Effects of Acquisitions on Product and Process Innovation and R&D Performance

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Abstract

The starting point of our analysis is that acquisitions internalize different externalities for product and process innovations, which evoke a respective change in R&D investments and dynamic efficiency. On the basis of a game theoretical model where firms simultaneously invest in product and process innovation we deduct and empirically test hypotheses about the optimal R&D portfolio in acquisitions and in independently competing firms. The model also allows us to formulate and test hypotheses about the aggregate investment, performance, and dynamic efficiency of acquisitions. For empirical testing we use cross sectional data from the Italian part of the first Community Innovation Survey, which cover 18467 firms across all manufacturing industries and size groups in 1992. The empirical findings support the results of the formal analysis in various aspects. Firms involved in acquisitions do invest in different R&D portfolios than independent firms, i.e. more in product and less in process innovation. Furthermore, they invest at least an equal amount in aggregate R&D. However, the empirical results also show that our hypotheses do not hold with regard to dynamic efficiency, since acquisitions lead to a comparatively worse overall R&D performance.

Keywords: Merger & Acquisition; Dynamic Efficiency; Process Innovation, Product Innovation
JEL: L1, L22, O31

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1. Introduction

An intensively debated question in U.S. and European antitrust regulation is whether merger policy should move beyond its traditional static focus on market power (allocative efficiency) and production efficiency (X-efficiency) to incorporate innovation and dynamic efficiency.\(^2\) The body of literature in this area is still very limited and most studies that analyze the effects of mergers and acquisitions on dynamic efficiency refer to innovative activities in general, regardless whether they are focused on processes or products. We argue that exactly this distinction between product and process innovation is important to fully understand the effects of acquisitions on dynamic efficiency.\(^3\) If product and process innovations have different externalities, changes in dynamic efficiency through an acquisition also depend on the magnitude of internalization of these effects. An overpowering influence of only one dimension, either product or process innovation, could then determine aggregate innovative investment and performance. In this paper, we adapt an existing theoretical model and deduct testable hypotheses. We then empirically show that acquisitions do have different effects on product and process innovation, both, with regard to R&D investment, performance and dynamic efficiency.

Generally, we can distinguish between three strands of previous research in this area: (i) studies on product and process innovation in independently competing firms; (ii) studies on aggregate R&D (i.e. without the distinction between product and process) and dynamic efficiency in acquisitions; and (iii) studies on product and process innovation in joint ventures.

(i) From an individual firm’s perspective, innovation strategies often focus either on process innovation or on product innovation. Michael Porter (1980) argued that a firm’s strategic position within a broad-scope market is determined by one of two fundamental options s: offer the lowest price or differentiate your products. Firms that attempt to pursue both strategies simultaneously, he claims, become ‘stuck in the middle’ between conflicting demand and cost parameters. His reasoning is based on the simple economic trade-off that higher quality or better performing products often

\(^2\) For a comprehensive examination of the developing role of innovation in U.S. merger policy see Katz and Shelanski (2004).

\(^3\) Throughout this paper we will use the term ‘acquisition’ synonymous for ‘mergers and acquisitions’ or any other kind of shared funding or equity-based interest with (shared) decision control or coordination.
cost more to develop and produce. Although Porter (1980) considered the two strategies of cost reduction and differentiation to be basically incompatible, several empirical studies provide evidence that the trade-off may not be as strong as originally suggested (e.g. Miller and Friesen, 1986a, 1986b). In fact, they make a strong case that a firm’s advantage is rarely based entirely on costs or product differentiation and that both dimensions ought to be modelled and studied jointly. Such a less polarized world suggests that there exists an optimal level of investment in process R&D (cost reduction) and in product R&D (product differentiation). This notion is also widely accepted in innovation research, which stresses the general importance of an optimal mix in firms’ R&D portfolio. A prominent research path in industrial dynamics can be traced back to the seminal work of Abernathy and Utterback (1982), who introduced a technological life-cycle model of industries. It depicts the development of an industry from an initial ‘fluid’ stage, where market needs for a new technology are ill-defined and product innovation proliferates, to a final mature stage where there is a ‘dominant design’ and cost advantages as well as process innovation become the new critical factors to success. A number of theoretical and empirical studies usefully elaborate on this concept (Agarwal and Audretsch, 2001; Duranton, 2000; Klepper, 1996; Yin and Zuskovitch, 1998; Tushman and Anderson, 1986; Anderson and Tushman, 1990; Klepper and Graddy, 1990; and Suarez and Utterback, 1991), but without specific focus on the strategic interdependence of firms’ decisions or the role of acquisitions.

(ii) When we depart from the distinction between product and process innovations, we find a growing debate whether acquisitions lead to higher or lower aggregate levels of innovation and dynamic efficiency. Unfortunately, despite the importance of the subject, the number of empirical studies is still very limited. This might be connected to the fact that, apart from industrial organizational models on joint ventures (see below), the theoretical literature largely remains mute on this issue. Some empirical studies on the financial and economic performance of acquisitions consider the consequences on firms’ technological activities. However, aggregate results with regard to the influence of acquisitions on innovation levels turn out to be heterogeneous and difficult to compare: Empirical analyses in industrial organization reach no consensus, but tentatively point towards a more positive relationship (Röller et al, 2001; also see Cohen and Levin, 1989; and Scherer, 1992, for useful reviews). Larger studies in the field of financial economics and corporate control are rather undecided, but tend to support the notion of a neutral or negative impact of acquisitions on

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4 For a comprehensive survey please see Cassiman et al (2003).
R&D (Hall, 1990, 1999; Ravenscraft and Scherer, 1987; Hitt et al, 1991, 1996; Blonigen and Taylor, 2000). In contrast to that, several smaller in depth studies on acquisitions and joint ventures convey a more positive outlook on innovative investment and performance (Gugler and Siebert, 2004; Ahuja and Katila, 2001; Cassiman et al, 2003; Adams and Marcu, 2004).

One reason why the empirical results are so mixed may be that many studies focus either on innovation input (e.g. R&D spending) or on innovation performance (e.g. patents). Any conclusion for innovative behavior in general then implicitly assumes a constant R&D efficiency. However, changes in static or dynamic efficiency – e.g. created through the elimination of R&D duplication or scale/scope economies – can have opposing effects on the two variables: while R&D investment may be cut, joint R&D performance or output can still be unchanged or even higher. For a thorough understanding of dynamic efficiency, we therefore have to take both sides into account.

Another reason why empirical results are mixed may be that efficiency gains in acquisitions are often implicitly interpreted as cost synergies and thus expected to reduce investment in R&D. However, the internalization of technological spillover or other positive externalities increases marginal returns to innovation and therefore provides an incentive to invest more in R&D after an acquisition, even under efficiency gains. As discussed below, we therefore include such externalities in our analysis.

(iii) A survey of the literature that studies the influence of acquisitions (or other forms of coordination) on product and process innovations quickly reveals that – next to a lack of empirical studies – most theoretical work is done in the field of industrial organization. Initiated by the work of D’Aspremont and Jacquemin (1988) these studies mainly focus on the internalization of positive or negative externalities through research joint ventures (RJVs) and their comparative static effects with regard to process and product R&D spending (de Bondt and Veugelers, 1991, de Bondt, 1997; Bonanno and Haworth, 1998). Process innovations can be seen as negative externalities, since lower prices force competitors to either ‘wastefully’ invest in corresponding cost reductions or accept lower profits due to the ‘business stealing effect’. However, by forming an RJV or acquiring a firm, this negative externality can be internalized and avoided. Technological spillovers, on the other hand, can be seen as positive externalities, since competitors profit from the know-how of others without own investment. With acquisitions the returns lost to the innovator due to unprotected spillovers are

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5 Especially when innovation measures are ill defined this can lead to some additional confusion whether terms like ‘innovation’ and ‘innovation level’ refer to R&D investment/spending (input) or performance (output).
(partially) captured and, depending on the magnitude of internalization, lead to higher incentives to innovate. Most of the RJV literature focuses on spillovers when it addresses positive externalities. However, horizontal product differentiation can have the same effect when it reduces the substitutability of competitors’ products and increases consumers’ willingness to pay. This leads to less direct competition and higher profits. An internalization of horizontal differentiation captures the positive externalities of consumers’ increased willingness to pay, which would otherwise be lost to competition. By modeling horizontal and vertical differentiation efforts in a strategic setting, Rosenkranz (2003) shows in a formal model that the formation of RJVs change the optimal combination of product and process R&D.

On the basis of past research we can thus assume for our analysis: Provided that product and process R&D have different externalities, an acquisition should lead to an adjustment of the optimal mix of innovation investments since it internalizes different degrees of positive and negative external effects. The analysis of these effects would not only explain changes in R&D portfolios when firms coordinate formerly independent innovation decisions, but also illuminate an acquisition’s impact on overall dynamic efficiency.

In this paper we adapt the model of Rosenkranz (2003) to our purposes and deduct testable hypothesis with which we can then empirically analyze the relative importance of process and product R&D in acquisitions and in independently competing firms. The model also allows us to formulate and test hypotheses about the aggregate investment, performance, and dynamic efficiency of acquisitions. In summary, the central questions addressed in our analysis are: Do firms involved in acquisitions invest more in cost reduction or more in product differentiation than independent firms? Do firms that are involved in acquisitions generally invest more or less in product and process

6 Much in line with Eswaran and Gallini (1996) this refers to horizontal innovations where no new product is automatically superior in the absolute sense. They simply have more distinctive characteristics, which generally increase consumers’ valuation. An extreme example for such horizontal innovations in alliances is a multi purpose vehicle (MPV) dubbed ‘Eurovan’, which is produced by a joint venture of PSA Peugeot/Citroën and Fiat/Lancia. For each of the companies involved a technically identical van with slightly differentiated bodies is produced and then sold under the brand names Peugeot 806, Citroën Evasion, Fiat Ulysse, and Lancia Zeta. (These are the brand names used for the first generation of ‘Eurovans’ produced since 1994. For the second generation, which is produced since 2002, the names were partially changed to Peugeot 807, Citroën C8, Fiat Ulysse, and Lancia Phedra.) Other examples can be frequently found within automotive groups. In the Volkswagen group, for instance, Seat, Audi, Škoda, and Volkswagen build some of their cars on identical chassis platforms and with nearly identical technical characteristics, but these cars are nevertheless differentiated by interior and exterior design, branding and positioning.
R&D than independent firms? Do acquisitions increase or decrease R&D performance and dynamic efficiency?

For empirical testing we use cross sectional data from the Italian part of the first Community Innovation Survey (CIS), which covers 18467 firms across all manufacturing industries and size groups (over 20 employees) from 1989 to 1992. We construct two samples, one with independent firms and one with firms that are members of a group. Based on the questionnaire of the CIS, membership in a group can be interpreted as a coordination of innovation strategies and decisions in acquisitions, mergers, joint ventures, cross holdings, or any other kind of shared funding or equity-based interest with (shared) decision control or coordination.

The empirical results support the propositions of the formal analysis in various aspects. Firms involved in acquisitions do invest differently in R&D than independent firms, i.e. more in product and less in process innovation. Furthermore, they invest at least an equal amount in aggregate R&D. However, the empirical results also show that our hypotheses do not hold with regard to dynamic efficiency, since acquisitions lead to a comparatively worse R&D performance.

The contribution of this paper to the current state of research is threefold: First, to our knowledge this is the first study that empirically analyzes the relationship between product and process innovation in combination with acquisitions. Second, this study provides theoretically motivated and empirically tested results about the effect of acquisitions on aggregate R&D investment, performance and dynamic efficiency. Third, in an area with relatively sparse theoretical and empirical literature, this analysis also contributes to the fundamental understanding of relevant forces that determine the overall level of dynamic efficiency in acquisitions.

The paper is organized as follows: the following section 2 presents the game theoretic model used including the formulation of testable hypotheses. In section 3 we describe the data, the variables, and the statistical methods employed for the econometric test. The empirical results and their implications are then presented in section 4 followed by concluding remarks in section 5.

2. Formal Analysis and Hypotheses
2.1 The model

We consider a duopolistic industry, consisting of two firms \( i, j \) that produce quantities \( x_i \) and \( x_j \). The two firms operate under constant returns to scale. Firms’ unit costs of production are given by \( c_i \) and \( c_j \) with \( c_i, c_j \in [0, a] \), which can be chosen through R&D investment before the market opens. The product characteristics which determine the degree of product substitutability by \( \delta := \delta_i + \delta_j \) can also be influenced by the firms \( i, j \) through R&D investment in \( \delta_i \) and \( \delta_j \) respectively, with \( \delta_i, \delta_j \in [0, \frac{1}{2}] \).

The cost function for R&D is the same for both firms and is described by \( K(c_i) + G(\delta_i) \) with \( K' < 0 \), \( G' < 0 \) and \( K'' > 0 \), \( G'' > 0 \). The higher the marginal costs and the lower product differentiation the lower is the needed research investment. We assume that there exists an initial level of costs \( c^o \) with \( K(c^o) = 0 \) for all \( c_i \geq c^o \) and \( \lim_{c_i \to c^o} K(c_i) = 0 \) and an initial level of product differentiation \( \delta_i^o \leq \frac{1}{2} \) with \( G(\delta_i^o) = 0 \) for all \( \delta_i \geq \delta_i^o \) and \( \lim_{\delta_i \to \delta_i^o} G(\delta_i) = 0 \). Further, (to guarantee interior solutions) we impose that \( \lim_{c_i \to 0} K(c_i) = \infty \) as well as \( \lim_{\delta_i \to 0} G(\delta_i) = \infty \), and we assume that no technological spillovers exist.

Firms play a non-cooperative two-stage game under complete information. In the first stage, they decide on their marginal costs by investing in a research project generating a process innovation. Simultaneously, they decide on the optimal degree of product differentiation by investing in another research project generating a product innovation. On the second stage, firms choose quantities. Anticipating the outcome of the stage-two game as \( x_i^*(c_i, \delta_i) \) and \( x_j^*(c_j, \delta_j) \), firms choose optimal R&D portfolios. Possible R&D projects in such a portfolio are targeted at process innovation and at product innovation. Through the former they choose marginal costs of production and through the latter they choose a degree of product differentiation. Firms’ strategies are \((c_v, \delta_v) \in R^2\), with \( c_v \in [0, c^o] \) and \( \delta_v \in [0, \delta_v^o] \) with \( v = i, j \).
Now suppose that firms coordinate their R&D activities through an acquisition. For simplicity we assume that they remain competitors in the second stage of the game. Assume that firms coordinate their strategies as to maximize joint profit but do not achieve efficiency gains because they utilize research technologies (both, for new products as well as processes) with decreasing returns. This rather unrealistic scenario is included in the analysis because it allows us to isolate the strategic effects of cooperative R&D investment and the influence of efficiency gains.

Firms’ joint profit is

\[(c_i, c_j, \delta_i, \delta_j) \in \arg \max_{c_i, c_j, \delta_i, \delta_j} \{ \Pi_k = \pi_i^*(c_i, \delta_i, c_j, \delta_j) + \pi_j^*(c_i, \delta_i, c_j, \delta_j) - K(c_i) - K(c_j) - G(\delta_i) - G(\delta_j) \}. \]

Optimization with respect to \(c_i\) leads to the following first order condition which characterizes optimal investment into process innovation under coordinated R&D decisions, for \(c_i^* = c_j^* = c_k^*\):

\[
\frac{\partial \Pi_k}{\partial c_i} = \frac{\partial \Pi_i}{\partial c_i} + \frac{\partial \Pi_j}{\partial c_i} = 0,
\]

where \(\Pi_{ji}\) is the (negative) externality conferred by firm \(i\)'s cost reduction on the profit of its rival \(j\). Analogously, also the (positive) externality induced through product innovation by firm \(i\) on the profit of firm \(j\) is added to the competitive advantage externality that firm’s R&D effort has on its own profit through increasing the amount of differentiation of its competitor. Maximizing joint profit with respect to the level of product differentiation \(\delta_i\) yields the implicit function for optimal investment into product innovation in acquisitions, for \(\delta_i^* = \delta_j^* = \delta_k^*\):

\[
\frac{\partial \Pi_k}{\partial \delta_i} = \frac{\partial \Pi_i}{\partial \delta_i} + \frac{\partial \Pi_j}{\partial \delta_i} = 0,
\]

Those externalities, positive or negative, are ignored when each firm chooses its R&D expenditure so as to maximize its own profit. They are internalized when the firms coordinate their R&D strategies. This makes the individual maximization problems equivalent to the joint maximization problem that would be solved e.g. by a single decision maker for two firms that are combined through an acquisition.

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7 This is a common assumption in the IO literature when firms coordinate research strategies. An more complex analysis without such an assumption leads to not only qualitative identical, but altogether stronger results.
To determine the effect of those strategic terms, the first-order conditions can be written as
\[ \pi_{i_i} - K' + \beta \pi_{j_{i_i}} = 0, \text{ and} \]
\[ \pi_{i_{i_k}} - G' + \beta \pi_{j_{i_{i_k}}} = 0, \]
respectively, with \( \beta = 1 \). By applying comparative statics with respect to \( \beta \), the effects of adding these strategic terms to firms’ first-order conditions of profit maximization (and thus the effect of internalized externalities on firms’ investment incentives) can be analyzed. Taking all variables as functions of \( \beta \), differentiation of (1) and (2) with respect to \( \beta \) yields:
\[ (\pi_{i_{i_i}} - K' + \beta \pi_{j_{i_{i_i}}})d_{c_i} + (\pi_{i_{i_k}} + \beta \pi_{j_{i_{i_k}}})d_{\delta_i} + \pi_{j_{i_i}} d\beta = 0, \]
\[ (\pi_{i_{i_i}} + \beta \pi_{j_{i_{i_i}}})d_{c_i} + (\pi_{i_{i_k}} - G' + \beta \pi_{j_{i_{i_k}}})d_{\delta_i} + \pi_{j_{i_k}} d\beta = 0. \]

Cramer’s rule leads to:
\[ \text{sign} \left( \frac{dc_i}{d\beta} \right) = \]
\[ \text{sign} \left( -(\pi_{i_{i_i}} - G' + \beta \pi_{j_{i_{i_i}}})\pi_{j_{i_i}} + \pi_{i_{i_k}} (\pi_{i_{i_k}} + \beta \pi_{j_{i_{i_k}}}) \right), \]
\[ \text{sign} \left( \frac{d\delta_i}{d\beta} \right) = \]
\[ \text{sign} \left( -(\pi_{i_{i_i}} - K' + \beta \pi_{j_{i_{i_i}}})\pi_{j_{i_i}} + \pi_{i_{i_k}} (\pi_{i_{i_k}} + \beta \pi_{j_{i_{i_k}}}) \right). \]

The sign of the right-hand sides of both expressions is ambiguous if we do not make any further assumptions about the underlying demand functions. Obviously the slopes of the marginal R&D cost functions (together with the sign of the externalities) determine whether R&D investment increases or decreases. Now, assume negative externalities for process innovation and positive externalities for product innovation. This implies decreased investment in process innovation, e.g. \( c_{i_i} > 0 \), if the right-hand side of the first expression is positive, which is true in case:
\[ G' > (\pi_{j_{i_i}} (1 + \beta)\pi_{j_{i_{i_k}}} - \pi_{j_{i_i}} (1 + \beta)\pi_{j_{i_{i_k}}})/(\pi_{j_{i_i}}) := \hat{G}'. \]

Acquisitions increase investment in product innovation, e.g. \( d_{i_i} < 0 \), whenever the right-hand side of the second expression is negative, or if:

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8 Note that the equations represent the individual first order condition for \( \beta = 0 \), while they represent the joint profit maximization problem for \( \beta = 1 \).
\[ K'' > (\pi_{i_k} (1 + \beta)\pi_{i_{k\delta}} - \pi_{j_i} (1 + \beta)\pi_{j_{k\delta}})/(\pi_{j_i}) := \hat{K}'' \]

These conditions on the R&D-cost functions can only be met if they allow for the existence of an equilibrium. To ensure that there exists an equilibrium for all values of \( \beta \), the second-order condition has to be satisfied:

\[ G'' \geq \pi_{i_{k\delta}} + \beta\pi_{i_{k\delta}} - \frac{(\pi_{i_{k\delta}} + \beta\pi_{j_{k\delta}})^2}{\pi_{i_{k\delta}} + \beta\pi_{j_{k\delta}} - K''}. \]

Substituting \( \hat{K}'' \) into this second-order condition of profit maximization, reveals that whenever \( K'' < \hat{K}'' \) it is necessary for the equilibrium to exist that \( G'' \geq \hat{G}'' \). Similarly, \( G'' < \hat{G}'' \) requires that \( K'' \geq \hat{K}'' \). This leads to the following proposition:

**Proposition 1.** A coordination of strategies through acquisitions induces firms to invest:

(i) *more* in product differentiation and *less* in process innovation if \( K'' > \hat{K}'' \) and \( G'' > \hat{G}'' \).

(ii) *more* in process innovation and *more* in product innovation if \( G'' < \hat{G}'' \),

(iii) *or less* in process innovation and *less* in product differentiation compared to the non-cooperative equilibrium if \( K'' < \hat{K}'' \).

It can definitely be excluded that firms invest *more* in process innovation, \( c_{iy} < 0 \), and *less* into product differentiation, \( \delta_{iy} > 0 \), when they coordinate their research strategies through an acquisition (as compared to the competitive equilibrium).

**Proof:** See the arguments above.

Keeping in mind that \( \hat{K}'' \) as well as \( \hat{G}'' \) are functions of R&D spending one can simplify the interpretation as follows: If both marginal R&D-cost functions are sufficiently steep (such that \( K'' > \hat{K}'' \) and \( G'' > \hat{G}'' \)) acquisitions induce firms to invest *more* in product differentiation but *less* in process innovation. This finding corresponds to the general economic insight, that the internalization of positive externalities should increase incentives to conduct R&D while the opposite should hold for negative externalities.9 On the other hand, if marginal R&D costs increase slowly for process

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9 See DeBondt and Veugelers (1991) for a comprehensive discussion of the effects of investment externalities.
innovation, that is $K'' < \hat{K}''$, firms will invest less in both kinds of innovation compared to firms with independent R&D. If marginal costs for process innovation are low, negative externalities become strong for competing firms and the internalization of those strong negative externalities overcompensates positive externalities. If the slope of marginal R&D costs is low for product innovation, that is $G'' < \hat{G}''$, firms invest more in both kinds of innovation. If firms can easily differentiate their products, the internalization of positive externalities overcompensates negative externalities.

It is worthwhile to investigate whether firms also change the proportion of optimal R&D investment as compared to R&D competition if they invest either more in both or less in both kinds of innovations. Consider the ratio of the first-order conditions of profit maximization (1) and (2) given by:

$$\frac{K'}{G} = \frac{\pi_{i_k} + \beta \pi_{j_k}}{\pi_{i_k} + \beta \pi_{j_k}},$$

and differentiate it with respect to $\beta$. Using (3) this yields:

$$\frac{\partial K}{\partial \beta} = \frac{K'' (\pi_{i_k} + \beta \pi_{j_k}) - G'' (\pi_{i_k} + \beta \pi_{j_k})}{(\pi_{i_k} + \beta \pi_{j_k})^2}.$$

From this we can see that firms proportionately invest more into product innovation whenever

$$\frac{K'' (\pi_{i_k} + \beta \pi_{j_k})}{(\pi_{i_k} + \beta \pi_{j_k})} > G''.$$

Considering the conditions on the marginal R&D-cost functions from the proposition, this condition is most likely satisfied whenever firms invest more into both types of innovation. For the case that firms invest less into both kinds of innovation it is more likely that they shift their innovations towards more process innovation.

2.2 Deduction of hypotheses

Based on proposition 1 of the formal analysis we can now deduct testable hypothesis about (i) the optimal relation between product and process R&D, and (ii) the optimal level of aggregate R&D after an acquisition.
(i) With regard to the effects of acquisitions on the optimal relation between product and process R&D, the formal analysis predicts two clearly observable changes: First, it predicts that the relationship never changes towards less product R&D and more process R&D. Second, it predicts that there will be relatively more (less) investment in product (process) R&D if the marginal costs for both types of innovation are above a critical value. In other words, firms should not be right at the ‘beginning’ of convex cost functions where R&D is cheap and marginal costs are extremely small, neither for product nor process innovation.

According to research in industrial dynamics, discussed in the introduction, we would expect comparatively low marginal costs in product and process R&D primarily in the early (or ‘fluid’) stages of a technological life cycle, where firms experiment with various first designs and production technologies. Since we will test the hypotheses with a broad sample of Italian data across all manufacturing industries and several stages of the life cycle, we expect the average firm to be neither in a very early (formative) nor very late (declining) technological stage. This implies that marginal costs for product and process R&D (and respective innovation decisions) have reached a certain critical level of ‘non-triviality’ or impact, since the average cross sectional firm is bound to operate in a rather mature industry where both types of innovation are more or less equally developed. Hence, we can formulate the following hypothesis.

Hypothesis I (input related):

Firms that are involved in acquisition(s) invest more in product R&D and less in process R&D than independently competing firms.

If we assume that possible efficiency gains (or losses) in acquisitions are equally large for product and process investments we can restate the input related hypothesis I into an output-related hypothesis.

Hypothesis II (output related):

Firms that are involved in acquisition(s) have a better performance in product R&D and a worse performance in process R&D than independently competing firms.
Due to the ceteris paribus assumption any differences in the empirical results of hypothesis I and II should indicate disproportionate changes in the efficiency of product and process R&D due to acquisitions.

(ii) When we turn to the effect of acquisitions on aggregate R&D the results of the formal model are a bit more complex and do not exclude certain possibilities. In principle, low marginal costs for process (product) R&D can lead to a decrease (increase) in aggregate R&D while at least moderate marginal costs for both types of R&D can lead to offsetting counter effects and thus to more or less unchanged aggregate investments. However, as the formal discussion of proposition 1 shows, acquisitions with a higher (lower) investment in product (process) R&D in relative terms should make a higher or at least equal investment in absolute and aggregate terms. Hence, if hypothesis 1 and its underlying assumptions are supported, the following hypotheses over the effects of acquisitions on aggregate R&D can be formulated.

_Hypothesis III (input related):_

*Firms that are involved in acquisition(s) do not invest less in R&D (product and process) than independently competing firms.*

Under the ceteris paribus assumption of unchanged efficiency, we can transform the input-related hypothesis III on aggregate R&D into an output-related hypothesis.

_Hypothesis IV (output related):_

*Firms that are involved in acquisition(s) have no worse performance in R&D (product and process) than independently competing firms.*

With regard to the discussion of dynamic efficiency in acquisitions any differences in the empirical results of hypothesis III and IV should indicate a change in total R&D efficiency due to acquisitions.

**3. Data and Statistical Methods**

3.1 Description of the data
Before the 1990s, publicly available and reliable data on innovation have been extremely sparse. However, since the first Community Innovation Survey (CIS) – covering the years from 1989 to 1997 – some firm-level data on investment in innovation (including non-R&D costs) and innovation performance are available. In a comparative analysis of innovative indicators Kleinknecht et al (1996, 2002) show that the CIS indicators measure innovation input and output more comprehensively and more directly than earlier measures.

For our empirical test we use the cross-sectional firm-level data on innovative investment and performance of the Italian part of the CIS for 1992. Altogether 18,467 firms in Italy have responded to the survey with data for the year 1992. A survey among non-respondents indicated that these did not differ systematically from the respondent firms. This suggests that the survey is relatively representative for firms with 20 and more employees in all manufacturing sectors of the country.

One question in the survey inquired, whether the firm was ‘part of a group of companies’. Out of the total of 18,467 firms 3302 respondents (17.9%) answered this question affirmatively. We consider them to be part of an equity-based coordination of innovation decisions and label them GROUP. 10

15165 respondents (82.1%) answered this question negatively. We consider them to be independently competing firms and label them INDEP. Table 1 describes the complete sample and the two sub samples in more detail.

Table 1
Descriptive Statistics (Italian manufacturing firms, 1992)

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<th>Total sample</th>
<th>GROUP</th>
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</tr>
</tbody>
</table>

10 As mentioned earlier, this definition can include acquisitions, mergers, joint ventures, cross holdings, or any other kind of shared funding or equity-based interest with (shared) decision control or coordination.
<table>
<thead>
<tr>
<th>75th pctl</th>
<th>15708</th>
<th>71</th>
<th>60075</th>
<th>230</th>
<th>11455</th>
<th>55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>37573600</td>
<td>101361</td>
<td>37573600</td>
<td>101361</td>
<td>3024241</td>
<td>12929</td>
</tr>
<tr>
<td>S.D.</td>
<td>366421</td>
<td>859</td>
<td>858360</td>
<td>1998</td>
<td>37753</td>
<td>128</td>
</tr>
</tbody>
</table>

Not surprisingly, the average size of companies in GROUP and INDEP is noticeably different with regard to most moments. Firms in acquisitions (GROUP) have joint average sales that are almost 9.5 times larger than those of independent firms (INDEP) and the median is 4 times larger. Furthermore the mean of the number of employees in GROUP is 6 times larger and the median almost 3 times. In order to exclude size bias we relate all variables in our analysis to total sales.

The Community Innovation Survey is not only professionally generated by several European statistical offices, but also frequently used in diverse economic studies. There are nevertheless some limitations with regard to sample and variable selection. Although the CIS was conducted in a number of European countries and over several years we only use the Italian part of the 1992 data since we do not have access to other national databases.\(^{11}\) However, since the innovativeness of the Italian economy is not exceptionally different from other European economies we do not expect a significant sampling bias. Another limitation of the data is that we cannot trace the exact date or modalities of the acquisition that led to the formation of a group. We therefore neither know the ‘age’ of the assumed externalities at work, nor the percentage of interest acquired in another firm. Fortunately, although these details would give our analysis more substance, the formal model and deduction of hypotheses only require a differentiation between coordinated and independent decisions in innovation, regardless of corporate control or age of relation. Thus, even when only a minority interest in another firms or joint venture should have been acquired, the fact that the respondent nevertheless considers himself to be a ‘part of a group’ indicates his willingness to coordinate his behaviour and fulfils our definition of ‘acquisition’.

3.2 The variables

The CIS questionnaire had two parts. The first part asked for general information on the firm, like total sales, number of employees, and industry affiliation. At the end of the first part, firms were

\(^{11}\) Furthermore, the data may only be accessed and analyzed in the buildings of the national statistical office in the respective country.
asked to indicate whether they have developed any technologically changed products or processes in
the last 2 years or planned to do this in the following 2 years. Only if this was the case, the firm was
asked to complete the second part of the questionnaire. The second part contained questions on
innovative activities and provides detailed measures of innovation input and output, which we
partially transformed into the following variables:

**Investment variables (input-related):**

- **TOTRD-IN:** total R&D expenses (in mil. Lire) divided by total sales (in mil. Lire)
- **TOTIN-IN:** total innovation expenses (in mil. Lire) divided by total sales (in mil. Lire).
  (next to R&D, total innovation expenses also include costs for patents and licences, project engineering, prototype testing, and market research.)
- **PROD-IN:** product R&D expenses as a percentage of total R&D expenses
- **PROC-IN:** process R&D expenses as a percentage of total R&D expenses
  (PROD-IN and PROC-IN complement to 100% of total R&D expenses)

**Performance variables (output-related):**

- **TOT-OUT:** percentage of total sales realized with new products (incremental and radical) and innovative processes
- **PROD-OUT:** percentage of total sales realized with new products (incremental and radical)
- **PROC-OUT:** percentage of total sales realized with innovative processes

4. **Empirical Results**

4.1 Effect of acquisitions on product and process R&D

In order to test the effect of acquisitions on the investment in product and process R&D we
statistically compare the two samples GROUP (coordinated innovation decisions) and INDEP
(independent innovation decisions) for those firms that report a formal (and positive) R&D budget.
Table 2 describes this sub sample containing 3696 firms. Compared to the entire sample of 18467
firms (described in table 1), 38.3% of the firms in GROUP and 16% of the firms in INDEP invest in

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12 This procedure was an attempt to minimize selective non-response on non-innovators who otherwise would have been
bothered with a number of irrelevant questions.
R&D. Since the median (mean) of sales of all firms in GROUP is about 4 (9.5) times larger than the corresponding size in INDEP (see table 1) it is not surprising that formal R&D budgets are more frequently observed in larger firms. It is interesting to note that the magnitude of this size difference persists in the sub sample of firms investing in R&D: The median (mean) of sales of all firms in GROUP is about 4.2 (11.2) times larger than the corresponding size in INDEP (see table 2). This indicates that – with respect to size distribution – R&D active firms represent a non-biased sub sample out of the total population of firms.

Table 2
Descriptive Statistics (Firms investing in R&D)

<table>
<thead>
<tr>
<th>GROUP</th>
<th>INDEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>total sales (in mil Lire)</td>
<td>total sales (in mil Lire)</td>
</tr>
<tr>
<td>N</td>
<td>1266</td>
</tr>
<tr>
<td>Mean</td>
<td>213387</td>
</tr>
<tr>
<td>Median</td>
<td>41189</td>
</tr>
</tbody>
</table>

Table 3 shows the results of two sample tests (GROUP vs. INDEP) for hypothesis I and II. With regard to R&D investment, hypothesis I states firms involved in acquisitions (GROUP) invest relatively more in product and less on process R&D than independent firms (INDEP). This is supported with a statistical significance on the .01 level not only for the means (t-test), but also for the entire distribution (Kolmogorov-Smirnov). In fact, firms involved in acquisitions invest on average 2.9 percentage points more (less) out of their total R&D budget in new products (processes) than independent firms.\(^{13}\) When we turn to the performance of R&D, hypothesis II is only moderately supported: As predicted, the average performance in process R&D is lower for firms in GROUP, although it is only the Kolmogorov-Smirnov Z that indicates a statistically significant difference between the two samples. However, with regard to product R&D, the performance in acquisitions does not increase (as predicted), but decreases with a fairly significant Kolmogorov-Smirnov Z (p=0.042) for the entire distribution. This implies that the assumption of constant

\(^{13}\) Since the investments in product and process R&D (variables PROD-IN, PROC-IN) are related to the total R&D budget, they complement to 100%. This explains why the magnitude of standard deviation, variance, skewness and kurtosis are identical.
efficiencies, which led to the deduction of hypothesis II out of hypothesis I, does not hold for product R&D. To the contrary, this result seems to support the notion of post-merger inefficiencies or diseconomies of scale in product R&D that are strong enough to turn an increase in investment into a decrease in performance.

Table 3
Investment and Performance of Product and Process R&D

<table>
<thead>
<tr>
<th>GROUP</th>
<th>R&amp;D Investment (input)</th>
<th>R&amp;D Performance (output)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Product (PROD-IN)</td>
<td>Process (PROC-IN)</td>
</tr>
<tr>
<td>N</td>
<td>1266</td>
<td>1266</td>
</tr>
<tr>
<td>Mean</td>
<td>64.526</td>
<td>35.474</td>
</tr>
<tr>
<td>Median</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Variance</td>
<td>976.387</td>
<td>976.387</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.657</td>
<td>0.657</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-0.686</td>
<td>-0.686</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INDEP</th>
<th>R&amp;D Investment (input)</th>
<th>R&amp;D Performance (output)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Product (PROD-IN)</td>
<td>Process (PROC-IN)</td>
</tr>
<tr>
<td>N</td>
<td>2430</td>
<td>2430</td>
</tr>
<tr>
<td>Mean</td>
<td>61.647</td>
<td>38.353</td>
</tr>
<tr>
<td>Median</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>S.D.</td>
<td>32.492</td>
<td>32.492</td>
</tr>
<tr>
<td>Variance</td>
<td>1055.748</td>
<td>1055.748</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.502</td>
<td>0.502</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-0.881</td>
<td>-0.881</td>
</tr>
</tbody>
</table>

Levene’s test
- F: 4.849, p-value: 0.280
- t-test: t: 2.622, p-value: 0.009
- Kolmog.-Smir test: Z: 1.919, p-value: 0.001
For a robustness check we construct another sample of innovative firms: Some companies do not have formal R&D budgets but nevertheless introduce new products and processes into the market. The CIS survey therefore provides another variable for innovative investment, called ‘total innovation expenses’, which includes non-R&D costs, like costs for patents and licences, project engineering, prototype testing, and market research (TOTIN-IN). Table 4 shows the frequencies of these types of innovative firms.

Table 4
Sub Samples of Innovative Firms

<table>
<thead>
<tr>
<th></th>
<th>Total sample</th>
<th>GROUP</th>
<th>INDEP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>pct</td>
<td>N</td>
</tr>
<tr>
<td>1: inv R&amp;D</td>
<td>3696</td>
<td>20.0</td>
<td>1266</td>
</tr>
<tr>
<td>2: inv innov</td>
<td>4418</td>
<td>23.9</td>
<td>1413</td>
</tr>
<tr>
<td>all firms</td>
<td>18467</td>
<td>100.0</td>
<td>3302</td>
</tr>
</tbody>
</table>

* Sample 1 contains all firms with TOTRD-IN>0 and sample 2 all firms with TOTIN-IN>0

Unfortunately, the additional variable ‘total innovation expenses’ (TOTIN-IN) is not split up into product and process innovation. We therefore cannot use it for robustness on the input related hypothesis I, but we can utilize sample 2 to check the output related results of hypothesis II. Table 5 reports the results for sample 2, which confirm the above findings with regard to sample 1. With regard to product R&D, hypothesis II is still not supported since the percentage of sales generated through new products (PROD-OUT) does not rise. With regard to a higher performance for acquisitions in process R&D, hypothesis II and the findings in connection with sample 1 are fully confirmed.

Table 5
Performance of Product and Process R&D (2 Samples of Innovators)

<table>
<thead>
<tr>
<th></th>
<th>Performance Product R&amp;D (PROD-OUT)</th>
<th>Performance Process R&amp;D (PROC-OUT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sample 1</td>
<td>sample 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14 To enable a better overview, table 5 once again reports the output related results from sample 1, which are also included in table 3.
The effects of acquisitions on dynamic efficiency are thus split: While inefficiencies turn significantly higher investments in product R&D into a lower or at most equal innovation performance, acquisitions enjoy efficiency gains in process R&D, which enable a comparatively higher performance with less investment. However, the analysis of these individual effects does not yet allow for conclusions about aggregate efficiency. In the following section we therefore conduct separate tests for hypotheses III and IV.

4.2 Effect of acquisitions on aggregate R&D investment and performance
Hypothesis III predicts that aggregate investment in R&D will not be lower after acquisitions when compared to independent firms. This is fully supported by the results in table 5, not only for firms with a positive formal R&D budget (sample 1), but also for firms with positive total innovation expenses (sample 2). It thus seems that the higher investments in product R&D and the lower investments in process R&D (see table 3) offset each other.

For innovation performance, table 5 also shows that the assumption of constant efficiencies in aggregate R&D, which led to Hypothesis IV, cannot be held up. Both samples in table 5 clearly show a decrease in aggregate innovation performance. With no significant difference in aggregate R&D investment this clearly points towards a dynamic inefficiency in acquisitions, which seem to originate primarily from product R&D (see table 5).

<p>| Table 6 |
|---|---|---|---|---|---|
| <strong>Investment and Performance of Aggregate R&amp;D (2 Samples of Innovators)</strong> |
| <strong>Investment (input)</strong> | <strong>Performance (output)</strong> |
| | sample 1 | sample 2 | sample 1 | sample 2 |
| <strong>TOTRD-IN</strong> | | | | |
| <strong>TOTIN-IN</strong> | | | | |
| <strong>N</strong> | 1266 | 1413 | 1266 | 1413 |
| <strong>Mean</strong> | 0.03258 | 0.03899 | 55.043 | 54.887 |
| <strong>Median</strong> | 0.0144 | 0.0204 | 60 | 60 |
| <strong>S.D.</strong> | 0.0645 | 0.06251 | 32.613 | 32.812 |
| <strong>Variance</strong> | 0.00416 | 0.003908 | 1063.61 | 1076.612 |
| <strong>Skewness</strong> | 7.96 | 6.421 | -0.145 | -0.114 |
| <strong>Kurtosis</strong> | 90.16 | 69.802 | -1.259 | -1.302 |
| <strong>TOT-OUT</strong> | | | | |
| <strong>TOT-OUT</strong> | | | | |
| <strong>N</strong> | 2430 | 3005 | 2430 | 3005 |
| <strong>Mean</strong> | 0.02856 | 0.03843 | 57.5819 | 57.967 |
| <strong>Median</strong> | 0.01435 | 0.02147 | 60 | 60 |
| <strong>S.D.</strong> | 0.0498 | 0.05673 | 30.734 | 31.286 |
| <strong>Variance</strong> | 0.00248 | 0.003218 | 944.593 | 978.789 |
| <strong>Skewness</strong> | 6.258 | 5.056 | -0.283 | -0.257 |
| <strong>Kurtosis</strong> | 56.35 | 39.617 | -1.062 | -1.123 |</p>
<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>2.117</th>
<th>15.701</th>
<th>13.652</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levene’s test</td>
<td>10.481</td>
<td>2.117</td>
<td>15.701</td>
<td>13.652</td>
</tr>
<tr>
<td>p-value</td>
<td>0.001</td>
<td>0.146</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>t-test</td>
<td>1.936</td>
<td>0.296</td>
<td>-2.470</td>
<td>-2.954</td>
</tr>
<tr>
<td>p-value</td>
<td>0.053</td>
<td>0.767</td>
<td>0.014</td>
<td>0.003</td>
</tr>
<tr>
<td>Kolmogorov-Smirnov test</td>
<td>1.310</td>
<td>0.981</td>
<td>1.776</td>
<td>1.974</td>
</tr>
<tr>
<td>p-value</td>
<td>0.065</td>
<td>0.291</td>
<td>0.004</td>
<td>0.001</td>
</tr>
</tbody>
</table>

5. Concluding Remarks

Following concepts in industrial dynamics the magnitude of marginal returns to product and process innovation are likely to change through the life cycle of a technology (e.g. Abernathy and Utterback, 1982). Based on the formal model in this paper it can be argued that, especially at the beginning of a technological life cycle, marginal returns to innovation are so high that there incentive to expand generally overcompensates the opposing incentive to reduce absolute investment in process innovation, which an acquisition creates through the internalization of negative externalities. Following this line of argument, exactly the opposite could be hypothesised for a very mature or even declining phase of a technological life cycle in which marginal returns to innovation (product as well as process) are significantly lower. Positive externalities of product differentiation are then overcompensated by the generally decreasing absolute investments in innovation (although firms involved in acquisitions will still employ relatively more resources for product innovation than cost reduction). Between these two extremes there also is a stage of moderate marginal returns to innovations in the technological life cycle. Here, the absolute and relative effects of product and process R&D should be aligned. The fact that this is only partially supported by our results can have two explanations: From an industrial dynamics’ view it may be argued that our data of the Italian manufacturing industry have a bias towards more mature technologies, which generally reduces incentives to invest in R&D. However, this would not completely explain our finding of increasing investment and decreasing return in product R&D. We therefore take on a firm’s perspective in interpreting the empirical results and argue that acquisitions lead to inefficiencies in product R&D, which overcompensate possible efficiency gains in process R&D.

Following this line of argument the implications for aggregate dynamic efficiency effects in acquisitions hinge on the performance in product R&D. While externalities seem to have a relatively
direct impact on process R&D, which leads to a decrease in investment and performance, in our analysis organizational inefficiencies in product innovation represent the critical factor that prevents acquisitions to increase or at least maintain aggregate dynamic efficiency.

**Bibliography**

Abernathy, W.J. and J.M. Utterback, 1979, Patterns of Industrial Innovation, Technology Review, 80, 41-47.


Hall, B. 1999, Mergers and R&D revisited, mimeo.


