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Does additionality persist? A panel data investigation of the legacy effects of public support for innovation

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Abstract

In many countries significant amounts of public funding is devoted to supporting firms? R&D and innovation projects. However, policy evaluations often focus on short-term outputs rather than longer-term policy outcomes. Here, using panel data on the innovation activities of Irish manufacturing firms, and instrumenting to control for potential selection effects, we identify the legacy effects of innovation support at the level of the individual plant. Five potential legacy effects are examined relating to outputs, inputs, behavioural change, networking and resilience. Our results suggest a rather mixed picture with strong evidence of sustained output additionality, weaker evidence of sustained additionality linked to behaviour, networking and resilience and no evidence of sustained input additionality. In other words the legacy effects of innovation support operate primarily through firms? enhanced innovation outputs rather than through any resource or capability effects. Our results have implications for innovation policy design and evaluation.

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Does additionality persist? A panel data investigation of the legacy effects of public support for innovation

1. Introduction

In many countries significant amounts of public funding is devoted to supporting R&D and innovation projects in individual firms with positive evidence on additionality (Hsu, Horng, & Hsueh, 2009; Licht, 2003; Luukkonen, 2000). In recent years, however, the breadth of impacts which have been considered in evaluating the impact of public support for R&D and innovation has extended beyond quantitative indicators of input additionality and output additionality to reflect the effects of public intervention on the behavioural and innovation capabilities of firms (Afcha Chavez, 2011; Clarysse, Wright, & Mustar, 2009; Hsu et al., 2009; Norrman & Bager-Sjogren, 2010). Evaluations have also become sophisticated in terms of allowing for the potential impact of selection biases in estimating policy effects (Hewitt-Dundas & Roper, 2009) and undertaking social experiments (Reiner, 2011). However, due to the short-term needs of scheme managers and policy makers, evaluations often focus on short-term outputs rather than longer-term policy outcomes with potentially misleading results (Hewitt-Dundas & Roper, 2011).

The short-term nature of many innovation policy evaluations is particularly disappointing given the relatively long time horizons which are often needed for innovations to achieve scale in the market place. For example, recent UK guidelines on the evaluation of publicly funded projects suggest adopting a three-year period for the persistence of benefits in individual enterprise support measures (BIS, 2009, p. 26). The short-term nature of many innovation policy evaluations may also under-estimate the longer-term benefits of such initiatives through their organisational learning effects (Bartezzaghi, Corso, & Verganti, 1997; Clarysse et al., 2009; Cohen & Levinthal, 1989; Jimenez-Jimenez & Sanz-Valle, 2011) and/or wider innovation spillovers (Beugelsdijck & Cornet, 2001). Not capturing these persistence effects is important as it may mean that innovation policy evaluations under-estimate the benefits of innovation policy leading to an under-investment in such policy. This ‘policy failure’ has the potential to exacerbate the standard ‘market failure’ which leads firms to under-invest in R&D and innovation due to their positive externalities (Martin & Scott, 2000; Woolthuis, Lankhuizen, & Gilsing, 2005).

Here, using panel data on the innovation activities of Irish manufacturing firms, we focus on whether, and how, the additionality effects of innovation policy persist at the level of the individual plant. For example, do publicly supported innovation projects generate behavioural additionality which persists beyond the project (Aschhoff & Fier, 2005; Clarysse et al., 2009; Falk, 2004; Georghiou, 2004; Kim & Song, 2007)? Or, do publicly supported innovations made in one period provide an enhanced basis for innovation in subsequent periods (Hewitt-Dundas & Roper, 2009)? Evidence of either would suggest that additionality persists. Evidence of neither would suggest that the effects of public support for innovation are essentially project specific with little sustained benefit. Aside from the question of whether additionality persists, there is also the question of 'how'? Here, we are able to test five different mechanisms through which persistence might occur, reflecting five notions of additionality discussed in the evaluation literature.

The remainder of the paper is organised as follows. Section 2 provides our conceptual framework and hypotheses which relate to the five potential mechanisms for the persistence of additionality. Section 3 describes our data source – the Irish Innovation Panel – and the operationalization of our tests for the persistence of additionality. Inter alia our tests also provide an indication of the economic significance of the different types of additionality effects identified earlier. Section 4 outlines the main empirical results and Section 5 concludes with a range of conceptual and policy implications. Our empirical results are clear: output additionality is the only type of additionality which persists; input, behavioural, network and resilience effects are all transitory.

2. Conceptual framework

Innovation policies aimed at promoting economic growth have changed in recent years to become more systemic, incorporating a mix of direct and indirect policy instruments to address innovation system failures (Woolthuis et al., 2005) or stimulate endogenous growth. Central to both these rationales is the notion of 'additionality', i.e. the extent to which additional innovation activity is stimulated by public support, activity which would not have been undertaken without support (Buisseret et al. 1995; Davenport et al 1998; Luukkonen, 2000; Georghiou et al 2004). This in turn would be expected to lead to greater spillover benefits than would have taken place in the absence of public support. This leads to the question of the mechanism or mechanisms through which additionality occurs? Public support for R&D or innovation may, for example, reduce the costs associated with building firm's knowledge stocks for innovation (Trajtenberg, 2000), by enhancing business performance (Klette and Johansen, 1998) and firms' ability to conduct future research projects (Mansfield & Switzer, 1984; Luukkonen 2000). Alternatively, public support for R&D activity may contribute to developments in firms' human resources and innovation capability (Freel, 2005) or absorptive capacity (Veugelers and Cassiman, 1999; Cassiman and Veugelers, 2002).

In the evaluation literature discussion of the different mechanisms through which additionality can occur has led to the identification of (at least) five types of additionality: output additionality, input additionality, behavioural additionality, network or relational additionality and resilience. Output additionality is generally said to occur where the results of an innovation process are different to those which would have occurred in the absence of public support (Luukkonen, 2000). This may, for example, reflect the impact of public support on the timing or quality of firms' new innovation. Input additionality, a notion attributed by Hsu et al., (2009) to Georghiou (1994), occurs where public support for R&D or innovation reduces the cost to firms of undertaking innovation, allowing them to increase the scale of the knowledge inputs to innovation. Behavioural additionality reflects the potential for public support for innovation activity to contribute positively to more behavioural aspects of firms' innovation activity influencing skill levels, attitudes to change and risk etc. (Georghiou, 2004). Similarly, network or relational additionality occurs where public support for innovation enhances firms' innovation networks[1]. Finally, we might also consider resilience effects through which public support for innovation enhances firms' ability to cope with uncertainty in the business environment.

Definitions and applications of the various notions of additionality vary depending on the specific context in which the different concepts are being applied (Hsu et al., 2009). In general terms, where additionality is being considered as part of an ex post evaluation,

[1] Network or relational additionality is sometimes also treated as an element of behavioural additionality. Given the increasing importance of openness in innovation strategy, however, it seems more appropriate to treat it separately.

however, evaluation timescales are generally short, often 1-2 years. Here, we are interested not so much in the immediate – project level - effects of public support for innovation but in its longer-term effects on firms' innovation success. We envisage a two period model in which some firms receive public support for innovation in period 1. In the short-term, this public support may lead to some or all of the five types of additionality effects identified earlier. We might then anticipate that where firms innovate in period 2, those firms which received public support in period 1 and potentially benefitted from additionality, may be 'better' innovators. For example, by enhancing innovation outputs in period 1, an output additionality effect, public support may lay the foundation for enhanced future innovation. Period 1 innovations – enabled by public support – may be more novel, more complex or more successful than otherwise, enabling more successful innovation in period 2. We therefore anticipate that:

> ***H1: Sustained output additionality***
> Public support for innovation will generate sustained output additionality.

Paralleling discussion of input additionality, we might also envisage that where a firm receives public support in period 1, this enhances the innovation value of inputs in period 2. For example, public support in period 1 may enable a firm to invest in R&D infrastructure or equipment which may enhance the innovation value of future R&D investments. Hence, we suggest that:

> ***H2: Sustained input additionality***
> Public support for innovation will generate sustained enhancements to the innovation value of knowledge investments for innovation.

Third, reflecting discussion of behavioural additionality and the potential for learning-by-doing effects in innovation, we consider whether public support has persistent behavioural effects. For example, firms undertaking publicly supported innovation activities may develop new or improved skill sets which add value to subsequent innovation projects (Leiponen, 2005). Sakakibara (1997) for example, indicates that the managers of publicly supported collaborative R&D projects in Japan rated researcher training as the most important benefit which their companies derived from their project. Somewhat surprisingly, this 'intangible' benefit from collaborative R&D was seen as more important than 'increase in the awareness of R&D in general', 'breakthrough in a critical technology', and 'accelerated development of the technology'. This suggests:

> ***H3: Sustained behavioural additionality***
> Public support for innovation will generate sustained behavioural additionality with positive benefits for innovation outputs.

Behavioural additionality we consider here as largely an internal issue. It is now widely recognised, however, that firms' innovative outputs will depend not only on the quality and scale of internal resources but also on their external networks and operating environment (Chesborough, 2003, 2006). For example, there are possible financial benefits, the role of external linkages here being to increase a firms' ability to appropriate returns from innovation (Gemser and Wijnberg, 1995). Also, Powell (1998) argues that external linkages may help by stimulating creativity, reducing risk, accelerating or upgrading the quality of the innovations made, and signalling the quality of firms' innovation activities. Previous research has also found that participation in collaborations is indicative of an ability for interactive knowledge sharing that may prove very beneficial for further exploitation of knowledge, and thus inter-firm linkages promote innovativeness (Caloghirou, et al., 2002).

External links may also be a useful method of searching the technological environment in a systematic fashion, permitting access to improved technology developed elsewhere (Mowery, 1990; Niosi, 1999; Laursen and Salter, 2006). Recent studies have however also identified although limits to the benefits of openness as the number of firms' external relationships increases (Ahuja 2000; Love and Roper 2001; Katila and Ahuja 2002; Laursen and Salter 2006; Leiponen and Helfat 2010). Firms' operating environment may also influence their ability to innovate through partner availability (Hewitt-Dundas, 2006), regulatory or legislative effects (Rennings & Rammer, 2011) or the local availability of resources such as finance or skilled labour (Stuart & Sorenson, 2003). Such considerations have stimulated interest in the effects of locational choice and characteristics on innovation (Heidenreich, 2009; Mudambi, 2008) and in firm decentralisation strategies which seek to maximise innovation by combining knowledge drawn from different locations (Leiponen & Helfat, 2011). This suggests the potential for sustained network additionality – to contribute to firms' innovation success:

H4: Sustained network additionality

Public support for innovation will generate sustained network additionality with positive benefits for innovation outputs.

Finally, we consider whether public support for innovation endows firms with greater resilience in the face of market uncertainties related to regulatory issues or a lack of finance. The potential importance of this type of 'resilience additionality' is evident given global market uncertainties. In the innovation research literature both conceptual and empirical analyses of sustainability and/or resilience in the face of external shocks remains very limited. There has, however, been some discussion of the relationship between innovation and perceived environmental uncertainty (Freel, 2005; Czarnitzki and Toole, 2011) and innovation persistence (Raymond et al., 2010). Strategic perspectives, for example, suggest that market turbulence may create new competitive spaces as rivals close or retrench (Caballero and Hammour, 1994), potentially increasing the returns to innovation (Todd, 2010). Indeed, some firms may actively seek to create market turbulence by engaging in disruptive innovation in order to establish a position of market or technological leadership (Anthony et al., 2008). As Russell and Russell (1992) observe, however, while more entrepreneurial companies might seek to capitalise on opportunities from the environment more conservative organisations would innovate as a means of 'strategic adaptation'. The potential for such effects suggests:

H5: Resilience

Public support for innovation will generate sustained improvements in the resilience of firms' innovation outputs.

3. Data and methods

Our empirical analysis is based on data from the Irish Innovation Panel (IIP) which provides information on the innovation activities of Irish manufacturing plants' technology adoption, networking and performance over the period 1991 to 2008. More specifically, the IIP comprises six surveys or waves conducted using similar survey methodologies and questionnaires with common questions (Hewitt-Dundas & Roper, 2008; Roper & Anderson, 2000; Roper & Hewitt-Dundas, 1998; Roper, 1996). Each of the six surveys covers the innovation activities of manufacturing business units with 10 or more employees over a three-year reference period. The resulting panel is highly unbalanced reflecting non-response in individual surveys but also the opening and closure of business units over the 18 year period covered. The panel contains 2,896 observations on 1,596 individual business units representing an overall response rate of 31.2 per cent.

For the current analysis we focus on two innovation variables. First, the proportion of plants' total sales (at the end of each three-year reference period) derived from products newly introduced during the previous three years. Secondly, a more broadly defined variable representing plants' sales of both newly introduced and improved products. These variables reflect not only plants' ability to introduce new/improved products to the market but also their short-term commercial success. Across the IIP 12.3 per cent of plants' sales were derived from newly introduced products, while 21.1 per cent were derived from new and improved products (Table 1)[2].

Our empirical approach focuses on the innovation or knowledge production function which represents the process through which inputs to the innovation process are transformed into innovation outputs (Griliches, 1995; Laursen & Salter, 2006; Love & Roper, 2001). In any period this transformation process will reflect the innovation capabilities of the plant which may themselves reflect plants' receipt of public support for innovation in previous periods, or sustained additionality. If I_i is an innovation output indicator for plant i, here the percentage of innovative sales, the innovation production function can be written as:

$$I_i = \beta_0 + \beta_1 I_{it-1} + \beta_2 RD_i + \beta_3 SK_i + \beta_4 XS_i + \beta_5 EN_i + \beta_6 RI_i + \beta_7 PS_i + \delta_i \qquad (1)$$

Where: RD_i are plants' investments in R&D, SK_i are skills inputs into innovation, XS_i represents external knowledge search or openness, EN_i is a set of indicators of plants' business environment, RI_i is a set of plant level control variables. PS_i is a binary indicator of whether the plant received public support for innovation in the current period.

[2] Correlations between the two innovation output variables are strong, however, (correlation coefficient is 0.805) suggesting firms which perform well on the narrower innovation output measure also tend to perform well in terms of their development of new and improved products.

Now to capture potential sustained additionality consider partitioning each of the variables I_{it-1}, RD_i, SK_i, XS_i, EN_i between those firms which received public support for innovation last period, i.e. for which $PS_{it-1}=1$, and those which did not receive public support last period, i.e. $PS_{it-1}=0$[3]. Re-writing equation (1) this suggests:

$$
\begin{aligned}
I_i &= \beta_0 + \beta_1^A I_{it-1} \times PS_{it-1} + \beta_1^B I_{it-1} \times (1-PS_{it-1}) + \beta_2^A RD_i \times PS_{it-1} + \beta_2^B RD_i \times (1-PS_{it-1}) \\
&+ \beta_3^A SK_i \times PS_{it-1} + \beta_3^B SK_i \times (1-PS_{it-1}) + \beta_4^A XS_i \times PS_{it-1} + \beta_4^B XS_i \times (1-PS_{it-1}) \\
&+ \beta_5^A EN_i \times PS_{it-1} + \beta_5^A EN_i \times (1-PS_{it-1}) + \beta_6 RI_i + \beta_7 PS_i + \delta_i \qquad (2)
\end{aligned}
$$

In statistical terms equation (2) essentially relaxes the restrictions – imposed by equation (1) – that $\beta_i^A = \beta_i^B, i = 1,5$. Or, in other words, that receipt of public support for innovation in the previous period has no impact on the innovation value of previous innovation, skill levels etc. in the current period. If, however, $\beta_i^A > \beta_i^B$ i=1,5 this would suggest sustained additionality. More specifically: $\beta_1^A > \beta_1^B$ would suggest sustained output additionality; $\beta_2^A > \beta_2^B$ would suggest sustained input additionality; $\beta_3^A > \beta_3^B$ would suggest sustained behavioural additionality; $\beta_4^A > \beta_4^B$ would suggest sustained network additionality; $\beta_5^A > \beta_5^B$ would suggest sustained resilience effects.

Public support for product development plays a central role in our analysis, and in both Ireland and Northern Ireland this has been an important element of industrial development policy over the last two decades. In Ireland, measures to support innovation in externally-owned firms have been operated primarily through the Irish Development Agency (or IDA), with support for locally-owned firms operated by Enterprise Ireland (Hewitt-Dundas & Roper, 2008). In Northern Ireland, public support for innovation has been operated primarily through Invest Northern Ireland and, before 2001, the Industrial Research and Technology Unit (IRTU) (Cooke, 2003; Roper, 2009). In the IIP plants are asked to 'indicate whether you have received government support for product development over the last three years'. Overall, 21.2 per cent of plants reported receiving such support, an average of 21.5 per cent in Northern Ireland and 21.1 per cent in Ireland. Equally important perhaps given the nature of our analysis is the extent to which the same plants received public support for product development in subsequent periods. The correlation between receiving public support for

[3] In the IIP, as each wave of the panel relates to a three-year reference period this relates to whether firms received public support for innovation in the previous wave, i.e. in the period 4-6 years ago.

product development in the current period and previous period was 0.344[4]. In crude terms, given the average proportion of plants receiving public support, this suggests that plants which received public support in one period were also 75 per cent more likely to receive support in the subsequent period than a previously un-supported plant suggesting the potential importance of endogeneity and/or sample selection issues in operationalising equations (1) and (2). Indeed, Garcia and Mohnen (2010) in their analysis of Austrian CIS data found that not allowing for the potential endogeneity of public support for innovation can lead to a significant under-estimate of additionality effects.

Operationalising (1) and (2) draws on a range of other data from the IIP. To reflect the potential impact of input additionality we consider its effects on the innovation value of plants' in-house R&D, a factor which has been linked positively to innovation success by previous studies (Griffith, Redding, & Van Reenan, 2003; Love & Roper, 2001, 2005). In the IIP an average of 45.2 per cent of plants were undertaking in-house R&D, a proportion which varied relatively little over the 1991-2008 period (Hewitt-Dundas & Roper, 2008). The potential for sustained behavioural additionality effects are measured by their effects on the innovation value of two skills variables: the proportion of plants' workforces with a degree and whether plants reported that a lack of technical skills were a barrier to innovation. Both variables have previously been linked to innovation success in previous studies using an innovation production function approach (Freel, 2005; Hewitt-Dundas, 2006; Leiponen, 2005). On average across the IIP, 9.6 per cent of plants' workforces had a degree level qualification, while 55.8 per cent of plants reporting that technical skills were a 'significant' or 'very significant' barrier to innovation (Table 1)[5].

Network additionality reflects the extent to which plants' innovation networks may be enhanced or developed as a result of public support (OECD, 2006). Sustained network additionality requires that the innovation value of a given level of network activity – reflected in the estimated coefficients in the innovation production function - is greater where a plant received previous public support for innovation. Here, we include two measures: whether a lack of technical information was a significant barrier to plants innovation activity, and the

[4] These correlations differed very little between Northern Ireland and Ireland. Single period correlations were 0.339 in Northern Ireland and 0.347 in Ireland.

[5] In the IIP plants were asked to indicate the importance of various barriers to innovation on a 1 to 5 Likert scale. In the operationalization of equations (1) and (2) these variables were transformed into binary indicators taking value one if an innovation barrier was said to be 'significant' or 'very significant' and zero otherwise.

‘breadth’ of plants’ innovation network activities or ‘openness’ measured as per Laursen and Salter (2006). This is an index which takes values between one and eight depending on the number of different types of innovation partners that a plant is engaging with. In the models we also include a square of this variable to reflect the standard finding of an inverted-U shaped relationship between innovation outputs and network breadth (Leiponen & Helfat, 2011). Interestingly, the potential for organisational learning in plants’ innovation networking activity has recently been examined by Love et al. (2011). Their analysis, using the same data set as that used here, suggests positive evidence of learning effects and perhaps the potential for sustained network additionality. Finally, to capture the potential for resilience additionality we consider two measures which reflect potential environmental barriers to business innovation: regulatory or legislative factors and a lack of finance for innovation. In both cases we would anticipate that the provision of public support in one period might reduce the effect of these innovation barriers in subsequent periods. In the estimated models we also include two other control variables which give an indication of the scale of plants’ resources – e.g. size – as well as the potential for the cumulative accumulation of knowledge capital by older plants (Klette & Johansen, 1998) and plant life-cycle effects (Atkeson & Kehoe, 2005). Sector dummies at the 2 digit level and wave dummies are also included in each model (but not reported).

The estimation approach we adopt for equation (1) is essentially dictated by the nature of our dependent variable which is expressed as a percentage of sales. We therefore use a panel tobit estimator with upper and lower limits and random effects. To estimate equation (2) we adopt a two-step approach reflecting the potential endogeneity of the probability of receiving public support for product development even though this is lagged[6]. In the first stage, we instrument the receipt of public support for product development using a series of observable plant characteristics which might have guided the allocation of public support in the previous period[7]. In the second stage, we use this instrumented variable to partition each explanatory variables between plants receiving and not receiving public support as in equation (2). To

[6] As indicated earlier this is more likely as firms in receipt of grant support in one period were also more likely to receive grant support in subsequent periods.

[7] Key instruments are plant size (employment), whether or not the plant had an R&D department, the age of the plant, the proportion of the plants’ workforce with a degree, whether or not it was exporting, a locational dummy indicating whether or not the plant was in Ireland or Northern Ireland and sectoral dummies. These are strong instruments: $\chi^2(19)=400.82$, $\rho<0.000$.

avoid potential issues of multi-collinearity we estimate a series of panel tobits testing the equality of the coefficients on the partitioned variables one at a time.

4. Empirical Results

Estimates of equation (1) are reported as Model 1 in Tables 2 and 3 for the narrow and wider definitions of the dependent variables. The results are relatively robust and largely as expected. Lagged levels of innovation and in-house R&D both have strongly significant and positive effects on innovation success in both baseline models. The percentage of plants' workforce with a degree has a positive coefficient in both models but is more significant where the dependent variable is focussed on more radical innovation, a similar result to that found in some other studies (Freel, 2005). A perceived lack of technical skills is a significant barrier to innovation in both models (Model 1, Table 2 and 3). The breadth of plants' external knowledge search proves highly significant in both models and has the expected inverted-U shape relationship with innovative sales (Laursen & Salter, 2006). A perceived lack of technical information is also a barrier to innovative sales, although only marginally significant in terms of innovative sales of new products (Model 1, Table 2). Regulatory barriers to innovative sales of new products are also significant, although these prove less important for the wider definition of innovative sales. A perceived lack of finance for innovation takes an unexpected positive sign, a relatively common feature of this type of model (Roper, Du, & Love, 2008).

Estimating equation (2) partitioning lagged innovative sales provides an indication of the extent of any sustained output additionality. For both innovation output measures we find significant differences between the estimated coefficients on the partitioned lagged innovative sales measure, with plants which received previous support benefitting more from prior innovation. This provides strong support for Hypothesis 1 and sustained output additionality. One possibility here is that plants with previous public support were able to develop better or more novel innovations in previous periods and this provided a better starting point for their current innovation activity.

Our second hypothesis relates to the potential for sustained input additionality and, in particular, whether the innovation value of plants' R&D investments are enhanced by prior public support. Partitioning the in-house R&D variable does suggest that plants with prior support for innovation derive more innovation value from future R&D in both model specifications. In neither case, however, is the difference in the coefficients statistically significant (Table 2 and 3). Our evidence therefore provides little support for Hypothesis 2.

Hypothesis three relates to behavioural additionality and the potential effects of prior public support for innovation on the innovation value of human capital. Again we find consistent results across the two different model specifications and little evidence of sustained behavioural additionality related to graduate skills. There is, however, clear evidence that prior public support for innovation has a significant effect on offsetting the innovation effects of perceived weaknesses in technical skills. Indeed, in plants receiving public support in the previous period perceived skills weaknesses were having no significant negative effects on innovation outputs (Tables 2 and 3). Two possibilities are evident here. First, it may be that the experience of working on publicly supported innovation projects has given survey respondents in plants' senior management a better understanding of the quality of their skill base for innovation. This may be reducing management perceptions of any lack of technical skills. A more likely scenario, perhaps, is sustained behavioural additionality, i.e. that plants' prior experience of publicly funded innovation projects has resulted in learning and an upgrading of plants' human capital. This provides partial support for Hypothesis 3.

In the baseline models knowledge search plays a significant role with evidence of an inverted-U shape relationship between search breadth and innovation, and a negative innovation effect associated with a perceived lack of technical information (Model 1, Tables 2 and 3). Partitioning these variables provide an indication of sustained network additionality as suggested in Hypothesis 4. In fact, as Tables 2 and 3 suggest, there is no evidence of any sustained network additionality effect on network breadth. In Table 2, the model for innovative sales of new products only, there is however some evidence of a marginally significant additionality effect on the innovation effect of a perceived lack of technical skills.

Finally, partitioning the two business environment variables (regulation and lack of finance) provides consistent but rather confused results for sustained resilience additionality. We find no significant effects for sustained additionality in terms of plants' ability to deal with regulatory or legislative barriers to innovation (Tables 2 and 3), but do see a significant effect on lack of finance. Specifically, for plants which had previously received public support a perceived lack of finance proves a more important innovation constraint than for firms which had not received such support. This may reflect the results associated with sustained output additionality made earlier as plants which previously received support seek to further extend their innovation outputs and encounter more significant finance constraints. This provides little support for Hypothesis 5 that the receipt of public support in one period may enable firms to cope better with environmental uncertainty better in future periods.

Overall, our results suggest a rather mixed picture with strong evidence of sustained output additionality, weaker evidence of sustained additionality linked to behaviour, networking and resilience and no evidence of sustained input additionality. These results are very similar whether we consider plants' sales of new products (Table 2) or their sales of new and improved products (Table 3). To check for robustness we also considered the profile of sustained additionality effects resulting from public support for R&D rather than for product innovation. This grant support is likely to relate more directly to plants' technical development rather than the broader technical and commercial development which might be envisaged as part of an innovation project. As a result around 23.4 per cent of plants in the IIP had received government support for innovation compared to 11.2 per cent of plants receiving support for R&D (Table 1)[8]. Results using this alternative public support for R&D measure were very similar to those in Tables 2 and 3 – significant sustained output additionality, weak evidence of behavioural and resilience additionality effects and no evidence of sustained additionality linked to either inputs or networking.

5. Conclusions

Three main empirical conclusions follow from our study. First, our results provide strong evidence of the importance of sustained output additionality from public support for

[8] The correlation coefficient between the two variables was 0.408.

innovation – enhanced innovation outputs in one period create market or strategic advantages for publicly funded firms in subsequent periods. How is this happening? One possible route is that public support is enhancing the quality or novelty of firms' innovative output in the assisted period, which then provides an enhanced basis for subsequent innovation. Such innovation quality effects from public innovation support have been recognised in a number of studies (Bérubé & Mohnen, 2009; Hewitt-Dundas & Roper, 2009). Our evidence here, however, suggests that the effects of these innovation quality improvements persist, giving previously assisted plants longer-term strategic advantages perhaps by helping them to achieve positions of technology or market leadership or first-mover advantage. Alternatively, public support for innovation may be allowing firms to invest in platform technologies which may allow the development of variants in future periods (Pasche & Magnusson, 2011). Or, by enhancing the market reputation of an enterprise with consumers, firms' innovation may be more successful in the market place (Henard & Dacin, 2010).

Second, our results suggest only weak evidence of sustained additionality linked to behavioural changes, networking and resilience, and third we find no evidence of sustained input additionality. This is, of course, not to say that there are no short-term additionality effects or outputs associated with behaviour, networking, inputs etc. Indeed, as the literature reviewed by Hsu et al. (2009) suggests such effects can often be substantial, however, our evidence suggests that such effects are short-lived, and may be limited to the duration of the publicly funded project (Hewitt-Dundas & Roper, 2011).

Taken together our results suggest that the primary legacy of public support for innovation is not through its resource or capability enhancing effects but rather through its effects on plants' innovation outputs or product portfolio. This has implications for the type of medium or long-term spillovers which might be expected from innovation projects suggesting that any spillovers will be linked to innovation outputs rather than any wider network or capability effects. For policy makers this suggests that it is difficult to justify innovation policy interventions in terms of their longer-term capability effects but instead such measures need to be justified in terms of their longer-term effects on innovation outputs and related spillovers.

Our results also have implications for the evaluation of innovation policy measures. Crucially they emphasise again the importance of the choice of impact period. In the short-term, for example, behavioural, network and input additionality may be significant but our results suggest these effects are not sustained into the longer term. This emphasises the necessity of balancing – and examining – the short-term additionality and longer-term sustainability of any benefits in innovation policy evaluations. The other main implication of our study stems from the empirical strength of sustained output additionality and the relative weakness of the other dimensions of sustained additionality. This empirical evidence contrasts strongly with the emphasis in much of the recent evaluation literature on behavioural and network additionality. Our analysis also suggests the potential value of a stronger – and more nuanced – view of the different dimensions of output additionality related perhaps to product quality, novelty, commercial success, market penetration etc.

Table 1: Sample Descriptives

|	No. of observations	Mean	Std. Dev.
Innovation Measures			
Sales of new products (percentage of sales)	1649	12.315	19.716
Sales of new and improved products (percentage of sales)	1646	21.149	28.096
Public support indicators			
Public support for product development (yes/no)	1732	0.234	0.423
Public support for R&D (yes/no)	1733	0.112	0.316
Additionality measures			
In-house R&D (yes/no)	1765	0.452	0.498
Workforce with degree (percentage of workforce)	1666	9.602	12.711
Innovation barrier: Technical skills (yes/no)	1765	0.558	0.497
Breadth of external search (number of partner types)	1731	1.200	1.889
Innovation barrier: Lack technical information (yes/no)	1765	0.358	0.480
Innovation barrier: Regulatory or legislative factors (yes/no)	1765	0.388	0.487
Innovation barrier: Lack finance for innovation (yes/no)	1765	0.473	0.499
Control variables			
Plant employment	1734	78.276	238.573
Plant vintage (years)	1761	32.437	30.134

Source: Irish Innovation Panel, waves 2-6 of the survey are included. Observations are weighted to give representative results.

Table 2: Sustained additionality for sales of new products

	Model 1			Model 2					
	Baseline Model			Plants with prior Public support		Plants without prior public support		Wald test of equality in Model 2	
	Coeff	z-stat		Coeff	z-stat	Coeff	z-stat	Chi2(1)	rho
Innovative sales (-1)	0.299	18.11		0.398	11.89	0.282	16.43	11.67	0.00
In-house R&D	15.885	22.47		16.64	10.88	15.82	22.1	0.32	0.57
Workforce with degree	0.063	2.52		0.053	0.8	0.064	2.51	0.03	0.83
Innovation barrier: Technical skills	-4.235	-4.73		1.016	0.67	-0.596	5.11	18.72	0.000
Breadth of external search	3.192	7.35		3.32	5.56	3.182	7.31	0.11	0.746
Breadth of external search - squared	-0.202	-2.83		-0.163	1.65	-0.209	2.88	0.33	0.566
Innovation barrier: Lack technical information	-1.515	-1.76		1.293	0.71	-1.834	2.08	3.16	0.077
Innovation barrier: Regulatory or legislative factors	-2.291	-2.88		-1.094	0.62	-2.408	-2.97	0.57	0.45
Innovation barrier: Lack finance for innovation	1.800	2.57		8.083	5.46	1.071	1.5	23.44	0.000
Employment	0.010	3.7							
Employment squared	-0.009	-1.44							
Plant vintage (years)	-0.078	-7.13							
Pubic support: innovation	4.952	6.41							
Constant	-6.017	4.74							
Observations	1496								
Groups	917								
Wald chi2	2760								
rho	0.000								

Source: Irish Innovation Panel, waves 2-6 of the survey are included. Random effects tobit models. Models include a set of sectoral and wave dummies Observations are weighted in regression analysis to give representative results.

Table 3: Sustained additionality for sales of new and improved products

	Model 1			Model 2					
	Baseline Model			Plants with prior Public support		Plants without prior public support		Wald test of equality	
	Coeff	z-stat		Coeff	z-stat	Coeff	z-stat	Chi2(1)	rho
Innovative sales (-1)	0.296	17.02		0.365	10.6	0.285	15.83	5.42	0.019
In-house R&D	25.437	26.04		27.36	12.83	25.27	25.54	1.03	0.309
Workforce with degree	0.040	1.15		0.129	0.14	0.043	1.19	0.11	0.744
Innovation barrier: Technical skills	-8.165	-6.53		-1.206	-0.58	-8.67	-6.91	17.14	0.000
Breadth of external search	7.232	11.96		7.023	8.33	7.246	11.96	0.13	0.721
Breadth of external search - squared	-0.616	-6.18		-0.622	4.48	-0.613	-6.1	0.00	0.948
Innovation barrier: Lack technical information	-4.003	-3.36		-3.11	-1.24	-4.106	-3.37	0.16	0.689
Innovation barrier: Regulatory or legislative factors	0.322	0.29		1.435	0.58	0.214	0.19	0.25	0.61
Innovation barrier: Lack finance for innovation	2.053	2.12		10.17	4.91	1.142	1.16	19.61	0.000
Employment	0.015	3.84							
Employment squared	-0.019	-2.1							
Plant vintage (years)	-0.139	-9.35							
Pubic support: innovation	6.582	6.17							
Constant	-2.015	-1.15							
Observations	1491								
Groups	915								
Wald chi2	3553.01								
rho	0								

Source: Irish Innovation Panel, waves 2-6 of the survey are included. Random effects tobit models. Models include a set of sectoral and wave dummies Observations are weighted in regression analysis to give representative results.

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