided to exclude EPI, R&D and Pilot fabs from our analysis. EPI fabs do not produce devices but instead form a thin epitaxial (epi) layer on wafers. This epi layer is a nearly "perfect" crystalline structure that is critical for some devices. Most of the epi companies deposit this layer for their customers, i.e., device makers, and send the wafer to them for fabricating the device. So, EPI is not a submarket for devices but a specialized materials technology required for some devices. We also excluded R&D fabs and pilot fabs as these fabs does not necessarily belong to a certain submarket; they are for early development and production, and the capacity

[20] Foundries are contract based manufacturers, such as TSMC, which focus solely on manufacturing but do not design chips.

impact is not big. This resulted deletion of 144 EPI, 693 pilot, 1,439 R&D, and 312 R&D-Pilot fab-year observations. In total, these yield 27 submarkets (that belong to 5 main submarkets) and 18,260 fab-year observations for our analysis (see Table 2).

---------- Insert Table 2 here ----------

According to our theorizing, probability of entry plays an important role as it signals the credibility of incumbent entry. The WFW data measures the probability of entry, which identifies, on a continuous scale, the status of a fab; whether it is rumored (<0.5), planned/announced (0.7), under construction/being equipped (at this point the company puts the money down) (0.9), or completed/in production (1.0). In order to locate occupied submarkets, we exploited this probability measure. While any fab with probability below 1 is still ramping up, this variable might also take values above 1, signifying an upgrade or expansion for a mature fab, which have already achieved volume production. Thus, this variable not only covers currently active fabs, but also future fabs with their corresponding probabilities. Investment rumors and announcements are clear signals to the whole industry that firms are aggressively aiming to remain competitive against their rivals. Before deciding to build a fab, a company has to understand the end market first, because the equipment, process steps and skills used in fabrication of, say, memory chips is quite different than those for the design of MEMS. Our operationalization is that incumbent chip manufacturers, without even making considerable, if any at all, investment (no money down), might divert entrants by creating a rumor or announcing a new fab in their submarket. The pattern in data corroborates with this view: not all rumored and announced fabs materialize over time (see Table 3). After 2 years, 74% of rumored fabs and 52% of announced fabs remain without any investment.[21]

---------- Insert Table 3 here ----------

[21] With a 5-year horizon, expectedly, these percentages drop to 29% and 22%, respectively.

EVOLUTION THROUGH SUBMARKETS IN THE GLOBAL SEMICONDUCTOR MANUFACTURING INDUSTRY

Semiconductor manufacturing is clearly an industry where 'size does matter'. Huge scale economies can be obtained through increasing capacity. Dividing fixed equipment and construction costs over a larger total output increases the minimum efficient scale for entry into certain submarkets, in line with our theory. Increased incumbent capacity serves as a commitment to threatening entrants by signaling sustained cost advantages related to size (Klepper, 1996). On the other side, incumbents enjoying the attractive ascending submarkets face the threat of entry and have different means of protecting their turf in the industry. Incumbents with smaller geometries and larger wafer sizes have barriers of capital intensive scale efficiencies which forces entrants to strategically focus on other submarkets and escape the capital intensity and scale required in these submarkets. In order to demonstrate that this is the case in semiconductor manufacturing submarkets, we here provide some descriptive evidence on patterns of efficiency, capital intensity, capacity, and entry into submarkets.

Looking at the important determinants of economies of scale in semiconductor fabrication, we can map submarkets on a two-dimensional scale: one dimension with 'geometry' or 'die size' in microns, and another dimension with 'wafer diameter' in inches.[22] In Figure 3, such a submarkets map can be seen. Highly cost-efficient fabs that focus on commodity chip production, such as memory and logic chips, are located in the high-wafer size and low geometry section, whereas low capacity ones with more particular product characteristics, such as discrete and analog chips, as well as MEMS, are located in the other extreme, in the higher geometry but

[22] de Figueiredo and Silverman (2007) builds a similar map for the laser printer industry where the resolution (measured in dots perinch, DPI) and printing speed (measured in pages per minute, PPM) form the two dimensions of the submarket map. Similarly Klepper and Thompson (2006) do the same in lasers, where they mention categorization of submarkets with regard to power and the wavelength of light lasers emit.

lower wafer size part. Our initial insight here is that as we move from the former groups of submarkets to the latter ones, minimum efficient scale for profitable entry increases, i.e., it becomes easier to enter.

---------- Insert Figure 3 here ----------

Capital intensiveness and capacity levels also confirm the efficiency pattern observed in Figure 3. Following the cutting edge technology in manufacturing, i.e., moving from one wafer (or geometry) size to the other requires new machines and the reconfiguration of fabs. Huge levels of capital for investment in equipment and construction of fabs is required. Furthermore, similar to what Klepper (1996) shows theoretically in his model, the incentives to involve in process innovation are bigger as the firm has bigger capacity. We calculate the capacity of a fab as the amount of ICs that can be produced using Leachman and Leachman (1999)'s formula;

$$C = (6.45 \times 10^{-4})(W)\{(3.14159)(D/2)^2\}/G^2$$

where W denotes the fully ramped wafer output capacity per month, D is the wafer diameter in inches, and G is the minimum feature size expressed in microns (G^2 is then the area of an IC, assumed to be square in shape). The first numerical coefficient is a conversion factor accounting for the mixture of English and metric units; the other numerical factor is the familiar π number for computing the area of a circle. Expressed this way, the capacity is a very large number indicating quadrillions of functions per month with an extreme skewed distribution (127.70), thus we show the average capacities of submarkets in logged form.

Figure 4 depicts the exponentially increasing investments required to build a new fab in different submarkets, with the memory DRAM and Flash, and the logic MPU submarkets reaching on average $3 billion. Some fabs of big companies like Samsung, Toshiba, or Intel in these submarkets cost more than $10 billion. The high amount implies extensive pressures on investment decisions as opening a new fab might include huge commitments to these submarkets. Only a handful of companies have enough capital ($3B and up) to build a new fab for smallest geometries and largest wafer sizes. The less advanced submarkets do not have the same technology requirements, so technically the larger node/smaller wafer submarkets, such as discrete, analog, and MEMS, are easier (less expensive) to build and equip a new fab.

---------- Insert Figure 4 here ----------

Back when the industry was using 150mm (6") wafers as the most advanced wafer size, there were over 100 companies with fabs. Table 4 highlights how the semiconductor industry has consolidated over the past years. In general, the number of new fabs has been slowing worldwide because with each new wafer size and process geometry, one new fab can produce many more chips per wafer than the previous generation. Therefore, due to both investments required and the scale economies obtained, number of new entrants decreases as wafer size increases and the geometry shrinks. For these reasons, there are practically no new entrants in the memory and logic submarkets, whereas discrete (specifically LED) and MEMS submarkets attract many entrants recently due to their ease of entry and future demand expectations. This pattern can be observed in Table 5.

---------- Insert Table 4 here ----------
---------- Insert Table 5 here ----------

EMPIRICAL ANALYSIS

Our baseline model measures the impact of incumbents' fab capacity investment probabilities (rumoring, announcement, money down, completed, or expansion) in a certain submarket (lagged) on number of entrants, capacity, and number of firms in other submarkets.

$$y_{jt} = \gamma_j + \sum_{J=1}^{5} \beta(Capacity * probability)_{J,t-1} + \alpha X_{it} + \varepsilon_{jt}$$

Where y_{jt} is number of entrants to submarket j in year t.[23] γ_j is fab-submarket fixed effects. $(Capacity * probability)$ is our main covariate of interest which accounts for the current and future capacities of incumbents interacted with five main submarket (Analog, discrete etc.) and five probability category (rumored, announced etc.) dummies (all lagged). While capacity depicts how cost efficient the incumbents are in the focal submarket (recall that capacity is calculated using wafer sizes, geometries, and wafer capacities together), probability adjusts the diversion effect of this capacity according to its credibility as an entry levee. Thus, rumors of a new fab with a certain capacity will be a less credible entry levee compared to the same capacity that is in the process of construction (money down). In other words, a strategic incumbent with an intention of credibly occupying one submarket will try to come up with the highest capacity*probability pair possible. Furthermore, $(Capacity * probability)_{J,t-1}$ covers all submarkets (J). This way, we distinguish our analysis from conventional view of entry deterrence to entry diversion by looking at not only the effect of incumbents' investments on entry within the same submarket, but between all possible submarket pairs, where change in incumbents' investments in one submarket may affect entry of new firms to other submarkets as well. X_{it} includes a set of controls that might affect the entry, capacity, and number of firms such as age, and technological complexity (geometry and wafer sizes).[24] We run random effects time-series regression model, and results are reported for each submarket*probability category pair.

[23] In line with Hypotheses 1a-1d , We test the model with number of submarkets in year t, capacity changes, and number of fabs in submarket j in year t, as well.
[24] Smaller geometries require more complex technology than larger ones, and wafer size is negatively correlated to geometry (ρ= -0.4881). So the smaller the geometries and the larger the wafers, the higher the barrier to entry for any submarket.

RESULTS

H1 tests our main concept, entry diversion, by looking at the effect of capacity installation probabilities on a) number of entrants, b) total number of submarkets, c) realized capacities, and d) firm density in each submarket. Results for the test H1a-c can be found in Table 6.

Overall, highly efficient submarkets such as logic and memory have the highest significance levels which are sustained over various probability categories. This is in line with our theory as capacity investment probabilities in these submarkets affect the overall industry evolution patterns, after controlling for own submarket dynamics. H1a is tested in the first five columns of Table 6. It can be seen that completed investments (P=1.0) on entry levees by incumbents in analog, logic, and memory submarkets significantly decrease the number of entrants into those submarkets (entry deterrence), whereas they all significantly increase the number of entrants into discrete submarkets (entry diversion), even after controlling for submarket fixed effects,[25] own submarket capacity trends, firm age, and technology.

---------- Insert Table 6 here ----------

H1b tests the link between entry diversion and opening new submarkets via product innovation. Completed investments in analog, logic and memory submarkets all significantly increase the number of submarkets. Furthermore, the pattern is sustained for many probability categories for logic and memory, i.e., even announcing capacity investments in these submarkets (without any considerable money put down by firms) increase product innovation and introduction of new submarkets in the industry. H1c tests entry diversion looking at changes in annual output of submarkets. Completed investments in discrete submarket decrease the capacity in that submarket (entry deterrence), whereas it increases capacity investments in MEMS (entry diversion). Completed investments and expansions in logic and memory also significantly

[25] Submarket fixed effects include 27 dummies for the submarkets we identified before.

increase MEMS capacity. Similarly, one year after money is down in logic and announcements are made in memory; analog submarket output significantly increases.

The test of H1d provides similar results to H1a, thus they are not reported here. The number of firms in MEMS and discrete are gradually increasing, and increased capacity investments in analog, logic and memory significantly explain these patterns. Overall, incumbents, mainly in the memory and logic submarkets, credibly announce to increase their capacities and push the entrants as much as they can to other submarkets. In these commodity submarkets, we see exactly what Klepper (1996) theorized about cost-efficient incumbents focusing on process innovation. Through wafer size enlargement, geometry shrinkage, and capacity installations, incumbents grow in size, causing new entry to decrease and eventually stop (recall from Table 5 that there are practically no new entrants into the memory and logic submarkets). Increasing returns to size is at the cost of entrants and weaker incumbents, as it increases minimum efficient scale for profitably operating and eventually creates the shakeout in these submarkets.[26] This process can be seen in Figure 5.

---------- Insert Figure 5 here ----------

On the other side, in submarkets where 'scaling manufacturing' and 'commoditizing the product' do not work, such as in analog, MEMS, and discrete, we see a totally different pattern of industry evolution. In these submarkets, less-advanced technologies, smaller wafer sizes, and greater geometries lower the barriers of entry and, thus, investments needed to operate a fab. Entrants that lack the scale required for memory and logic submarkets divert their efforts towards these submarkets and in Figure 6, very distinct patterns from usual shakeouts appear. Even

[26] Shakeout occurs by the decrease in number of producers even if the output of the industry is increasing (Bhaskarabhatla and Klepper, 2012).

though these submarkets' outputs all are increasing over time, so do the number of firms; failing to create a shakeout.

---------- Insert Figure 6 here ----------

In order to explain the different evolutionary ILC patterns in Figures 5 and 6 and also evaluate H2, we focus on the distance between submarkets, which we proxy by change of submarkets within fabs. The product/class variable can take different values per fab over time, meaning that fabs can change submarkets over time. For example, long after building fabs, Intel dropped out of memory business and "diverted" those resources into microprocessors. Similarly, many companies entered the memory market over past three decades, and most failed within one or two technology generations, so these fabs were often diverted to making analog or mixed signal products, and more recently MEMS or discrete LED and power devices. Thus, many companies that were originally in logic/memory evolved towards discretes/analog/mixed signal/MEMS as a strategic choice to focus on those submarkets. Examples range from Texas Instruments, National, Fairchild, and Renesas. Table 7 depicts these changes and the distribution of 517 submarket transitions observed in our data which we utilized as our distance measure.

---------- Insert Table 7 here ----------

While logic submarket is equally distant to all submarkets but MEMS (especially the analog, discrete and logic submarkets are equally distant to each other); memory is only close to logic submarket. In line with the shakeout patterns observed in memory and logic, and non-shakeout patterns observed in analog, discrete, and MEMS submarkets, we can use our 2x2 matrix in Table 1 to allocate these submarkets with regard to memory, which experiences the typical shakeout pattern and is dominated by cost-efficient incumbents that divert entry to other submarkets (see Table 8). Logic, being the closest submarket to memory, experiences dominance case where the incumbents start a shakeout similar to the memory submarket. On the other extreme, MEMS is a submarket that recently took off where investments required are lower. Number of entrants and firms in total is increasing and not affected by a shakeout (yet) as it is far from almost every submarket, especially from memory and logic. Isolation case fits perfectly for this submarket.

Finally, it should be noted that there can be changes in overlaps, leading to movements of submarkets between categories. For example, with further increases in volume, standardizing production and shrinking geometries, MEMS might move towards commoditization which can create a latent shakeout in that submarket.

---------- Insert Table 8 here ----------

DISCUSSION AND CONCLUSION

Existing models of ILC cannot account for the dynamics of no-shakeout and disruption from new entrants. In this paper, we attempt to solve the puzzle between ILC irregularities of firm turnover and shakeout, and entry barriers with a new mechanism, 'entry diversion', to build a submarket based theory of industry evolution. Entry diversion provides the initial missing link of ILC to make it a theory that accounts for heterogeneity in the competitive landscape and disruptions from other submarkets. It also provides a way-out for researchers who have been unable to provide conclusive empirical evidence about entry barriers. Looking at submarket and firm level variables in global semiconductor manufacturing industry, we test our entry diversion framework, and find support for it. Even an announcement of a new fab in memory and logic submarkets, with no considerable investment- no money down, can divert the attention of entrants to move to other submarkets, controlling for own submarket dynamics.

The traditional entry barriers literature grounds itself in how entry barriers decrease entrants' output to zero or their profits below zero to deter their entry. Putting the 'entry diversion' lenses enrich this limited view in at least two ways: First, since entry diversion occurs between submarkets, instead of observing general attractiveness in an industry, entrants will take into account profitability of each submarket and compare them while making their entry decisions. Second, rather than decreasing entrants' output to zero or profits below zero (i.e., deterrence), entry diversion happens when expected profits from the focal submarket decrease below those of their second or third best option. In other words entry diversion alters entrants' incentives to enter one of those comparably less attractive submarkets.

Capacity additions are a natural function of demand growth. However, pursuing Moore's law has two sides: one is a demand related market trend, but it also has a supply side effect i.e., the push of the technology by incumbents is beyond the market needs.[27] This is exactly what we intend to show in this paper; continuous push of the technology by incumbents can also be driven by strategic responses to competitive pressures which forces semiconductor manufacturers to scale production aggressively in order to maintain their competitive position. Companies that cannot withstand this pressure, fails. Only the biggest survive; shakeout follows. In short, once the product of a submarket becomes a commodity, consolidation follows as manufacturers are trimmed to a handful of firms. New submarkets are opened by diverted entrants, their product innovation is not only driven by demand growth, but also that there is no room left for profitable entry in other submarkets.

Our theory is applicable to all industries regardless of whether they are fragmented into submarkets or not. Composed of many submarkets, like it is the case in semiconductor

[27] In recent years, the technology race created overshot customers everywhere; we have now PCs and laptops that have faster MPUs than needed by the average Internet browser and MS Office user customer. The scaling-based technology race is not always based on demand opportunities.

manufacturing industry, some industries offer enough space for entrants to escape competition. Being diverted sufficiently far away from submarkets dominated by large and cost-efficient incumbents, entrants can evade unavoidable deaths due to shakeouts and have enough time and space for gaining a foothold in the industry. When there is not enough space to hide, incumbents sooner or later create a shakeout and convert the industry to one big homogenous market. In addition, the fundamental attribute of our theory – that different patterns of evolution can be observed with different appropriability conditions from technology and market sides– provides a novel insight into confusing views about 'why shakeouts do not occur?' Industries that are notorious for their latent (or no) shakeouts and continuous change in leaders such as lasers and disk drives (Buenstorf, 2007) perplexed even prominent scholars. A good example is Steven Klepper and his co-authors' progression in their understanding of the U.S. laser industry during a series of their papers on submarkets. In 1990s, laser industry is acknowledged by Klepper and Graddy (1990) and Klepper and Miller (1995) to be relatively young and not yet reached the point of shakeout;[28] when we look at his later studies, Klepper and Thompson (2006) illustrated with data that a steady growth in the number of producers is experienced over the 35 years of the industry with no shakeouts. The reflection on this same empirical irregularity is stated by Buenstorf (2007) for German laser industry: 'Similar to U.S., no shakeout is observed over the four decades of evolution in the German laser industry' (p. 180). Soon after, in their ongoing research, Bhaskarabhatla and Klepper (2012) crafted the submarket model to account for the latent shakeout in the industry which started recently (and it is still going on). The reason of this

[28] These two studies use Gort and Klepper (1982)'s data which has coverage until 1981.

delusion is simply that the laser industry had not reached the 'shakeout-point' yet.[29] Our entry diversion framework resolves these types of incomplete conclusions.

All in all, we believe our effort can be taken as a first step to illuminate the roadmap for research on competitive dynamics in ILC and improvement of entry barriers theories. A key takeaway of entry diversion framework is that what matters for survival of incumbents is related to whether they can keep up with industry evolution, both on the technology and market side. For the entrants, the corollary is that if the diverted entrants' submarket is too close (or overlapping) with the main submarket, start-ups and new entrants to this new submarket have little chance to survive. We hope that our developed framework and analysis can attract additional scholarly attention through which questions on industry evolution theories in general, and submarkets in particular can be effectively addressed.

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[29] This view is in line with overshooting models of Dixit and Shapiro (1986), Cabral (1993), and Klepper and Miller (1995), in which a certain number of firms, N*, can profitably be supported by the market. Once this point is overshot by the entrants, shakeout happens. Even though the overshooting models predict that a gradual ascendance to the peak number of firms lowers the probability of overshooting N*, thus the shakeout; Klepper and Miller (1995, p.582) state that these models generally fall short of accommodating the length and pre-peak periods of shakeouts, on which we focus as irregularities here.

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Table 1. Market and Technology Overlap between Submarkets

		Technology overlap with new submarket	
		High	Low
Market overlap with new submarket	High	Dominance	(Technology) Disruption
	Low	(Market) Disruption	Isolation

Table 2. Semiconductor manufacturing industry submarkets.

Initial submarkets		After organizing		Main Submarkets
Analog/Linear	Logic/Flash	Analog/Linear	Logic/System LSI	Analog
Analog/Mixed Signal	Logic/MCU	Analog/Mixed Signal	Memory/DRAM	Discrete
Analog/Other	Logic/MPU	Analog/Other	Memory/DRAM&Flash	Logic
Discrete/Diode	Logic/MPU&Flash	Discrete/Diode	Memory/Flash	MEMS
Discrete/LED	Logic/Opto	Discrete/LED	Memory/MRAM	Memory
Discrete/Opto	Logic/Other	Discrete/Opto	Memory/Other	
Discrete/Other	Logic/Power	Discrete/Other	Memory/SRAM	
Discrete/Power	Logic/System LSI	Discrete/Power	MEMS	
Discrete/Rectifier	Memory/DRAM	Discrete/Rectifier		
Discrete/Thyristor	Memory/DRAM&Flash	Discrete/Thyristor		
EPI	Memory/Flash	Logic/DSP		
Foundry/Dedicated	Memory/MRAM	Logic/Embedded		
Foundry/DRAM	Memory/Other	Logic/Flash		
Foundry/IDM	Memory/SRAM	Logic/MCU		
Foundry/MEMS	MEMS	Logic/MPU		
Foundry/R&D	Pilot	Logic/MPU&Flash		
Foundry/System LSI	R&D	Logic/Opto		
Logic/DSP	R&D-Pilot	Logic/Other		
Logic/Embedded		Logic/Power		

Table 3. 2-year Probability transition matrix for future fabs.

Probability Category	2 years later Rumored	Announced	Money down	Completed	Expansion	Total
Rumored	60	25	20	10	0	115
	52.17%	21.74%	17.39%	8.70%	0%	100.00%
Announced	36	111	79	60	0	286
	12.59%	38.81%	27.62%	20.98%	0%	100.00%
Money down	8	13	114	324	13	472
	1.69%	2.75%	24.15%	68.64%	2.75%	100.00%
Completed	5	8	18	8,638	259	8,928
	0.06%	0.09%	0.2%	96.75%	2.9%	100.00%
Expansion	0	0	0	171	229	400
	0%	0%	0%	42.75%	57.25%	100%
Total	109	157	231	9,203	501	10,201
	1.07%	1.54%	2.26%	90.22%	4.91%	100%

Table 4. Consolidation over wafer size: Companies building fabs.(Source: SEMI™)

150 mm Fabs	200 mm Fabs	300 mm Fabs	450 mm Fabs
AMD	AMD	AMD (now Global Found.)	
Intel	Intel	Chartered Semi (now Global Found.)	
Dallas Semi.	1st Silicon	Flash Alliance	
Harris	Altis	IBM	
Hitachi	AMI Semi.	IM Flash	
Kawasaki Steel	Anam Semi.	Intel	
Lucent	Cypress	Qimonda	
Motorola	Dominion	Powerchip	**3? 4? companies**
Nippon Steel	Grace Semi.	ProMOS	
Siemens	LSI Logic	RexChip	
SONY	Motorola	Samsung	
VLSI Technology	National	SMIC	
Yamaha…	SMIC	SONY…	
100 or more companies in total	SONY	**~30 companies**	
	Vanguard…		
	~70 companies		

Table 5. New fab entry by submarkets every year.

Submarkets	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Analog/Linear	1	0	0	1	0	1	1	0	0	1	0	0	0	0	0
Analog/Mixed Signal	1	1	2	3	2	0	3	3	2	1	1	1	3	0	0
Analog/Other	0	0	2	3	0	2	0	3	1	1	2	0	0	0	0
Discrete/Diode	1	1	1	4	0	0	1	0	1	0	5	4	1	0	2
Discrete/LED	0	0	0	0	0	1	0	0	0	0	0	66	65	28	7
Discrete/Opto	0	3	8	6	7	2	8	11	5	3	9	14	4	2	4
Discrete/Other	0	1	3	1	0	1	0	7	2	2	7	5	0	0	0
Discrete/Power	1	2	8	7	3	6	5	4	5	5	2	7	4	3	2
Discrete/Rectifier	2	0	0	0	0	0	0	1	0	1	4	2	0	0	0
Discrete/Thyristor	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1
Logic/DSP	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Logic/Embedded	0	0	4	0	2	1	2	3	1	0	1	0	0	0	0
Logic/Flash	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Logic/MCU	0	0	0	0	0	3	2	1	1	0	0	0	0	0	0
Logic/MPU	1	3	5	2	1	1	1	4	2	0	0	0	5	0	0
Logic/MPU&Flash	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Logic/Opto	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Logic/Other	1	6	10	10	7	13	13	4	6	7	3	2	5	1	2
Logic/Power[30]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Logic/System LSI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MEMS	0	0	0	2	1	4	8	7	13	2	5	6	5	3	4
Memory/DRAM	0	4	3	2	4	2	7	14	3	5	1	0	0	0	0
Memory/DRAM&Flash	0	0	0	0	2	0	0	0	3	1	1	0	1	2	3
Memory/Flash	0	4	3	0	1	0	6	3	4	4	1	0	0	2	0
Memory/MRAM	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
Memory/Other	0	1	1	1	0	0	3	1	0	0	0	0	0	0	0
Memory/SRAM	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0

[30] Logic/Power and Logic/System LSI did not receive any new entry, but some existing fabs were re-classified by SEMI™.

Table 6. Entry diversion in number of entrants, number of submarkets, and capacity per year

	(H1a) - number of entrants					(H1b)	(H1c) - capacity per year				
VARIABLES[1]	Analog	Discrete	Logic	MEMS	Memory	Nosubmarkets	Analog	Discrete	Logic	MEMS	Memory
Analog*rumored	-4.15e-05	-0.00239	-0.000248	-0.000567	0.000119	0.000102	0.000151	-3.44e-05	0.000206	0.000200	0.000293
	(0.000190)	(0.00541)	(0.000331)	(0.000712)	(0.000120)	(0.000549)	(0.000161)	(5.74e-05)	(0.000237)	(0.000137)	(0.000335)
Analog*announced	-4.76e-05	-0.000260	-5.89e-05	-1.39e-06	-1.37e-05	0.000130*	4.83e-05**	-8.28e-06	6.29e-05**	3.11e-05	0.000116***
	(3.11e-05)	(0.000883)	(5.41e-05)	(0.000116)	(1.96e-05)	(7.60e-05)	(1.98e-05)	(9.35e-06)	(2.93e-05)	(2.23e-05)	(4.25e-05)
Analog*money_down	1.51e-05**	-9.61e-05	-1.54e-05	3.36e-05	6.37e-06	-1.98e-06	-1.64e-06	5.20e-06**	-1.84e-06	-5.61e-06	-3.84e-06
	(7.11e-06)	(0.000202)	(1.24e-05)	(2.66e-05)	(4.48e-06)	(1.37e-05)	(3.19e-06)	(2.17e-06)	(4.75e-06)	(5.12e-06)	(7.01e-06)
Analog*completed	-3.22e-06*	8.71e-05*	-1.15e-05***	6.39e-06	-8.44e-07	7.46e-06*	1.43e-06	-2.34e-07	1.95e-06	8.93e-07	5.00e-06**
	(1.86e-06)	(5.28e-05)	(3.23e-06)	(6.96e-06)	(1.17e-06)	(3.86e-06)	(9.01e-07)	(6.02e-07)	(1.34e-06)	(1.34e-06)	(1.98e-06)
Analog*expansion	-4.30e-07	-3.29e-05	-1.35e-06	3.00e-06	1.12e-06	-1.36e-07	1.97e-07	2.34e-07	2.18e-07	-8.73e-08	8.46e-07
	(1.28e-06)	(3.64e-05)	(2.23e-06)	(4.80e-06)	(8.07e-07)	(2.26e-06)	(5.24e-07)	(3.89e-07)	(7.79e-07)	(9.21e-07)	(1.15e-06)
Discrete*rumored	-0.000114	-0.00360	0.000587	-0.00129	-0.000413	0.000587	7.47e-05	-0.000108	0.000231	-6.63e-05	0.000254
	(0.000607)	(0.0173)	(0.00106)	(0.00227)	(0.000382)	(0.00125)	(0.000298)	(0.000182)	(0.000443)	(0.000437)	(0.000653)
Discrete*announced	5.62e-06	-6.63e-05	9.43e-06	1.52e-05	2.94e-06	-1.29e-05	-2.90e-07	1.14e-06	-7.79e-07	-3.51e-06	-5.17e-07
	(5.84e-06)	(0.000166)	(1.02e-05)	(2.19e-05)	(3.68e-06)	(1.01e-05)	(2.33e-06)	(1.74e-06)	(3.47e-06)	(4.20e-06)	(5.13e-06)
Discrete*money_down	-3.65e-06	-8.50e-05	-4.87e-06	1.24e-06	-1.06e-06	5.66e-06	2.17e-06	-7.20e-07	2.21e-06	1.37e-06	5.55e-06
	(2.67e-06)	(7.59e-05)	(4.65e-06)	(1.00e-05)	(1.68e-06)	(6.46e-06)	(1.68e-06)	(8.03e-07)	(2.48e-06)	(1.92e-06)	(3.60e-06)
Discrete*completed	-5.84e-06***	9.69e-05	-5.68e-06	-7.33e-06	-1.82e-06	7.86e-07	9.05e-07	-1.67e-06**	2.92e-07	3.77e-06**	4.80e-06*
	(2.15e-06)	(6.11e-05)	(3.74e-06)	(8.05e-06)	(1.35e-06)	(4.81e-06)	(1.13e-06)	(6.91e-07)	(1.68e-06)	(1.55e-06)	(2.48e-06)
Discrete*expansion	3.66e-07	6.01e-05*	7.40e-07	-1.49e-06	-3.20e-07	-1.37e-06	-7.14e-07	-1.97e-07	-8.83e-07	4.62e-08	-1.46e-06
	(1.19e-06)	(3.37e-05)	(2.06e-06)	(4.44e-06)	(7.47e-07)	(2.13e-06)	(4.93e-07)	(3.65e-07)	(7.34e-07)	(8.53e-07)	(1.08e-06)
Logic*rumored	-1.65e-05	-0.000761	5.36e-05	3.41e-05	1.40e-05	9.51e-05	2.09e-05	7.89e-06	3.53e-05	9.46e-06	5.49e-05
	(2.26e-05)	(0.000642)	(3.93e-05)	(8.46e-05)	(1.42e-05)	(7.37e-05)	(1.94e-05)	(7.20e-06)	(2.87e-05)	(1.62e-05)	(4.16e-05)
Logic*announced	-2.73e-07	5.54e-06	-2.27e-07	-1.65e-07	-2.59e-08	8.74e-07*	1.88e-07	-5.60e-08	3.29e-07*	2.12e-07	4.42e-07*
	(2.50e-07)	(7.12e-06)	(4.36e-07)	(9.39e-07)	(1.58e-07)	(4.90e-07)	(1.16e-07)	(7.52e-08)	(1.72e-07)	(1.80e-07)	(2.54e-07)
Logic*money_down	-8.43e-08**	-1.72e-07	-9.69e-08*	-3.18e-08	-1.93e-08	3.55e-07***	1.17e-07***	-1.43e-08	1.69e-07***	3.82e-08	2.62e-07***
	(3.36e-08)	(9.55e-07)	(5.85e-08)	(1.26e-07)	(2.12e-08)	(9.33e-08)	(2.59e-08)	(1.02e-08)	(3.82e-08)	(2.42e-08)	(5.48e-08)
Logic*completed	-1.82e-07***	2.14e-06*	-2.20e-07***	-1.79e-07	-4.95e-08*	2.18e-07***	7.85e-08***	-5.62e-08***	7.93e-08***	9.46e-08***	2.46e-07***
	(4.15e-08)	(1.18e-06)	(7.22e-08)	(1.55e-07)	(2.61e-08)	(8.14e-08)	(1.92e-08)	(1.28e-08)	(2.85e-08)	(2.99e-08)	(4.20e-08)
Logic*expansion	-1.07e-07**	4.27e-07	-9.20e-08	-1.99e-07	-4.02e-08	4.91e-08	2.57e-08	-4.07e-08***	1.46e-08	5.92e-08**	1.03e-07***
	(4.17e-08)	(1.19e-06)	(7.27e-08)	(1.56e-07)	(2.63e-08)	(7.36e-08)	(1.70e-08)	(1.27e-08)	(2.53e-08)	(3.00e-08)	(3.75e-08)
MEMS*rumored	0	0	0	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
MEMS*announced	0.00917	-0.0190	0.0144	0.0251	0.00491	-0.0133	-0.000602	0.00279	-0.000283	-0.00539	-0.00367
	(0.00770)	(0.219)	(0.0134)	(0.0289)	(0.00486)	(0.0130)	(0.00300)	(0.00228)	(0.00446)	(0.00554)	(0.00661)
MEMS*money_down	5.80e-05	0.0127*	0.000232	0.000672	-0.000175	0.000399	3.98e-05	1.37e-05	0.000113	0.000157	4.35e-05
	(0.000270)	(0.00768)	(0.000470)	(0.00101)	(0.000170)	(0.000488)	(0.000113)	(8.07e-05)	(0.000169)	(0.000194)	(0.000249)
MEMS*completed	3.56e-07	-3.56e-05	1.70e-06	-3.72e-06	3.18e-07	-8.72e-06	-1.67e-06	-1.48e-07	-1.86e-06	-3.97e-07	-4.17e-06
	(1.43e-06)	(4.06e-05)	(2.49e-06)	(5.35e-06)	(9.00e-07)	(5.41e-06)	(1.35e-06)	(5.13e-07)	(1.99e-06)	(1.03e-06)	(2.92e-06)
MEMS*expansion	5.83e-06	-0.000153	-2.22e-06	-1.86e-05	1.52e-06	2.03e-06	-1.26e-06	2.36e-06*	3.91e-07	-3.55e-06	-2.68e-06
	(4.27e-06)	(0.000121)	(7.44e-06)	(1.60e-05)	(2.69e-06)	(7.46e-06)	(1.73e-06)	(1.29e-06)	(2.58e-06)	(3.07e-06)	(3.81e-06)

Table 6. Entry diversion in number of entrants, number of submarkets, and capacity per year (continued)

	(H1a) - number of entrants					(H1b)	(H1c) - capacity per year				
VARIABLES[1]	Analog	Discrete	Logic	MEMS	Memory	Nosubmarkets	Analog	Discrete	Logic	MEMS	Memory
Memory*rumored	-2.09e-06	-7.92e-05	1.38e-05*	1.48e-06	3.96e-07	-1.16e-05	-1.98e-06	-1.37e-06	-5.08e-06*	-3.22e-06	-3.78e-06
	(4.68e-06)	(0.000133)	(8.15e-06)	(1.75e-05)	(2.95e-06)	(7.91e-06)	(1.83e-06)	(1.39e-06)	(2.72e-06)	(3.37e-06)	(4.02e-06)
Memory*announced	-3.08e-08	9.97e-07	-6.34e-08	6.24e-08	-4.11e-09	2.38e-07***	6.44e-08***	-5.42e-09	9.05e-08***	2.54e-08	1.67e-07***
	(3.69e-08)	(1.05e-06)	(6.42e-08)	(1.38e-07)	(2.33e-08)	(8.00e-08)	(1.95e-08)	(1.11e-08)	(2.89e-08)	(2.65e-08)	(4.24e-08)
Memory*money_down	-3.72e-08**	3.12e-07	-5.88e-08**	-2.12e-08	5.57e-09	1.10e-07***	3.29e-08***	-5.49e-09	4.37e-08***	1.71e-08	8.93e-08***
	(1.47e-08)	(4.18e-07)	(2.56e-08)	(5.51e-08)	(9.27e-09)	(3.34e-08)	(8.19e-09)	(4.46e-09)	(1.22e-08)	(1.06e-08)	(1.78e-08)
Memory*completed	-6.82e-08***	6.58e-07*	-7.28e-08***	-5.48e-08	-2.55e-08***	6.76e-08**	3.30e-08***	-2.00e-08***	2.97e-08***	3.48e-08***	1.00e-07***
	(1.22e-08)	(3.48e-07)	(2.13e-08)	(4.59e-08)	(7.72e-09)	(2.73e-08)	(6.55e-09)	(3.84e-09)	(9.73e-09)	(8.81e-09)	(1.43e-08)
Memory*expansion	-3.49e-08***	1.21e-07	-4.09e-08**	-5.15e-08	-6.24e-09	7.64e-09	8.77e-09	-1.14e-08***	4.65e-09	1.85e-08**	3.94e-08***
	(1.20e-08)	(3.41e-07)	(2.09e-08)	(4.49e-08)	(7.55e-09)	(2.30e-08)	(5.36e-09)	(3.71e-09)	(7.97e-09)	(8.62e-09)	(1.18e-08)
age	-0.00505*	0.664***	-0.0393***	0.0696***	-0.00389**	0.432***	0.140***	0.00845***	0.206***	0.00351*	0.280***
	(0.00273)	(0.0776)	(0.00475)	(0.0102)	(0.00172)	(0.00766)	(0.00185)	(0.000932)	(0.00275)	(0.00196)	(0.00404)
age2	9.83e-05	-0.00680***	0.000319***	-0.000677***	3.37e-05	-0.00244***	-0.000745***	-8.63e-05***	-0.00110***	-7.75e-05*	-0.00138***
	(6.51e-05)	(0.00185)	(0.000113)	(0.000244)	(4.10e-05)	(0.000196)	(4.73e-05)	(2.27e-05)	(7.03e-05)	(4.68e-05)	(0.000103)
geom	-0.00598	-1.110***	0.0653***	-0.129***	0.00782	-0.516***	-0.134***	-0.0164***	-0.211***	0.00631	-0.256***
	(0.00763)	(0.217)	(0.0133)	(0.0286)	(0.00481)	(0.0375)	(0.00994)	(0.00290)	(0.0147)	(0.00549)	(0.0213)
wafsiz	0.00652	2.101***	-0.124***	0.244***	-0.00796**	0.571***	0.138***	0.0268***	0.206***	-0.00542	0.296***
	(0.00591)	(0.168)	(0.0103)	(0.0221)	(0.00372)	(0.0231)	(0.00603)	(0.00212)	(0.00892)	(0.00425)	(0.0129)
Constant	1.103***	-2.506	3.063***	1.207***	0.610***	16.49***	3.401***	3.810***	4.387***	4.232***	5.143***
	(0.0677)	(1.925)	(0.118)	(0.254)	(0.0427)	(0.292)	(0.0758)	(0.0252)	(0.112)	(0.0487)	(0.163)
Observations	9,708	9,708	9,708	9,708	9,708	9,708	9,708	9,708	9,708	9,708	9,708
Number of fabs	1,333	1,333	1,333	1,333	1,333	1,333	1,333	1,333	1,333	1,333	1,333
Submarket FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Wald chi2	646.9***	645.7***	911.0***	353.6***	157.1***	15726***	27302***	703.6***	26554***	314.2***	24379***
R-square (overall)	0.0628	0.0627	0.0862	0.0353	0.0160	0.136	0.110	0.0598	0.110	0.0315	0.120

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

[1] All variables except controls are in lagged form

Table 7. Submarket changes within fabs.

	Submarket	To: Analog	Discrete	Logic	MEMS	Memory	Total
From	Analog	8	13	12	4	-	37
		21.62%	35.14%	32.43%	10.81%	-	100%
	Discrete	18	50	21	4	-	93
		19.35%	53.76%	22.58%	4.3%	-	100%
	Logic	36	33	85	5	32	191
		18.85%	17.28%	44.5%	2.62%	16.75%	100%
	MEMS	-	-	-	-	-	-
		-	-	-	-	-	-
	Memory	12	4	101	1	78	196
		6.12%	2.04%	51.53%	0.51%	39.8%	100%
	Total	74	100	219	14	110	517
		14.31%	19.34%	42.36%	2.71%	21.28%	100%

Table 8. Submarket evolution between memory and other submarkets

		Technology overlap with new submarket	
		High	Low
Market overlap with new submarket	High	Dominance - Logic	(Technology) Disruption
	Low	(Market) Disruption	Isolation – Discrete, MEMS, Analog

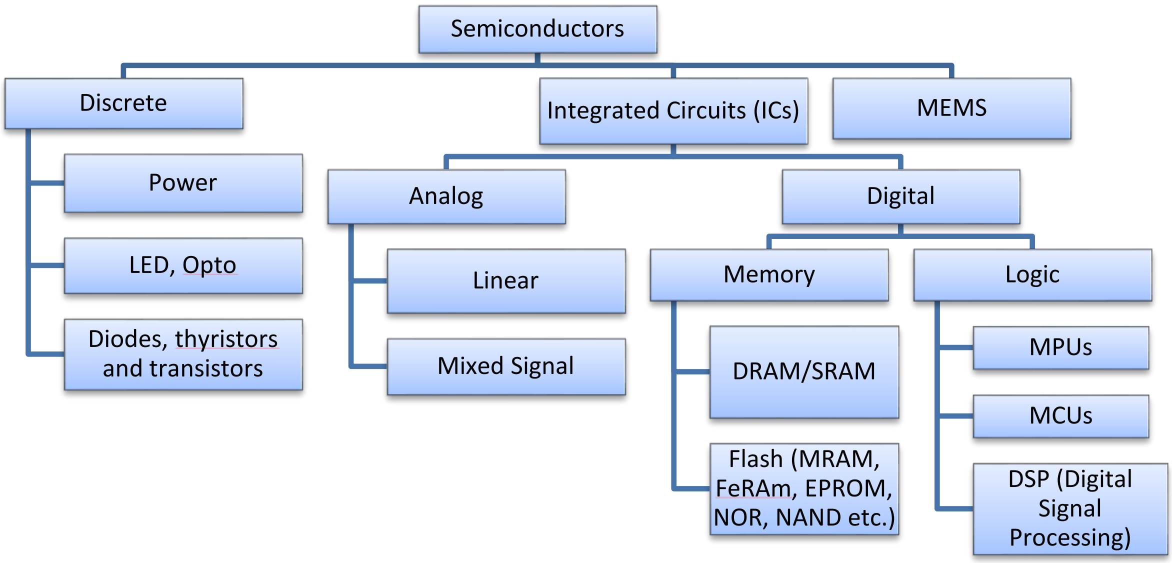

Figure 1. Structure of submarkets in the semiconductor manufacturing industry

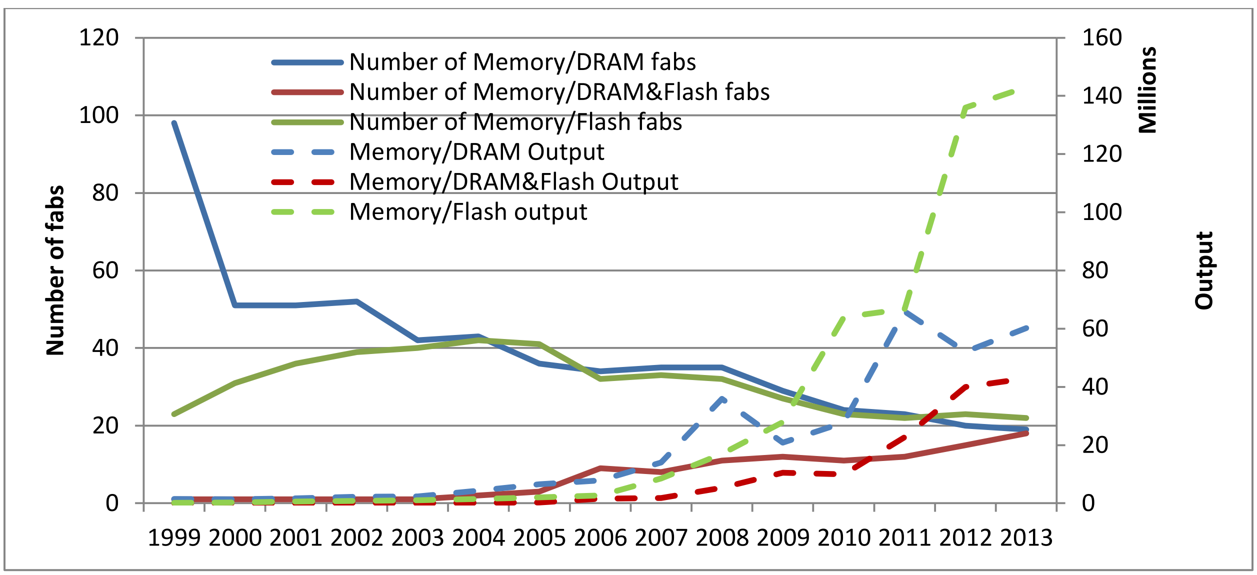

Figure 2. Flash and DRAM memory fab capacities over time (Source: Own compilation)

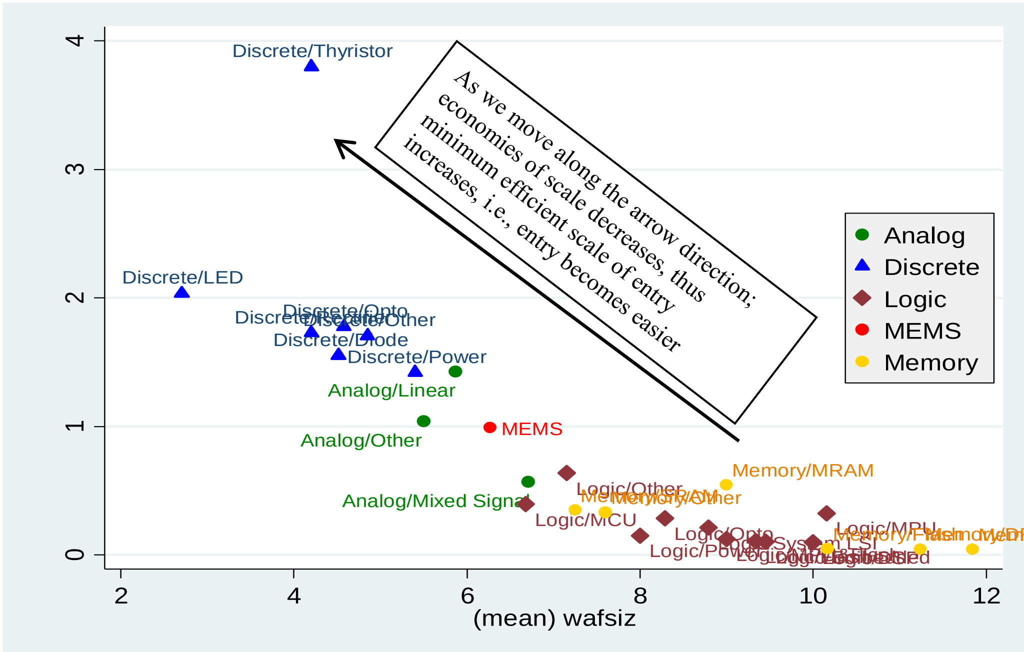

Figure 3. Semiconductor manufacturing submarkets map

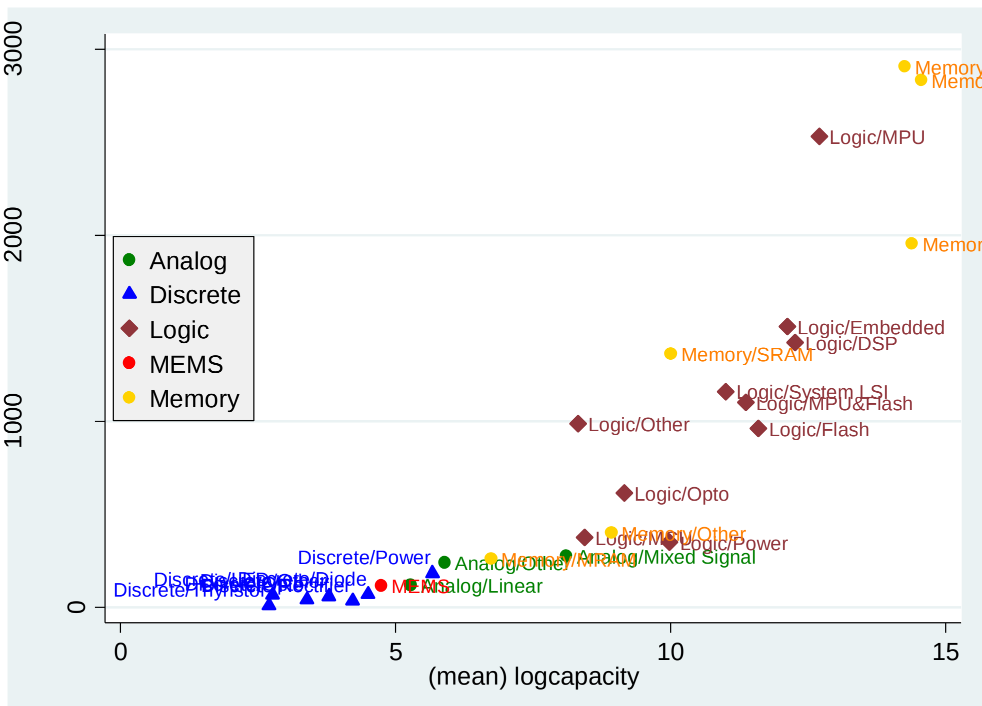

Figure 4. Fab capacities and investments by submarkets

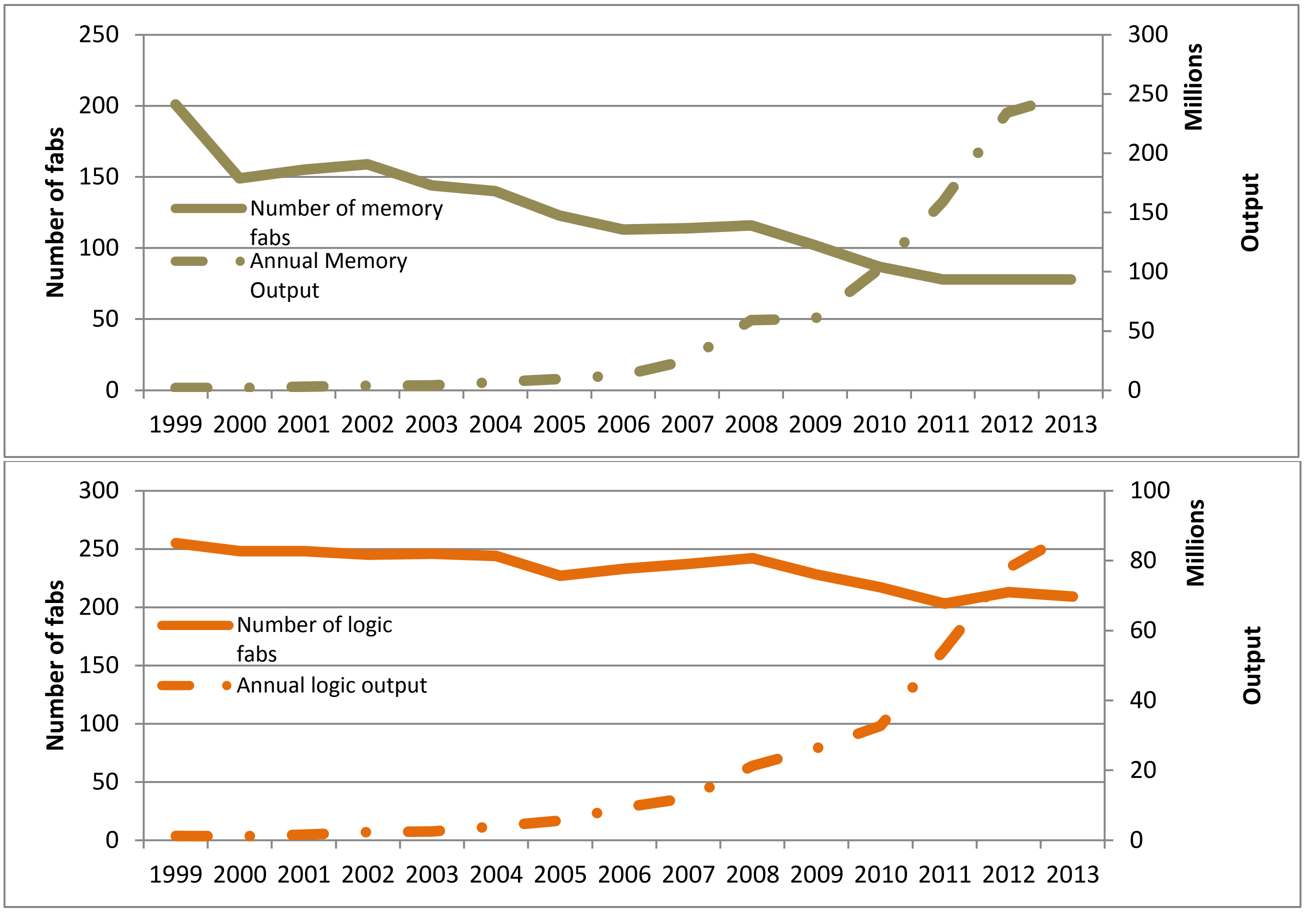

Figure 5. Shakeout in Memory and Logic submarkets

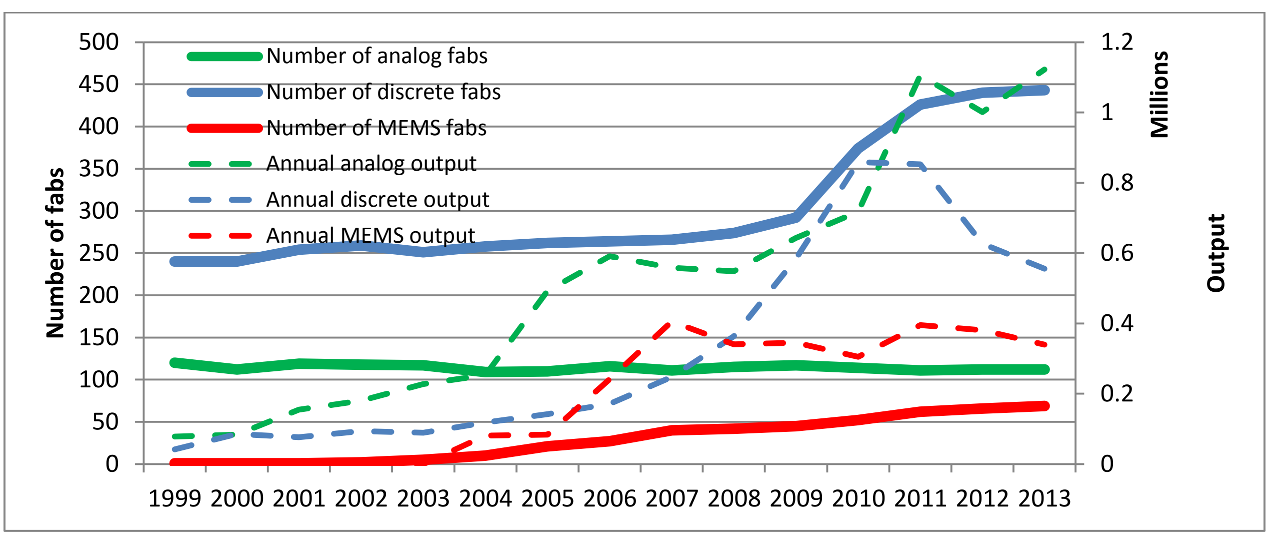

Figure 6. Evolution in Analog, Discrete, and MEMS submarkets