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The roles and effectiveness of design in new product development: A study of Irish manufacturers

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ABSTRACT

Investments in design can make a significant contribution to successful new product development (NPD). However, there is insufficient evidence on the most appropriate or effective role that design could play. Previous case-based research has identified alternative roles for designers in NPD, but there is only tentative evidence over such roles' contribution to NPD outcomes. Using data on a large sample (c. 1300) of Irish manufacturing plants we are able to examine the effectiveness of three different levels of involvement of designers in NPD and their impact on NPD novelty and success. Our analysis suggests that design is closely associated with enhanced performance regardless of the type of role it plays. However, the potential effects of involving design throughout the process appear to be much greater. The relationship between design and NPD outcomes is also strongly moderated by contextual factors; for example, its significance is only evident for organisations, which also engage in in-house R&D. Also, while both small and larger plants do gain from using design as functional specialism and in some stages of the NPD process, the additional benefits of a continuous involvement of design throughout the process are only evident in larger plants. Finally, while discourse and perceptions over design's role in NPD have certainly changed over time, suggesting a much more widespread and strategic use of design, our findings provide a more static picture, showing that design engagement with the NPD process has not changed significantly over the last two decades.

1. Introduction

Over the past decade a growing number of studies have identified design as a primary driver of innovation (see, e.g., Gemser and Leenders, 2001; Chiva and Alegre, 2009; Talke et al., 2009; Verganti, 2009; D'Ippolito et al., 2014; Moultrie and Livesey, 2014). Research findings show how the integration of design within new product development (NPD) can positively affect the financial performance of a company as well as its corporate identity and brand (Beverland, 2005; Ravasi and Stigliani, 2012). However, despite studies, which claimed that design is acquiring a new 'prominent position' in the NPD process (Perks et al., 2005; Noble and Kumar, 2010), design is still often perceived as 'just one of several inputs' (Goffin and Micheli, 2010) and a late stage add-on (Brown, 2008).

Research has also shown that there are several barriers to introducing design in NPD. While there is evidence that involving designers at different stages of the NPD process and using multi-functional teams in NPD positively impacts performance (Sarin, 2009), tensions among functions still exist (Beverland, 2005; De Clercq et al., 2011). Such tensions arise for several reasons, including divergences between designers' and managers' perspectives and goals, conflicts between marketers' and designers' priorities and ways of working, and cultural barriers related to language and designers' self-image (Micheli et al., 2012). The application of management systems and formal product development processes has been suggested as a possible way to reduce tensions and introduce design more effectively in NPD (De Luca and Atuahene-Gima, 2007).

Other studies have considered the different roles design could play in NPD (Veryzer, 1995; Goffin and Micheli, 2010). For example, Perks et al. (2005) empirically derived a taxonomy of design roles in NPD, differentiating among designers as functional specialists, members of multi-functional teams, and process leaders. In their study of UK manufacturing companies, these authors found that the roles the design function and designers adopt or are allocated substantially determine their influence and contribution

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to the NPD process (see also Beverland and Farrelly, 2007). Yet, evidence—particularly quantitative—is still lacking.

In this paper we look at the association of design with NPD outcomes in manufacturing, and focus on design roles in different phases of the NPD process. This research is particularly important as it improves our understanding of current uses of design, and design's contributions to NPD outcomes through a systematic quantitative analysis. In particular, this study builds on two main literatures: the primarily case-based literature profiling the engagement of designers with the NPD process (Perks et al., 2005; Goffin and Micheli, 2010), and the literature on the innovation production function, which relates inputs to the NPD process to outputs (Griliches, 1995; Roper et al., 2008). To test our hypotheses, we use data taken from a large plant-level database covering the 1991–2008 period. Because we have detailed data on the way in which a large group of plants engage designers in the NPD process, we are able to investigate the relationship between different roles of designers and NPD outcomes. Also, we are able to examine potential changes in the roles and effects of design.

In the next section we review the literature on design and formulate four hypotheses on the contribution of design to NPD outcomes and on the effectiveness of different design roles in NPD. We then discuss the process of data gathering and analysis, explaining the variables introduced in the innovation production function. Subsequently, we present and discuss the findings. We conclude by highlighting the main implications for theory, practice and policy, and outline avenues for further research.

2. Conceptual foundations and hypotheses

2.1. What is design?

In the literature, design has been mostly considered as either an outcome or a process (Talke et al., 2009). As an outcome, design is usually related to the final result of the NPD process and regarded as product appearance (Eisenman, 2013). As a process, design not only involves adding pleasing features to a final product, but it requires the performance of different activities pursuing the creation of an appealing, usable and functional object. Design therefore plays an important role in both the creation and development of meanings (Verganti, 2008) along the NPD process, and contributes to the functionality, aesthetics and usability of products (Chiva and Alegre, 2007).

Recently, academics and practitioners have started to examine design as a strategic approach, and as an alternative to traditional product and service development processes (Martin, 2009; Cross, 2011; Liedtka, 2014). In particular, several authors have argued that the processes and practices adopted by designers—often referred to as "design thinking" (Brown, 2008)—could be a potent means to innovate and to address customers' needs (Chen and Venkatesh, 2013). Also, a "designerly" approach—which goes beyond products and services, and brings together an understanding of technological aspects with an appreciation of the sociocultural context—has been advocated as a way to reinvent processes and business models (Gruber et al., 2015).

2.2. Impact of design

Various studies have shown that design can play a significant role in NPD (Lawrence and McAllister, 2005; Micheli et al., 2012). Good design can generate positive reactions from consumers (Yamamoto and Lambert, 1994), help differentiate products (Veryzer and Borja de Mozota, 2005), and lead to competitive advantage (Beverland, 2005). On the other hand, the relationship between design and performance seems to be rather nuanced and dependent on intermediary factors (Chiva and Alegre, 2009). For example, Gemser and Leenders (2001) identified that in situations where emphasising design in the NPD process is not new to the industry (e.g., in furniture or fashion) such a focus alone would not be sufficient to improve performance. Moreover, in cases of radical innovations in the functional attributes of products, changes in the design could lead to lower acceptance by the market (Goode et al., 2013; Mugge and Dahl, 2013).[1]

Not withstanding the effect of mediating and moderating factors, researchers interested in design effectiveness have mainly concluded that design investments lead to better NPD outcomes (Hertenstein et al., 2005; Utterback et al., 2006; Verganti, 2006; Ravasi and Stigliani, 2012). For example, Hertenstein et al. (2005) find that investments in design are capable of generating financial returns in the form of more profitable sales, higher returns on sales, and higher returns on assets. Marsili and Salter (2006) based their analysis on Dutch Community Innovation Survey data and considered the relationship between design expenditure (expressed as a proportion of sales) and various NPD output indicators.[2] Their results show that investment in design had a positive effect on sales from new products, but no significant link to sales of improved products. Using a comparable definition of design, Cereda et al. (2005) draw similar conclusions for the UK, again identifying a positive link between design spending and product innovation.[3] More recently, Czarnitzki and Thorwarth (2012) demonstrate the positive relationship of design expenditure with NPD outputs in a group of Flemish plants. This evidence suggests our first hypothesis:

Hypothesis 1 *(The contribution of design).* Design makes a positive contribution to NPD performance.

2.3. Roles of design and designers

While most studies have found a positive impact of design on performance, quantitative research has rarely considered why and how design affects NPD outcomes. In their review of the literature, Candi and Gemser (2010, p. 72) call for a "systematic quantitative research to test the theories and intuitive findings of existing in-depth research about the integration of designers in the NPD process", and D'Ippolito et al. (2014) highlight the paucity of empirical studies on how design-related skills and competencies are combined with firms' existing competencies.

In particular, few scholars have considered the different ways in which design can be utilised in the NPD process[4] (Goffin and Micheli, 2010). Case-based evidence, instead, suggests that design's contribution depends on the role design and designers play in NPD, e.g., whether design is embedded in organisational processes; whether it informs strategic choices; and whether it is utilised as a means to differentiate from competition (Chiva and Alegre, 2009). An important study is the analysis conducted by Perks et al. (2005) of 18 UK manufacturing companies, in which a taxonomy of three different roles of design and designers within NPD was derived: design as functional specialism; design as a perspective informing the work of multifunctional teams; and design as the leading perspective in NPD.

[1] Other authors have argued, however, that design may play a significant role in making technologically radical innovations more acceptable (Rindova and Petkova, 2007; Eisenman, 2013).

[2] Marsili and Salter (2006) note that the definition of 'design' in the Dutch Community Innovation Survey is 'The preparations aimed at taking into actual production new or improved products and/or services'.

[3] In the UK survey 'design expenditure' is said to cover 'all design functions, including industrial, product, process and service design and specifications for production or delivery' (Cereda et al., 2005, p. 7).

[4] A notable exception is Czarnitzki and Thorwarth (2012) who compare the impact of in-house and external design.

These authors find that, when design is utilised as functional specialism, designers are engaged only in specific NPD activities, often principally in one stage of the process, and excluded from others, typically production and launch. Essentially, in this scenario designers are required to respond to externally developed briefs and perform relatively defined and limited tasks. Such an approach may enable design to contribute to the functional and/or aesthetic aspects of new products, but may risk losing benefits, which may arise from complementarities between design staff and other staff (Lehoux et al., 2011) and from the potential for more radical innovation through design (Verganti, 2009).

When design is engaged in a broader set of activities, the NPD process tends to be less functionally demarcated, and designers are often part of multi-functional teams. This higher level of engagement recognises the nature of design as an essentially social process in which different individuals bring different skills and viewpoints, and that innovations require insights from various perspectives (Dougherty, 1992). For example, looking at medical device design projects, Lehoux et al. (2011) find that “in all of the cases, the object to be designed takes shape because knowledge circulates from one domain to another and is adapted or transformed along the way” (p. 328). Similarly, Marion and Meyer (2011) identify positive complementarities between cost engineering and design in NPD, while Tether (2005) emphasises complementarities between design and R&D. Adopting a wider approach to the use of design in NPD may therefore allow organisations to benefit from complementarities reflected in increased knowledge sharing (Lawrence and McAllister, 2005; Hsu, 2011), to develop trust and mutual learning (Creed and Miles, 1996), and to become more innovative through greater sharing and use of information (Christiansen and Varnes, 2009). In such configuration, designers could play a bridging role between aspects particularly related to the ideation and creation of a product (e.g., prototyping and testing) and subsequent NPD stages (e.g., marketing and product launch). The potential for complementarities between designers and other staff in the NPD process through design’s bridging role suggests our second hypothesis:

Hypothesis 2 *(Design’s bridging role in NPD and NPD outcomes).* Design’s bridging role in NPD will make a greater contribution to NPD performance than when design is employed as functional specialism.

The engagement of designers in several NPD stages and as part of multi-functional teams may be positive for NPD, but the evidence suggests that actual engagement may vary substantially between elements of the NPD process. Love and Roper (2004), for example, show that 51.7% of UK manufacturing plants were involving designers in developing prototypes, compared to only 26.8% of plants in which designers were involved in production engineering. The authors show even greater variation in relation to German companies. While such variation could be somewhat expected, Verganti (2009) suggests that lack of continuity in the engagement of design staff in the NPD process may lead to the type of inter-disciplinary conflicts identified by many authors (see, e.g., Beverland, 2005; Micheli et al., 2012). One way of avoiding these issues is the adoption of the third approach suggested by Perks et al. (2005)—design-led NPD—in which “designers drive and support actions throughout the entire development process and across a broad scope of functional activities” (p. 121). While empirical evidence of the impact of such an approach is limited (Verganti, 2009), innovation researchers have shown how consistency in NPD leadership is positively linked to NPD outcomes (see, e.g., Rosing et al., 2011) as well as being an important way to help maintain focus within a development team and protect development teams from diversion from other pressures within the organisation (Oke et al., 2009). In this configuration, design’s involvement in NPD is continuous and impacts all product development stages, and therefore goes beyond a mere ‘bridging role’ between creation and commercialization. Existing evidence of the benefit of such continuity leads us to formulate our third hypothesis:

Hypothesis 3 *(Continuous involvement of design throughout the NPD process and NPD outcomes).* Continuous involvement of design throughout the whole NPD process will make a greater contribution to NPD performance than when design is only playing a bridging role.

While a continuous involvement of designers[5] in the NPD process may enable an organisation to effectively coordinate resource inputs, Verganti (2009) argues that this approach may also help them achieve radical product innovation (Harty, 2010). This is because design’s high level of engagement in NPD could help promote possible new product meanings and languages that could diffuse in society as well as innovative ideas, which break away from how products are currently used and conceived (Utterback et al., 2006). Perks et al. (2005) also find tentative evidence that organisations employing designers as functional specialists in the NPD process tend to be focussed on more incremental product changes than organisations engaging designers in either multi-functional groups or a leadership role. This suggests our fourth hypothesis:

Hypothesis 4 *(Continuous involvement of design and degrees of innovativeness).* Continuous involvement of design in the NPD process will allow organisations to achieve more radical innovations than when it is involved in only one or some stages of the process.

2.4. The innovation production function

This study also draws on the concept of the innovation production function, which relates plants’ NPD outputs to the knowledge inputs of the NPD process (Griliches, 1995; Love and Roper, 2001; Laursen and Salter, 2006). This provides a framework within which to model the relationship between the engagement of designers in the NPD process and NPD outputs (Tether, 2005; Marsili and Salter, 2006; Talke et al., 2009). Adopting the innovation production function also allows to take into account plant characteristics and other elements of plants’ NPD strategies—e.g., investments in in-house R&D activities and multifunctional working—and so to generate more robust estimates of the contribution of alternative design roles to NPD outputs (Minguela-Rata and Arias-Aranda, 2009). Furthermore, it enables us to identify any contingent factors, which might be associated with aspects of plants’ operating environment (e.g. sector) or other dimensions of plants’ NPD activity (e.g. size). Prior studies in the innovation production function literature provide evidence that, even after accounting for other control factors, the use of design tends to be associated with higher innovation outputs and enhanced plant performance (Marsili and Salter, 2006; Love et al., 2011). Other papers, however, emphasise the heterogeneity of effects of different types of design activities (Czarnitzki and Thorwarth, 2012) and the complementarity of design activities with R&D and other investments (Tether, 2005).

[5] When defining the ‘design-led’ role, Perks et al. focused on the skills required and actions undertaken by designers who were leading the NPD process from identification of need to product launch. Our study also looks at the involvement of designers at different stages, but our data do not enable us to conclude whether such involvement is linked to a leadership role or to a simply higher level of participation. Hence, our decision to opt for the label ‘continuous involvement of designers’ rather than ‘design-led’.

3. Data and methods

Data for our study are taken from three plant-level surveys of manufacturing in Ireland and Northern Ireland covering plants' NPD activity in the periods 1991–1993, 2000–2002 and 2006–2008. Each of the three surveys comprises one 'wave' of the Irish Innovation Panel (IIP) dataset and was carried out by post with telephone follow-up to boost response rates. Sampling frames were either obtained from private sector providers (1991–1993 and 2006–2008) or government agencies (2000–2002) and were intended to be representative of the target population of manufacturing plants with more than 10 employees. Samples were structured by size band with different sampling fractions for plants of different sizes.[6] The initial survey, covering plants' NPD activity from 1991 to 1993 was undertaken between October 1994 and February 1995 and achieved a response rate of 38.2% (Roper et al., 1996; Roper and Hewitt-Dundas, 1998, Table A1.3). The 2000–2002 survey was undertaken between November 2002 and May 2003 and achieved an overall response rate of 34.1%. The postal element of the sixth wave of the IIP was conducted between April and July 2009 with subsequent telephone follow-up and achieved a response rate of 38%. The resulting panel is unbalanced, reflecting non-response in individual surveys, but also the opening and closure of individual plants: on average there are 1.7 observations per plant in the dataset. Non-response checks on survey responses suggest little significant difference in terms of innovation behaviour between respondent and non-respondent plants. In each case, surveys were targeted at either company Managing Directors, CEOs or senior managers with a responsibility for R&D or new product development.

Our analysis is based on answers to three questions asked in each of these surveys (Annex 1 includes variable definitions). First, plants were asked whether they had introduced any new or improved products over the previous three years. Plants answering in the affirmative were then asked what proportion of their current sales was derived from products newly introduced in the previous three years, and whether these new products were either 'new to the market for the first time' or simply 'new to the plant but had previously been made elsewhere'. These data were used for our two dependent variables. Our first dependent variable is percentage of sales from newly introduced products. This variable has been widely used in the NPD and innovation studies literatures (Leiponen, 2005; Roper et al., 2008; Love and Roper, 2009; Leiponen and Helfat, 2010; Love et al., 2011) and reflects both plants' ability to bring new products to market and the short-term success of those products. It therefore provides an indication of short-term NPD success. On average, for the sample as a whole, plants derived 20.6% of sales from newly introduced products (Table 1).[7] Our second dependent variable is NPD novelty—an ordinal variable reflecting the radicalness of plants' innovation, taking value 3 if the plant introduced 'new to the market products', 2 if the plant had introduced products new to the plant, and 1 where plants had introduced no new products in the previous three years.

Plants indicating that they had undertaken some NPD activity in the previous three years were then asked to indicate whether design staff[8] had been involved in seven separate stages of the NPD process: identifying new products, prototype development, final product design, product testing, production engineering, market research, and developing marketing strategy. Across the sample of manufacturing plants in the IIP, around 44% were involving designers in the final product design stage of the NPD process, with a slightly smaller proportion (41%) involving designers in prototype development (Fig. 1, Table 1). By contrast, only about 10–15% of plants were engaging designers in either market research or the development of marketing strategy (Table 1).[9] While these differences in the involvement of designers in the various elements of the NPD process are substantial, we see surprisingly little change in this pattern through time (Fig. 1). Pooling data from the three waves of the IIP also suggests little systematic difference in the pattern of design engagement in the NPD process between small, medium and large plants (Fig. 2). More difference is evident, however, between plants engaging and not engaging in R&D, with the former being more likely to engage design staff in all stages of the NPD process (Fig. 3).

Table 1
Descriptive statistics.

Variable	Obs.	Mean	Std. Dev.
New product development outputs			
Share of sales from new products (%)	1269	20.60	23.80
Design staff engagement in individual NPD elements (share of innovative plants)			
Identifying new or improved products	1317	0.32	0.47
Prototype development	1317	0.41	0.49
Final product design/development	1317	0.44	0.50
Product testing	1317	0.24	0.42
Production engineering	1316	0.18	0.38
Market research	1317	0.14	0.35
Developing marketing strategy	1317	0.13	0.34
Roles of design (share of innovative plants)			
Designers as functional specialists	1363	0.17	0.38
Designers playing a bridging role	1363	0.29	0.45
Continuous involvement of designers	1363	0.04	0.18
NPD but no design involvement	1363	0.50	0.50
Control variables			
R&D engagement (share of innovative plants)	1357	0.69	0.46
Multi-functionality indicator (0–28)	1363	9.17	4.95
External NPD linkages (share plants)	1356	0.58	0.49
Number of employees (mean)	1288	125.19	323.46
Age (mean years)	1097	28.62	36.71
External ownership (share of innovative plants)	1363	0.16	0.37
Share of employees with degrees (mean %)	1300	11.36	14.04

Notes: Figures relate to pooled data from three waves of the IIP relating to the periods 1991–1993, 2000–2002, 2006–2008 and only to innovating plants. Variable definitions in Data Annex.

From these data on the engagement of design in individual elements of the NPD process we derive three variables intended to capture three different roles played by designers in NPD, and are therefore able to test our hypotheses. First, to reflect the functional specialism role we define a variable, which takes value 1 if a plant involves designers in at least one of the main design-related stages of the NPD process—identifying new product, prototype development and final product design—but in no other stages. Second, to capture the bridging role of design in NPD we define a dummy variable, which takes value 1 if a plant involves designers in at least one of the three functional specialist stages (i.e. product identification, prototyping and final product design) *and* in any other single element of the process. Finally, to reflect the continuous engagement

[6] Sampling fractions were: 50% for plants with 10–19 employees, 75% for plants with 20–99 employees and 100% for plants with 100 plus employees.

[7] See Hewitt-Dundas and Roper (2008) for a discussion of the development of this variable as an indication of Irish innovation performance since the early-1990s.

[8] The survey asked about the involvement of five staff groups in NPD activities: scientists, engineers, skilled production staff, design staff, and marketing or sales staff. While we are not able to differentiate between internal and external designers, the questionnaire enables us to focus on design staff and to avoid the situation of 'silent design' (Gorb and Dumas, 1987) whereby design is not done by professional designers but by marketing, production or other non-design staff.

[9] An essentially similar profile of design engagement with NPD is evident in the case studies conducted by Perks et al. (2005), with significant engagement in 'Concept generation' and 'Design and development' in their study and significantly less involvement in 'Production' or 'Launch'.

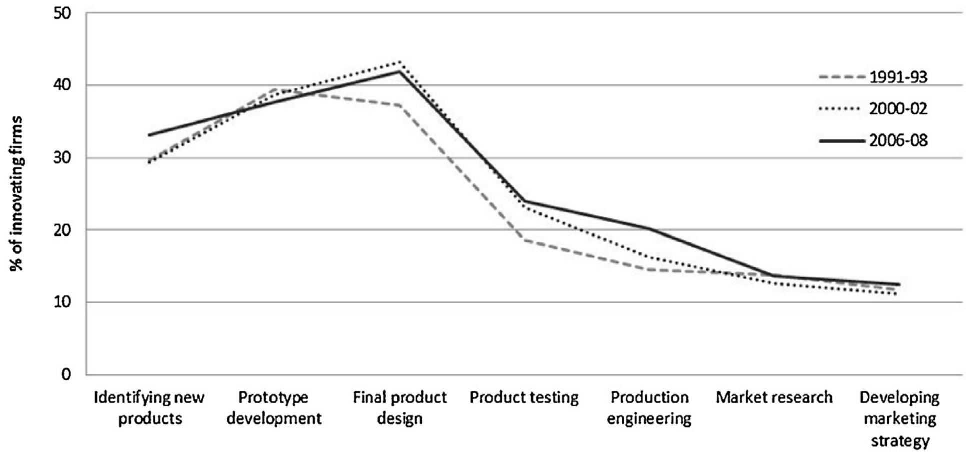

Fig. 1. Design engagement with the NPD process: by date.

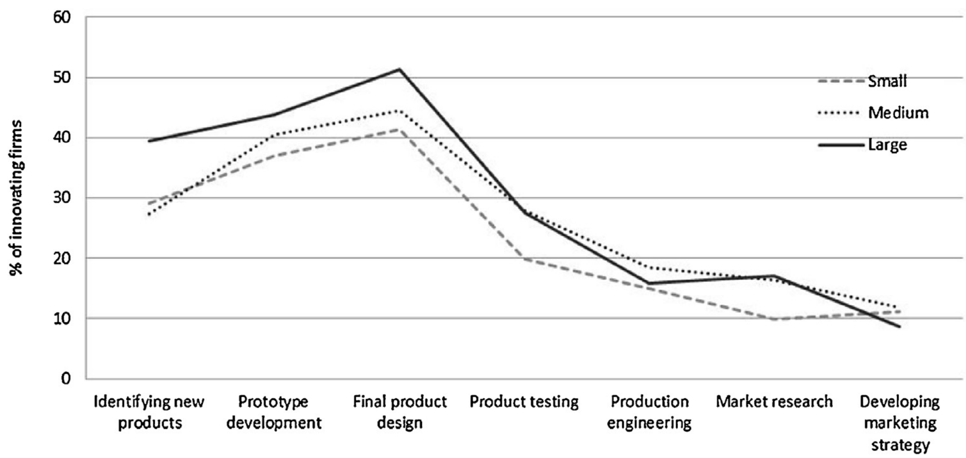

Fig. 2. Design engagement with the NPD process: by plant size.

of design throughout the NPD process, we define a dummy variable, which takes value 1 where a plant involves design staff in all stages of the NPD process.

Of the plants surveyed, 17% employed designers as functional specialists, 29% employed designers at various stages in NPD, and 4% of organisations involved designers throughout the NPD process. The remaining 50% reported no designers engaged in any NPD activity undertaken. These data accord with patterns noted in Fig. 1, with design staff routinely engaged in the prototyping and final product stages of the NPD process, but more rarely involved in production or marketing.[10]

To test our hypotheses, we utilise the innovation production function; expressing it in formal terms, if I_{it} is an NPD output indicator for plant i in period t, the innovation production function might then be summarised as:

$$I_{it} = \beta_0 + \beta_1 DFS_{it} + \beta_2 DMT_{it} + \beta_3 DPL_{it} + \beta_4 RI_{it} + \lambda_j + \tau_t + \delta_i \qquad (1)$$

where DFS_{it} denotes a dummy variable relating to plants' use of designers as functional specialists, DMT_{it} is a dummy variable relating to plants' wider use of designers, and DPL_{it} is a dummy variable relating to designers' involvement throughout the NPD process. In the innovation production function we also include a set of plant-level control variables (RI_i), which have been shown to influence innovation outputs in previous studies involving innovation production functions. These are necessary to ensure that the estimated design role coefficients are not systematically biased upwards or downwards.

First, we include a variable to reflect the engagement of the plant in R&D, which is generally associated positively with new product development (Crepon et al., 1998; Loof and Heshmati, 2001, 2002; Roper et al., 2008). Second, we introduce a variable to control for plants' multi-functional working practices in NPD more broadly (i.e., between all functional groups except designers), as previous studies have suggested that the use of multi-functional teams is strongly linked to innovation success (Sarin, 2009). This variable is defined in a similar way to our design role variable reflecting plants' use of designers across the various elements of the NPD process.[11] Third, we include a dummy variable to indicate whether or not plants were involved in innovation partnerships as part of their NPD activities. Previous studies provide strong evidence of the positive effects of such external partnerships on NPD outputs (Love and Mansury, 2007; Roper et al., 2008). Fourth, we include a plant size indicator (employment) which we interpret in the Schumpeterian tradition as a resource indicator, and which has been shown in

[10] Annex 2 provides detailed descriptives on the engagement of designers in the NPD process by date, plant size and whether plants were undertaking R&D.

[11] Specifically, this variable takes values from 0 to 28 depending on the engagement of four skill groups (engineers, scientists and technicians, skilled production staff, marketing staff) in the seven elements of the NPD process. For example, a plant involving all skill groups in all elements of the NPD process would score 28 on this variable.

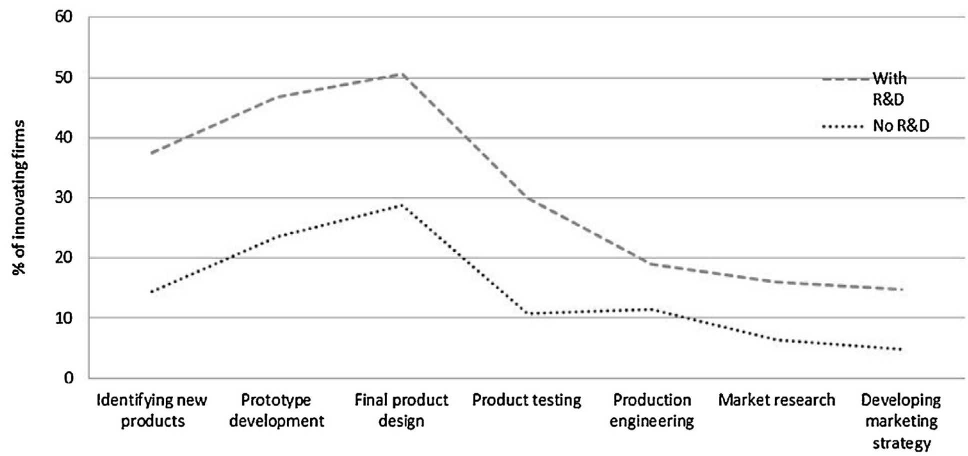

Fig. 3. Design engagement with the NPD process: with or without R&D.

previous studies to have a strong relationship to innovation outputs (Jordan and O'Leary, 2007). Fifth, we include an indicator of enterprise vintage to capture potential plant life-cycle effects (Atkeson and Kehoe, 2005). Sixth, we include an indicator of whether or not a plant is externally-owned to reflect the potential for intra-firm knowledge transfer within a multinational enterprise (Jensen, 2004). Seventh, we include an indicator of the level of graduate skills in the business unit, which we expect to have a positive relationship to innovation outputs (Freel, 2005; Arvanitis et al., 2007). As standard we also include sectoral dummies λ_j, period dummies τ_t and a regional dummy relating to Northern Ireland in each model (not reported). δ_i in Eq. (1) denotes an error term, $\delta_i \sim N(0, \sigma^2)$.

Our estimation approaches are dictated by the fact that we are using plant level data from three waves of a highly unbalanced panel and the nature of our dependent variables. As Fig. 1 suggests, design engagement within the NPD process has remained relatively stable over the three survey waves and we therefore pool observations across the three waves of the survey and include time dummies to isolate any temporal fixed effects. Our first dependent variable—the share of sales from new products—is expressed as a percentage of plants' sales and is therefore bounded at zero and one hundred. For these models we therefore use an upper and lower censored tobit estimator. Our second dependent variable—an ordinal indicator of innovation quality—requires an ordered probit.

Finally, this study could suffer from common method bias (CMB). CMB is the variance due to the general measurement methods rather than due to the measured key explanatory variables themselves (Podsakoff et al., 2003; Sharma et al., 2010) and may lead to biased estimates of the effects of key variables of interest in survey-based studies. Three aspects of our analysis reduce the potential for CMB: first, our analysis is based on three separate surveys rather than a single survey; second, we estimate a relatively complicated innovation production function with the dependent variable measured at the end of the period and key explanatory variables reflecting plants' NPD activities during the previous three years; third, the answer scales of our dependent variable and key explanatory variables are very different. Formally, we have checked for CMB using the Harmon's one factor test which suggests that in our data the most important single factor explains only about 27% of the total variation of the main variables in our model, well below the norm of 50% (Podsakoff and Organ, 1986). Using the alternative marker variable technique with a range of different marker variables suggests a similar pattern with no evidence that CMB is likely to be an issue in our study (Malhotra et al., 2006).

4. Empirical results and discussion

The results of our estimation with percentage of sales from newly introduced products as the dependent variable are shown in Table 2. Hypotheses 1–3 are tested for the whole sample in Model 1. In each case the size of the coefficients on the three design role variables reflects the impact of employing each approach relative to situations where organisations were undertaking NPD activity, but had no engagement of design staff. Thus, at the most basic level, plants employing design as functional specialism had, on average, a level of sales from new products around 9 percentage points higher than plants with no design engagement in their NPD activity, even after allowing for the effects of R&D, size, ownership, etc. (Table 2, Model 1). This initial result provides strong support for Hypothesis 1 and the value of the engagement of design in NPD even where its role is limited to that of functional specialism. It also provides support for other studies, which have emphasised the value of design as part of the NPD process irrespective of the role it plays (Cereda et al., 2005; Hertenstein et al., 2005; Marsili and Salter, 2006).

Following our second hypothesis, a broader involvement of design in the NPD process should allow an organisation to exploit potential complementarities between designers and other staff. In our analysis, however, the increase in NPD outputs associated with broader involvement was only marginally greater than that of engaging design as functional specialism (Table 2, Model 1). Moreover, a χ^2 test of the equality of the estimated coefficients relating to design as functional specialism and design playing a bridging role in NPD proves insignificant (Table 2, Model 1). This therefore provides little support for the contention of Hypothesis 2 that design's bridging role in NPD generates significant complementarities. Various explanations for this result are possible. First, synergies between designers and other staff involved in NPD may simply be not empirically significant. However, a more likely scenario may be that such synergies are possible, but are being undermined or offset by skill limitations or other contextual factors. As Perks et al. (2005) comment in relation to designers' wider involvement in NPD, organisations should make "considerable effort to generate on-going interaction between designers and relevant stakeholders [and] designers need the interfacing skills to interact and to communicate with other functions . . . For some designers, acquiring the skills to implement team-based NPD can be a long and problematic learning process' (p. 120–121). Similarly, Micheli et al. (2012) argue that designers' education and skills may not be adequate, particularly when considering commercial aspects of projects. Moreover, designers and other staff (e.g., marketing and R&D) may desire closer working relationships, as they

Table 2
Tobit models of the share of sales from new products (%).

	(1) Whole sample	(2) R&D performers	(3) Plants with no R&D	(4) Small plants	(5) Larger plants
Roles of designers					
Design as functional specialists	9.179*** (2.405)	11.917*** *(2.824)*	3.341 *(4.384)*	12.851*** *(3.465)*	7.100** *(3.418)*
Designers playing a bridging role	9.604*** (2.117)	12.248*** (2.389)	3.489 (4.184)	10.050*** (2.986)	8.165** (3.001)
Continuous involvement of designers	20.023*** (4.802)	22.965*** (5.178)	12.012 (11.267)	11.593 (8.067)	22.732*** (6.056)
Control variables					
R&D done in-plant	5.291*** (1.995)			5.191* (2.700)	5.993** (2.946)
Multi-functional teams indicator	−0.457** (0.205)	−0.419* (0.236)	−0.478 (0.368)	0.189 (0.320)	−0.839*** (0.272)
External NPD linkages	2.871* (1.743)	1.960 (2.009)	2.976 (3.283)	−0.731 (2.379)	5.383* (2.546)
Number of employees	−0.001 (0.004)	−0.006 (0.005)	0.021 (0.011)	−0.110 (0.109)	−0.002 (0.005)
Age	−0.081** (0.032)	−0.056 (0.038)	−0.112** (0.057)	−0.072 (0.042)	−0.089* (0.045)
External ownership	−3.212 (2.476)	0.351 (2.934)	−11.916*** (4.167)	−0.531 (4.383)	−5.264 (3.082)
Share of employees with degree	0.092 (0.063)	0.113 (0.074)	0.119 (0.125)	0.028 (0.082)	0.192* (0.097)
Constant	16.014*** (4.060)	20.860*** (4.830)	9.113 (7.111)	14.606** (6.026)	19.101*** (5.870)
Observations	917	635	282	451	466
Log-likelihood	−3646.8	−2586.8	−1041.1	−1737.3	−1895.0
χ^2 Des. as functional specialists = Des. involved in several NPD stages	0.03 (0.87)	0.01 (0.909)	0.00 (0.978)	0.55 (0.46)	0.09 (0.763)
χ^2 Des. as functional specialists = Des. involved throughout NPD	4.75 (0.029)	4.22 (0.04)	0.57 (0.449)	0.02 (0.881)	6.27 (0.012)

Notes: Standard errors in parentheses. Models are based on pooled data for 1991–1993, 2000–2002, 2006–2008. All estimated models include also sector dummies (10 sectors), period dummies and Northern Ireland dummy. Variable definitions in Data Annex.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

value each other's input into the NPD process (Zhang et al., 2011), but they often disagree over how integration between functions should happen (Luo et al., 2005).

The final role we consider is characterised by the continuous involvement of design in NPD, i.e., where design is involved in all NPD stages. In our sample, plants adopting this design approach have, on average, a level of sales from new products around 20 percentage points (pp) higher than plants not engaging design staff in their NPD activity, and 9 pp higher than plants where design plays a bridging role (Table 2, Model 1). Both differences are statistically significant as indicated by the χ^2 tests, providing strong support for Hypothesis 3 and the contention that innovation outputs benefit significantly in plants where designers are involved throughout the NPD process.

Where they are significant, our control variables largely take the anticipated signs. In-house R&D has a positive and significant relationship to innovation outputs (Crepon et al., 1998; Loof and Heshmati, 2001, 2002; Roper et al., 2008), while plant vintage—measured in years—has a negative relationship to the percentage of innovative sales. This may reflect plant life-cycle issues and the increasing maturity of its product range as the firm itself ages (Atkeson and Kehoe, 2005).

The second potential impact of design we investigate is on the novelty of NPD outcomes. Table 3 reports ordered probit models with Model 1 relating to the whole sample. Positive coefficients in the table suggest that an increase in the independent variable is associated with an increase in the novelty of NPD outcomes. Here, unlike the situation with sales from new products discussed earlier, plants engaging design purely as functional specialism achieved no significant increase in the novelty of their NPD outputs (Table 3, Model 1). Where design was engaged more widely or throughout the process, however, significant association with the novelty of NPD outputs was evident (Table 3, Model 1). The implication is that both of these design roles can increase the novelty of NPD outcomes relative to lack of use of design in NPD. Interestingly, however, as the χ^2 tests reported in Table 3 suggest, there is no difference in terms of NPD novelty between design playing a bridging role and being involved in all NPD stages.

Overall, the estimation for our whole sample suggests that all three roles have positive and significant relationship with NPD outcomes: the use of design as a functional specialism is associated with an increase in sales from new products; the bridging role played by design across several NPD stages contributes positively to both novelty and new product sales, but, in this latter case, its effect is similar in scale to that of design used as a functional specialism. The continuous involvement of design in the NPD process is also associated with higher levels of new product sales and NPD novelty, with the premium in new product sales being significantly larger than that where design works as functional specialism.

Our results therefore emphasise not only the importance of whether, but also how design is engaged at different stages within the NPD process. More specifically, for our whole sample of respondents, while engaging designers in the NPD process as functional specialists or more broadly in NPD is associated with an increase in new product sales by around 9 pp, a continuous involvement of designers is associated with more than twice as high an increase in NPD outputs. In other words, employing design staff is important, but so is their actual utilisation.

Our analysis so far has dealt with the roles of design in the sample of plants as a whole. We now examine the importance of R&D and plant size as potential moderators of the design roles-NPD outcomes relationship. In particular, we consider the relationship between design and NPD outcomes separately for plants that do and do not conduct in-house R&D, and for small and larger plants.[12] The potential importance of R&D as a moderator of the impact of design on NPD outcomes is suggested by Fig. 3, where design engagement is shown to be consistently higher among R&D-performing establishments. Previous studies have also emphasised potential complementarities between R&D and design in NPD (Tether, 2005, 2009), and found that design investment and R&D spend are highly correlated (Moultrie and Livesey, 2014). The question therefore is whether the relationship between alternative design roles with

[12] The role of e.g. R&D could be investigated by interacting the R&D dummy variable with each of the design dummies. The disadvantage of such an approach is that it assumes that the coefficient signs and significance of all other variables are the same for R&D performers and non-performers. The results of Table 2 and Models 2 and 3 indicate that this is an invalid assumption, supporting the use of separate estimations.

Table 3
Ordered probit models of the novelty of plants' innovative products.

	(1) Whole sample	(2) R&D performers	(3) Plants with no R&D	(4) Small plants	(5) Larger plants
Roles of design					
Design as functional specialists	0.195 (0.133)	0.124 (0.159)	0.439* (0.260)	0.037 (−0.176)	0.366* (0.216)
Designers playing a bridging role	0.396*** (0.124)	0.435*** (0.148)	0.256 (0.246)	0.551*** (0.185)	0.196 (0.179)
Continuous involvement of designers	0.565* (0.333)	0.604 (0.413)	0.533 (0.596)	0.075 (0.464)	0.846* (0.508)
Control variables					
R&D done in-house	0.111 (−0.106)			0.057 (0.142)	0.187 (0.168)
Multi-functional teams indicator	0.022* (0.011)	0.024* (0.014)	0.008 (0.020)	0.060*** (0.018)	−0.008 (0.015)
External NPD linkages	0.137 (0.097)	0.027 (0.123)	0.377** (0.172)	0.135 (0.131)	0.086 (0.152)
Number of employees	0.000 (0.000)	0.000 (0.000)	0.001 (0.000)	0.003 (0.006)	0.000 (0.000)
Age	−0.003** (0.001)	0.000 (0.002)	−0.008*** (0.003)	−0.002 (0.002)	−0.003* (0.002)
External ownership	−0.137 (−0.136)	0.062 (0.182)	−0.423* (0.228)	−0.080 (0.232)	−0.256 (0.184)
Share of employees with degree	−0.006** (0.003)	−0.006 (0.003)	−0.008 (0.006)	−0.006 (0.004)	−0.003 (0.006)
Observations	975	675	300	489	486
Log-likelihood	−581.91	−362.58	−207.00	−309.36	−255.51
Equation Chi-2	77.2	51.1	39.79	57.61	38.22
Pseudo R-2	0.062	0.066		0.085	0.070
χ^2 Des. as functional specialists = Des. involved in various stages	2.16 (0.14)	3.18 (0.07)	0.33 (0.56)	5.73 (0.02)	0.55 (0.46)
χ^2 Des. as functional specialism = Des. involved throughout NPD	1.78 (0.18)	1.30 (0.25)	0.02 (0.88)	0.01 (0.94)	0.84 (0.36)

Notes: Standard errors in parentheses. Models are based on pooled data for 1991–1993, 2000–2002, 2006–2008. All estimated models include also sector dummies (10 sectors), period dummies and Northern Ireland dummy. Variable definitions in Data Annex.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

NPD outputs is conditional on plants' in-house R&D. Models 2 and 3 in Tables 2 and 3 report the relevant estimation results. For sales from new products we find a clear result: only where plants have in-house R&D is design significantly correlated with NPD outcomes (Table 2, Model 2); where plants have no in-house R&D, neither the presence nor the choice of design approach influence NPD outcomes (Table 2, Model 3). In terms of the novelty of NPD outcomes our results are less clear, although again the strongest role of design is evident when R&D is being undertaken in-house (Table 3, Models 2 and 3). Taken together, these results suggest strong complementarities between the presence of R&D in a plant and roles played by design in NPD. Note, however, that our data relate purely to manufacturing plants. This is important as previous studies have suggested that in the service sector innovation activity may depend much less strongly on R&D than in manufacturing (Leiponen, 2005; Moultrie and Livesey, 2014).

We now turn to the role of plant size as a potential moderator of design effects on NPD. Here, we anticipate that the relationship between design and innovation performance will be proportionately stronger where other resources are less constrained, i.e. in larger plants (see also Moultrie and Livesey, 2014). Our results indicate that engaging design either as functional specialism or in several NPD stages is associated with enhanced NPD success and novelty in both small and larger plants (Models 4 and 5, Tables 2 and 3). This suggests the generality of results relating to Hypotheses 1 and 2. However, only in larger plants (i.e., with more than 50 employees) does the continuous involvement of design add greater value, thus providing more conditional support for Hypothesis 3. This result also suggests the greater need for coordination in bigger plants where NPD teams are likely to be larger and operating within a more complex organisational environment. Note, however, that the value of design in a bridging role (as opposed to a continuous role) is evident in small plants both for new product novelty and sales from new products.

5. Conclusions and managerial implications

The importance of design as a significant contributor to NPD success has been emphasised by many authors (e.g., Verganti, 2009; D'Ippolito et al., 2014; Moultrie and Livesey, 2014). However, there is limited evidence over the effectiveness of different roles designers can play in NPD (Perks et al., 2005; Candi and Gemser, 2010), and the difficulties of integrating design into the NPD process have been emphasised repeatedly (Beverland, 2005; Micheli et al., 2012).

The aim of this study was to combine the insights of previous qualitative studies on the roles played by design in NPD with a systematic quantitative analysis. The main contribution of this research is to our understanding of the impact of alternative roles of designers on NPD outcomes. More specifically, using detailed data from three waves of the Irish Innovation Panel, we are able to quantify the value of extending the role of design beyond that of functional specialism to having higher levels of engagement within the NPD process. In more conceptual terms, our analysis examines the relative value for NPD outcomes of utilising design in NPD, and the benefits of a continuous involvement of design in NPD.

Our results have several implications for theory, practice and policy. First, we find that greater use of design corresponds to higher performance, measured as both sales from new products and product innovation. This supports existing research on design effectiveness (e.g., Hertenstein et al., 2005), but contradicts claims that overly novel designs could trigger negative responses from consumers and lead to worse NPD outcomes (Hekkert et al., 2003; Goode et al., 2013; Mugge and Dahl, 2013).

Second, larger organisations, which continuously involve designers in NPD, tend to outperform those employing design either in a purely functional capacity, or just in some NPD stages. This finding reaffirms the benefit of investing in design, but also, and more importantly, emphasizes the importance of collaboration between designers and other functional groups. Indeed, previous studies (e.g., Perks et al., 2005) have related designers' involvement in several NPD activities with the presence of multifunctional teams. While our research did not directly investigate team dynamics and collaboration across functions (De Luca et al., 2010), we can assume that involving designers more widely in NPD would expose them to a higher level of interaction with other functional groups. Therefore, our results support extant tentative evidence that greater engagement of designers in NPD could be positive, but "to gain the full benefits of design . . . an organisation needs to develop internal capability for its management and delivery" (von Stamm, 2004, p. 18).

Third, the proportion of plants with a design-intensive approach remains small, however, suggesting the potential for achieving competitive advantage through the wider use of design in NPD. On the other hand, such finding may be relevant only to larger organisations, as small ones appear to benefit the most from engaging design purely as functional specialism. For these plants our evidence suggests that there is little gain in terms of sales from new products in extending the role of design beyond one stage in the NPD process, although there is a clear benefit in the bridging role of design in terms of product novelty. This approach may also help to minimise costs and potential conflicts between designers and other staff groups involved in NPD activity (Perks et al., 2005; Goffin and Micheli, 2010).

Fourth, our results also identify another important precondition for maximising the value of design to NPD—the need for in-house R&D activity. From a managerial point of view, this suggests the need to consider design and R&D investment decisions together, or at least to make decisions about which role design should play in light of decisions about R&D. However, our survey data provide only tentative evidence on either the precise structure of the relationship between R&D and design contribution to the NPD process or how this relationship actually works. One possibility is that there is complementarity between technological and aesthetic aspects, or more generally that plants' R&D competence and skills allows the more effective implementation or adoption of new design ideas (see also Tether, 2009; Moultrie and Livesey, 2014).

Fifth, over the last decade scholars and practitioners alike have emphasised the rise of design as a strategic approach, and its elevation from functional specialism to leading perspective in the development of products and services (see, e.g., Verganti, 2009; Liedtka, 2014). This study, however, challenges such claims and shows that design engagement with the NPD process has *not changed* significantly over the last two decades.

Finally, over the past decade several governments have promoted investments in design to enhance a country's industrial competitiveness (see, e.g., Cox, 2005; Design Denmark, 2007; Design for the Public Good, 2013). This research indicates that simply spending more in design would not be effective. Instead, contextual factors should be taken into account (e.g., size of organisations, engagement in R&D activity) and organisations should create a sufficient level of appreciation and awareness of the potential contributions of design. This suggests a dual role for governments in terms of design policy: to support the development of design investment and competencies to enable firms to access appropriate design resources but also to play a promotional or advocacy role to ensure that firms are aware of the advantages of design-led NPD processes. There are also implications for design education. If designers to play a significant, sometimes leading, role in NPD, they should develop a new skill set that goes beyond technical abilities and encompasses skills to manage, negotiate, motivate and persuade (Perks et al., 2005).

5.1. Further research

Our results suggest three areas for future research. First, while our findings highlight the importance of how designers are managed and the roles they play in NPD, they also emphasise the relevance of contextual factors in influencing the success of different roles. Therefore, this research suggests the need for a context specific or at least a strongly contextualised approach to developing an understanding of the management and organisation of design. For example, market context may play a significant role with design playing a potentially more significant role in consumer goods industries. Market structure may also play an important role with the potential for design to be used as a response to competitive pressure.

Second, our results underline the value in larger plants of engaging design throughout the NPD process. In our dataset, however, only a small percentage of plants were adopting such an approach. Moreover, this study shows that design's role has almost remained the same over two decades, despite claims by several commentators of its rise from functional to strategic or leading perspective. Why is this? What are the barriers to implementing a more design-intensive NPD approach? Both questions require further investigation, adopting a longitudinal perspective and perhaps a more in-depth, qualitative approach than the one chosen here. Such an approach may also be useful in more fully understanding the use, roles and impact of designers in smaller firms.

Finally, further research is necessary to understand the interrelation between R&D and design inputs to the NPD process and also to clarify whether the complementary relationship we identify for manufacturing is also evident in other sectors. Such research may also inform recent calls for a more effective design policy to support successful innovation activities (Hobday et al., 2012).

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Annex 1. Variable definitions

NPD outcomes	
New product sales (% sales)	An indicator representing the percentage of plants' sales at the time of the survey accounted for by products which had been newly introduced over the previous three years.
NPD novelty	An ordinal indicator taking value 3 if the product was new to the market, 2 if the product was new to the plant and 1 if the plant had undertaken no NPD activity over the previous three years.
Roles of designers	
Designers as functional specialists	A dummy variable taking value 1 if designers were engaged in at least one stage among identification, prototyping and final product design, but no other stage of the NPD process. 0 otherwise
Designers playing a bridging role	A dummy variable taking value 1 if designers were engaged in at least one stage among identification, prototyping and final product design, and at least one other element of the NPD process. 0 otherwise
Continuous involvement of designers	A dummy variable taking value 1 if designers were engaged in all stages of the NPD process. 0 otherwise
Control variables	
In plant R&D	A binary indictor taking value 1 if the plant has an in-house R&D capacity
Multi-functionality indicator	An indicator of the breadth of multifunctional working across the NPD process. Four skill groups (engineers, scientific and technical staff, marketing and sales staff, production staff) by seven elements of the NPD process. Index takes maximum value of 28 if all skill groups were involved in each stage of the NPD process.
External NPD linkages	A binary indicator taking value 1 where a plant was involved in innovation partnerships (e.g. with suppliers or customers) and 0 otherwise.
Employment	Number of employees at the time of the survey.
Plant age	The age of the site (in years) at the time of the survey.
Externally owned	A binary indicator taking value 1 if the plant was owned outside Ireland at the time of the survey.
Share of employees with a degree (%)	Percentage of the workforce with a degree or equivalent qualification

Annex 2. Design by sizeband, research and development and time period

In this annex we provide more detail on the involvement of designers across the NPD process by time period (Table A2.1), plant sizeband (Table A2.2), and whether or not plants were undertaking R&D (Table A2.3). As suggested by Fig. 1 differences in the involvement of designers across the NPD process between plants in different sizebands and time periods are small. More significant differences are evident between R&D and non-R&D performing plants.

Table A2.1
Design engagement with the NPD process by date.

	1991–93 N = 529	2000–02 N = 519	2006–08 N = 269	Total N = 1317
Design staff engagement in individual NPD elements (share of innovative plants)				
Identifying new or improved products	0.32	0.31	0.36	0.32
Prototype development	0.40	0.41	0.43	0.41
Final product design/development	0.39	0.46	0.47	0.44
Product testing	0.20	0.26	0.26	0.24
Production engineering	0.16	0.17	0.22	0.18
Market research	0.15	0.13	0.16	0.14
Developing marketing strategy	0.13	0.12	0.15	0.13
Roles of design (share of innovative plants)				
Designers as functional specialists	0.17	0.16	0.19	0.17
Designers playing a bridging role	0.26	0.32	0.29	0.29
Continuous involvement of designers	0.04	0.02	0.05	0.04

Table A2.2
Design engagement with the NPD process by plant size.

	Employment sizeband			
	Less than 20 N = 223	20–99 N = 604	100 plus N = 446	Total N = 1273
Design staff engagement in individual NPD elements (share of innovative plants)				
Identifying new or improved products	0.26	0.32	0.34	0.32
Prototype development	0.35	0.42	0.43	0.41
Final product design/development	0.35	0.45	0.45	0.44
Product testing	0.20	0.24	0.24	0.24
Production engineering	0.13	0.19	0.18	0.18
Market research	0.10	0.14	0.16	0.14
Developing marketing strategy	0.09	0.15	0.11	0.13
Roles of design (share of innovative plants)				
Designers as functional specialists	0.19	0.17	0.18	0.17
Designers playing a bridging role	0.20	0.30	0.30	0.29
Continuous involvement of designers	0.03	0.03	0.03	0.04

Table A2.3
Design engagement with the NPD process: with or without R&D.

	With R&D N = 911	No R&D N = 400	Total N = 1311
Design staff engagement in individual NPD elements (share of innovative plants)			
Identifying new or improved products	0.39	0.18	0.32
Prototype development	0.48	0.25	0.41
Final product design/development	0.50	0.29	0.44
Product testing	0.28	0.14	0.24
Production engineering	0.20	0.13	0.18
Market research	0.17	0.09	0.14
Developing marketing strategy	0.16	0.07	0.13
Roles of design (share of innovative plants)			
Designers as functional specialists	0.18	0.14	0.17
Designers playing a bridging role	0.34	0.17	0.29
Continuous involvement of designers	0.04	0.02	0.04

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