Within-Industry Diversification, Product Innovation, and Firm Performance: Evidence from the Integrated Circuit industry

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The semiconductor industry is widely recognized as a key driver for economic growth in its role as a technology enabler for the whole electronics market. Transistors and integrated circuits, first introduced at the beginning of the '50, have been applied in an increasing range of industries: computers, telecommunications, consumer electronics, automobile, aerospace and military sector, home appliances, industrial systems, etc. The present work is built upon the new trajectories occurring in the industry and attempts to analyse the impact of both within-industry diversification and product innovation on firm performance[1]; in particular, it focuses on IC's segment.

Semiconductors have been widely investigated in applied economics research. An extensive literature described the historical evolution of the industry (Braun and McDonald, 1978), patterns of international diffusion of technology (Tilton, 1971; Malerba, 1985), the relation between market structure and technological paradigms (Dosi, 1984), and the formation of semiconductor firms clusters in Silicon Valley and Taiwan (Saxenian, 1994, 2001; Mathews, 1997). Other contributions concentrated on the vertical disintegration of the industry and the occurrence of the fabless/foundries business mode[2] (Macher, Mowery, and Hodges, 1998; Langlois and Steinmueller, 1999; Langlois, 2000; Macher, Mowery, and Simcoe, 2002; Linden and Somaya,2003). Particular attention has been devoted to the patent activity of semiconductor producers, its determinants and impact on firm's performance (Poldony et al, 1996; Grindley and Teece, 1997; Teece 2000; Stuart 2000; Hall and Ziedonis 2001), and the role of capabilities and learning economies in strategic product innovation (Gruber, 1994, 1995; Iansiti and West, 1999; Macher and Mowery, 2003). However, further investigation is required to shed light on firms' heterogeneity in terms of assets, product portfolio strategies, and innovative behavior. Starting from within industry diversification, this issue appears extremely important but it received little attention in the otherwise extensive semiconductor literature; at the same time, both the existing literature on *within-industry* diversification and on incremental product innovation lack of empirical evidence concerning this interesting and peculiar industry. Taking the peculiarities of the industry, we would expect that a higher diversification within the same product family (where activities are related by input factors, functional technology, degree of customization) will positively affects firm performance. On the contrary, we are sceptic about the effect of diversification across product classes belonging to different product families.

Hypothesis 1: Diversification in IC's product classes, belonging to the same product Family, positively affects firm performance.

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[1] We use Market share as firm performance measure

[2] Fabless are firms which design and commercialize semiconductor devices, outsourcing fabrication services to specialized contract manufacturers called foundries. Integrated device manufacturer (IDM) are firms which perform in house all the stages along the value chain.

Research based on the "*object*" approach to innovation indicators (Kleinknecht et al, 2002; Smith, 2004) provided precious insights on issues broadly debated in the technology and innovation literature, and generally addressed by means of traditional innovation indicators like R&D expenditures and counts of patents. Empirical evidence coming from this stream of literature emphasize that it doesn't appear to be any evidence for increasing return to R&D expenditures exist in producing innovation output (Acs and Audretsch,1987; 1988; 1993), while innovating firms tend to have a permanent higher profitability than non-innovating competitors that is not closely related with the introduction of a specific innovation (Geroski et al, 1993; Banbury and Mitchell, 1995; Roberts, 1999). Drawing on this literature, we examine whether a firm's ongoing ability to introduce substantially innovative products affects its performance, within the IC industry, an economic environment characterized by a very short product life cycle. We predict that:

Hypothesis 2: Own introduction of incremental innovative products, in a product class, on a timely base, positively affects firm's market share.

We take account, also, for the impact of rivals' innovation behaviour on the focal firm performance and for potential innovation spillovers across different IC segments. Empirical support for the role of competition as a spur to performance comes from recent econometric research using a variety of performance measures (Nickell (1996; Aghion, Bloom, Blundell, Griffith & Howitt (2002); Kwoka, 1996; Neven & Roeller, 1996; Ng & Seabright, 2001;Nicoletti & Scarpetta, 2003; Bloom N et al, (2005)) IC industry is the largest segment in the semiconductor market, representing about the 84% of total revenues and it is characterized by high and unstable rates of growth and a pervasive concentration process, started in the early'90. This phenomenon is characterizing the IC's segment, leading the industry towards an *inverted pyramid model* era where few firms control a large share of total revenues leaving very few room for second tier competitors and start ups.

Hypothesis 3: Rivals' introduction of incremental innovative products in a product class, on a timely base, has a negative impact on firm's market share.

Moreover, we take account for the impact of rivals' innovation behaviour on the focal firm performance and for potential innovation spillovers across different IC segments.

Innovation spillovers have been a major topic of economic and managerial research over the last thirty years. Theoretical studies have explored the impact of research and development (R&D) on strategic interaction among firms and long run growth, and while many empirical studies appear to support the presence of technological spillovers, there remains a major problem at the heart of the literature due to the role of product market rivals. Spillovers arising from the innovation process, in fact, may benefit firm performance, but unlike economies of scope they affect output irrespective of expenditures (Henderson and Cockburn, 1996). A company's sales in a given product class may be positively affected by its own innovations or other companies' innovations in different product class belonging to different product families.

Hypothesis 4: Market share is positively associated with Internal innovation spillovers between product classes belonging to different families.

The type of innovations described above is a case of autonomous innovations – i.e. they can be pursuit independently from each other. In this situation, a decentralized organization can manage their development and commercialization more efficiently than a vertical integrated manufacturer (Chesbrough and Teece, 1996), and innovation spillovers may arise across the boundaries of the firm. In the semiconductor industry the adoption of the *Complementary Metal-Oxide Semiconductor (CMOS) process* facilitated the division of labour between fabless and foundries (Macher et al 1998), promoting the development of independent innovations that can be later interconnected by means of standard interfaces. One further hypothesis of this article is that:

Hypothesis 5: Market share is positively associated with External innovation spillovers between product classes belonging to different families.

We have presented five hypotheses that we believe represent key relationships between diversification, product innovation an d firm's performance. Our next step is to test these hypotheses in a large sample of product introduction in IC industry.

The empirical analyse exploits quantitative data on firms' performance and product innovation at the firm-niche level. We address these issues identifying major market niches within the IC industry according to a taxonomy elaborated by STMicroelectronics and using data from the iSuppli's Competitive Landscaping tool, a comprehensive database providing sales figures of more than 200 semiconductor producers over a large number of semiconductor segments; moreover, we collected all trade magazine articles announcing a new semiconductor product during the period 1999-2003. Trade magazine articles were downloaded from the Gale Thompson's PROMPT database and Markets and Industry News database. In a period of one year and a half we read those articles and classified them in order to: 1) select announcements describing product introductions, holding aside other events like product enhancement, product information, product development[3]; 2) delete all announcements describing the same product; 3) keep in the database only announcements referring to integrated circuits. We use a linear regression model to test the impact of diversification and innovation activity on market share (Buzzell and Wiersema, 1981; Robinson, 1990; Banbury and Mitchell, 1995). The model takes the form $MS = \beta X + \varepsilon$, where the market share of firm *j-th* in niche *i-th* at time *t* (MS_{ijt}) is explained by a vector of lagged linear covariates X_{ijt-1} with coefficient vector β (including an intercept) and an error term ε.

The empirical results and the managerial implications, will be provided in the full paper.

[3] The identification of a product introduction was based on the product part number that uniquely identifies each component in the company's catalogue. In few cases where the part number was not available the selection was based on the comparison of texts from different articles.