External Interaction, Innovation and Productivity: An Application of the Innovation Value Chain for Ireland

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Abstract

This paper analyses the innovation value chain for the Irish Community Innovation Survey: 2004-2006. The contribution is to estimate innovation and productivity simultaneously. The key finding is that feedback effects are vital, with more productive firms being more innovative and more innovative firms being more productive. External knowledge sources may affect the decision to innovate but have no positive effect on innovation performance. There is evidence of dichotomous knowledge sourcing in Ireland, with some firms sourcing from market agents and others, especially high-technology businesses, from universities.

Key words: Innovation, Productivity, Innovation Value Chain.

JEL Classification: O31; L29; R31

1. Introduction

The innovation value chain framework has been increasingly employed in the literature to analyse the inter-relationships between external interaction, innovation and productivity as part of the innovation system. In a regional context there is a consensus that geographically proximate or distant interaction with external agents is important for innovation (Gordon and McCann, 2005 and Bathelt, Malmberg and Maskell, 2004). However, this literature has paid less attention to the systemic relationship between innovation and productivity. External interaction may influence innovation, but so also might productivity.

Studies such as Lööf and Heshmati (2006) for Sweden, Janz, Lööf et al. (2003) for Germany and Sweden and Klomp and Van Leeuwen (2001; 2006) for Holland estimate the relationship between innovation and productivity in a simultaneous setting. This paper models the innovation value chain for a sample of Irish firms from the 2004-6 Community Innovation Survey (CIS) using simultaneous estimation techniques. In the Irish case Roper, Du and Love (2008) analyse each stage of the innovation value chain separately.

The innovation value chain is comprised of three interlinked elements. These are the process whereby firms source knowledge through research and development (R&D) and external interaction, transform this knowledge into innovation output and finally exploit innovation output for performance gains (Hansen and Birkinshaw 2006). Roper, Du and Love (2008) argue that the innovation value chain is linear in nature so that innovation output such as new products and processes are necessarily pre-determined prior to exploitation. Following Kline and Rosenberg (1986), this paper stresses that the innovation process could be characterized by feed-back effects, the most important of which are from exploiting new products on the market to the continuing development of the product itself. Thus, in addition to productivity being affected by innovation output, productivity gains realised within the business through feedback from market and other sources may also influence the innovation output of a business.

In an Irish context Jordan and O'Leary (2008) analyse the knowledge sourcing and innovation output elements of the innovation value chain for a survey of high-technology businesses. Roper (2001) analysed the knowledge transformation stage for manufacturing firms in the Republic of Ireland and Northern Ireland while Love and Roper (2001) investigated both knowledge sourcing and transformation for manufacturing firms in Ireland, the UK and Germany. As already mentioned Roper, Du and Love (2008) analyse all three stages of the innovation value chain separately. This paper adds to the literature by being the first to consider innovation output and productivity in a simultaneous setting for Ireland. It is also the first to use the country's large-scale Community Innovation Survey.

The next section presents a review of the literature on the innovation value chain. This is followed by a description of the model to be estimated. The measures used from the CIS data set, after which the empirical results are presented. The final section concludes.

2. The Innovation Value Chain

The innovation value chain is concerned with the process whereby firms source knowledge, transform this knowledge into innovation output and finally exploit innovation output for performance gains (Hansen and Birkinshaw 2006). Its chief advantage is to highlight the structure and complexity of the innovation process. This increasingly popular perspective has echoes in the work of Kline and Rosenberg (1986) who argue that "*innovation is complex, uncertain, somewhat disorderly and subject to changes of many sorts. Innovation is also difficult to measure and demands close coordination of adequate technical knowledge and excellent market judgement in order to satisfy economic, technological and other types of constraints – all simultaneously. The process of innovation must be viewed as a series of changes in a complete system*" (1986: 275).

Kline and Rosenberg's (1986) chain-link model captures the systemic nature of the innovation process. Their central chain of innovation begins with a design based on a potential market and then progresses from development and production to marketing. At each stage feedback links iterate the process and connect back from perceived market needs to potential improvements in design. The feedback link depicting the experience gained by selling on the market represents the most important source of knowledge for improvement. According to this view knowledge acquired from the market influences the on-going development and exploitation of innovation output. In particular, the important knowledge gleaned through external interaction with market and, where necessary, non-market agents, such as universities, may play a key role in the development of innovation output by the business. This systemic view implies that business performance influences innovation output.

This view is broadly consistent with the approach adopted by the growing number of empirical studies of the innovation value chain (Klomp and Van Leeuwen 2001; Janz, Lööf and Peters 2003; Klomp and Van Leeuwen 2006; Lööf and Heshmati 2006). It differs from Roper, Du and Love (2008) who view the innovation value chain as a process in which innovation output is necessarily pre-determined prior to exploitation. They model knowledge sourcing, transformation and exploitation as a series of steps without feedbacks. In particular they do not allow a role for the knowledge gleaned at the exploitation stage to have any influence on innovation output. The perspective taken in this paper follows Kline and Rosenberg (1986) and is that the systemic nature of innovation dictates that this feedback be considered.

Turning to the first stage of the innovation value chain, it is well known that knowledge sourcing can be both internal and external to the firm. External sources of knowledge can be interaction with external agents which include but are not limited to those that are geographically proximate (Bathelt, Malmberg and Maskell, 2004). Kline and Rosenberg (1986) and Lundvall (1988) highlight the importance of interaction for innovation. A firm may source knowledge from other enterprises in their group, customers, suppliers, competitors, consultants, universities and government research institutes. However, Kline and Rosenberg (1986) also emphasize the sourcing of knowledge inside the business through the performance of R&D, which involves solving "problems all along the chain of innovation from the initial design to the finished production processes (1986: 303). Internal and external sources of knowledge may act as complements or substitutes (Audretsch, Menkveld and Thurik. 1996). In an Irish context this part of the innovation value chain has been studied in part or in full by Jordan and O'Leary (2008), Love and Roper (2001) and Roper, Du and Love (2008). The emerging consensus in these studies is complementarity between the different external agents and between R&D and different external interaction agents.

The next stage in the innovation value chain involves transforming knowledge into innovation output. While some papers use R&D as a proxy for innovation output (Griffith, Huergo, Mairesse and Peters 2006) this paper considers R&D as an input in the innovation process. Innovation output can take the form of either product or process innovation. Product innovation involves the introduction of new or improved goods/services, which may be either new to the market or new to the business. This approach is used here. In addition to the internal and external sources of knowledge, other factors may influence a firm's ability to generate innovation output. These include the absorptive capacity of the workforce (Cohen and Levinthal 1990) as well as the size, age, sector and ownership of the business (Jordan and O'Leary 2008).

In the Irish context Roper (2001), Love and Roper (2001), Jordan and O'Leary (2008) and Roper, Du and Love (2008) analyse how firms generate innovative output using single equation estimations of binary innovation production functions. Generally, they find that both R&D and external interaction have a positive effect on the likelihood product innovation. For example, Jordan and O'Leary (2008) and Roper, Du and Love (2008) show that the decision to introduce new products is positively related to the presence of forward, backward and horizontal linkages. Similarly, Roper (2001) finds that networking plays an important part in determining the probability that Irish manufacturing plants are innovative. Interestingly when their analysis extends to the determinants of innovation performance for innovators only, the importance of external interaction lessens. Thus, Roper (2001) and Love and Roper (2001) find that networking has no effect on either innovation intensity or innovation success.[i] Similarly, when Roper Du and Love (2008) model innovation success, only forward linkages persist in importance. Roper (2001) explains these results by suggesting that networking may assist firms in overcoming the initial hurdles faced in becoming an innovator, but that once this threshold is overcome, it plays a less important role.

The final stage in the innovation value chain is the exploitation of innovation output by utilizing it for the overall benefit of business productivity or profitability. In an Irish context only Roper, Du and Love (2008) have analysed this stage. They find that innovation output positively affects the firms' performance. In particular, both product innovation success and process innovation have strong and significant effects on sales and employment growth. Curiously, product innovation success, defined as the percentage sales from new products in total sales, has a negative effect on productivity which the authors ascribe to a disruption effect. This paper expands on a suggestion in the concluding section of Roper, Du and Love (2008) by allowing for potential feedback between performance and innovation output.

3. Methodology

This paper uses an extension of the model developed by Crépon, Duguest and Mairesse (1998), referred to hereafter as the CDM-model. The CDM-model is a four equation model including three equations for the innovation value chain, representing knowledge sourcing, transformation and exploitation (see also Loof and Heshmati, (2006). The first equation is the innovation decision. In analysing the innovation value chain it is necessary to concentrate on the behaviour of innovating firms. Since these are not randomly drawn from the population, selection bias may arise. The CDM-model corrects for this by including a selection equation, the innovation decision, and estimating an inverse Mill's ratio for inclusion in all subsequent regressions (Heckman 1979; Janz, Lööf and Peters 2003; Lööf and Heshmati 2006).

Equation (1) therefore analyses the firm's decision to engage in innovative activity. The inclusion of the decision equation also allows for an analysis of factors which may impact on a firm's decision to engage in innovation activity. Equation (1) is estimated using a probit model.

$$y_{0i} = \begin{cases} 1 \text{ if } y_{0i}^* = x_{0i}\alpha_0 + \varepsilon_{0i} > 0 \\ 0 \text{ if } y_{0i}^* = x_{0i}\alpha_0 + \varepsilon_{0i} \leq 0 \end{cases} \qquad (1)$$

where y_{0i}^* is a latent innovation decision variable measuring the decision of a firm to innovate and y_{0i} is the corresponding observed binary variable being 1 for innovating firms and 0 for non-innovating firms. Innovating firms are defined as those introducing products that are either new to them or new to the market. This concentration on product innovation differs from the CDM-model, where R&D expenditure is the latent dependent variable. Also x_{0i} is a vector of explanatory variables, α_0 is the associated coefficient vector and ε_{0i} is the error term.

The explanatory variables used to explain a firm's decision to engage in product innovation are:

$$x_{oi} = (I_i, Z_i)$$

where I_i is a vector of factors that might influence the decision to innovate. One of the advantages of the CIS is that it provides a range of cost, technological, market and past innovation outcomes that might influence the decision to innovate. Ideally human capital measures should be included. However, the CIS is deficient in this regard. Instead R&D expenditure is used. Z_i is a vector of control variables representing size, ownership and sector. Previous Irish research by Roper, Du and Love (2008) and Jordan and O'Leary (2008) suggest that larger firms are more likely to innovate and that the nationality of a firm may affect its probability of innovating.

Equation (2) models how firms acquire knowledge among several different internal and external sources of knowledge. These sources of knowledge include R&D and external interaction sources which are other firms in the same group, customers, suppliers, competitors, consultants, universities and government research institutes. This closely follows the approach of Roper, Du and Love (2008) and allows for a detailed analysis of the impact of various knowledge sources. It differs from Crépon, Duguest and Mairesse (1998) and Janz, Lööf and Peters (2003) who analyse the determinants of R&D. Equation (2) is estimated using a series of probit models.

$$KS_{ji} = KS_{ki}\beta_0 + x_{1i}\beta_1 + \varepsilon_{1i} \quad \text{if } y_{0i} = 1 \qquad (2)$$

where KS_{ji} represents firm i's knowledge sourcing activity j for both new to firm and new to market innovation during the three years 2004 to 2006. KS_{ki} represents firm i's knowledge sourcing activity k where $j \neq k$, x_{1i} is a vector of explanatory variables, β_{1i} is the associated coefficient vector and ε_{1i} is the error term. While the CDM model estimates knowledge sourcing simultaneously, the approach is limited to modelling R&D expenditure with external interaction not included. This paper follows Klomp and Van Leeuwen (2001), Janz, Lööf and Peters (2003); Klomp and Van Leeuwen (2006) and Lööf and Heshmati (2006) who use a wider range of knowledge sourcing variables.

Following from Roper, Du and Love (2008) and Jordan and O'Leary (2008), knowledge sources may act as complements ($\beta_0 > 0$) or substitutes ($\beta_0 < 0$). The explanatory variables used to explain a firm's knowledge sourcing are:

$$x_{1i} = (M_i, Z_i)$$

where M_i is the inverse Mills' ratio derived from equation (1) and Z_i is as before.

The final two equations are estimated simultaneously using three stage least squares[ii]. The use of simultaneous estimation techniques is necessary as productivity in equation (3) and innovation output in equation (4) are endogenous respectively. Crépon, Duguest and Mairesse (1998) and Klomp and Van Leeuwen (2001) have shown that the single equation estimation techniques for such models may result in biased estimates of the coefficients.

Equation (3) presents the transformation stage of the innovation value chain, where sourced knowledge is transformed into innovation output:

$$IO_i = KS_{ji}\lambda_0 + P_i\lambda_1 + x_{1i}\lambda_2 + \varepsilon_{2i} \qquad \text{if } y_{0i} = 1 \qquad (3)$$

where IO_i is innovation output and P_i is productivity. Innovation output is measured as the natural log of innovation turnover per worker in 2006. Innovation turnover is the turnover from new to firm and new to market innovation. Productivity is measured as the natural log of turnover per worker in 2006. In a similar study, Klomp and Van Leeuwen (2006) measure productivity using both turnover and value added and conclude that turnover measure provides more satisfactory estimations than value added.[iii] The use of the log transformation is consistent with the literature on the CDM model. The remaining variables are defined as before.

It is expected that knowledge sourcing should positively influence innovation output ($\lambda_0 > 0$) due to firms transforming knowledge obtained from external sources into new products (Jordan and O'Leary, 2008; Roper, Du and Love 2008). However, it might also be expected that productivity will positively influence innovation output through potential feedback effects within the business ($\lambda_1 > 0$). The level of productivity represents the overall performance of the business from the sale of its products, whether existing or new. It is assumed that, all other things being equal, higher productivity businesses are likely to have, by demonstrating greater efficiency through cumulative learning and experience, a greater level of innovation turnover per worker. The key issue is therefore the relative importance of external knowledge (λ_0) and productivity (λ_1) for innovation output.

Equation (4) then investigates the effect of innovation output on productivity.

$$P_i = IO_i \chi_0 + x_{1i}\chi_{1i} + \varepsilon_{3i} \qquad \text{if } y_{0i} = 1 \qquad (4)$$

where all variables are defined as before. Also included under X_{1i} is innovation capital investment per worker. For consistency this is measured as the natural log of expenditure per worker on the acquisition of machinery, equipment and software for innovation purposes.

It is expected that increased levels of innovation turnover per worker will positively affect productivity ($\chi_0 > 0$). Hansen and Birkinshaw (2006) suggest that firms which can exploit and develop new products and services should experience increased performance. This is similar to Kline and Rosenberg's (1986) assertion that successful innovations are ones which satisfy a market need, thus benefiting the business.

4. Description of Data

The data is the Irish CIS for 2004-2006. This survey was conducted jointly by Forfás (Ireland's national policy advisory body) and the Central Statistics Office (CSO) in Ireland. A total of 4,150 surveys were issued with 1,974 responses. This response rate of 48% is high relative to other Irish studies (Roper 2001; Jordan and O'Leary 2008). The survey is directed to companies employing more than 10 persons engaged in selected sectors. According to Table 1 the mean size of firms is 124 workers with a standard deviation of 524. A total of 74% of the firms surveyed are Irish owned, with the remainder being foreign-owned and likely to be branch plants of multi-nationals operating in Ireland.

The selected sectors are the complete range of manufacturing sectors and *Wholesale, Transport, Storage and Communication, Financial Intermediation* and *Computer, Architecture and Engineering Services.* For the purposes of this paper manufacturing is sub-divided between *High-Tech Manufacturing* and *All Other Manufacturing.*[iv] The rationale for this division is the focus of Irish innovation policy on high-technology manufacturing and services. The services sector selected for the survey, *Computer, Architecture and Engineering Services* is a high-technology service sector.[v] Table 1 shows that 27% of the sample are in either of the high-technology sectors with 30% in *All Other Manufacturing*, 35% in *Wholesale, Transport, Storage and Communication* and 8% in *Financial Intermediation.*

The CIS collects information about knowledge sourcing and innovation output in the reference period 2004 to 2006. Product innovation is defined as the introduction of a new, or significantly improved, good or service during the three years 2004 to 2006. Product innovation can either new to the firm or new to the market. New to firm innovation is defined as the introduction of a new or significantly improved good or service to the firm's market which is already available from competitors. New to market is the introduction of a new good or service to the firm's market, which is not already provided by the firm's competitors. As such this is a more risky form of innovation, although it is not necessarily high risk as firms may be developing products already present in markets in which they do not compete. It can be observed in Table 1 that 25% and 22% of firms introduced new to firm and new to market innovation respectively, while 33% introduced either new to firm or new to market innovation.

Turning to knowledge sourcing, 25% of firms report that they have in-house R&D expenditure in 2006. R&D is defined as expenditure by the firm on creative work to increase its stock of knowledge for innovation. Mean R&D expenditure per worker for innovating firms is €6014 with the standard deviation of €18,884. In associating R&D with a formal budget line, this definition does not include the more informal activities that may be part of R&D activity. For example, Jordan and O'Leary (2008) found that it is the performance of R&D and not having a dedicated R&D department that matters for product innovation.

For external knowledge sources, the CIS considers only formal cooperation which involves the active participation of the firm with other forms or non-commercial institutions during the three years 2004 to 2006.[vi] It can be observed that the most common forms of cooperation by firms are with suppliers, at 11% followed by customers and within their own group (9%). Cooperation with consultants is 6% and competitors only 3%. Turning to non-market cooperation 5% of firms interact with universities with 3% interacting with government research institutes, which relates to public research institutes other than in the higher education sector.

The CIS provides estimates of turnover in 2006 from the product innovation introduced during 2004 to 2006. For innovators only, mean innovation turnover per worker in 2006 from new to firm innovation is €77,000 whereas from new to market innovation it is €102,000. It can be noted that the coefficient of variation is higher for new to market innovation at 3.4 compared to 2.7 for new to firm, perhaps suggesting that this form of innovation is more risky. The overall turnover estimates are sourced from the CSO's Business Register. The mean overall turnover per worker in 2006 is €621,000 with a standard deviation of approximately €3,513,000. Innovation turnover accounts for between 12% and 17% of overall turnover. The businesses surveyed are established with over 10 persons employed.

5. Empirical Results

Table 2 displays the marginal effects derived from a probit estimation of Equation (1). It can be observed that size of business makes no difference to the decision to innovate but Irish firms are less likely to engage in either new to firm or new to market innovation than foreign-owned firms. As might be expected the performance of R&D is positively associated with the decision to introduce both forms of innovation. Turning to sectors it is notable that, compared to the reference sector, which is *High-Tech Manufacturing*, firms in each of the sectors are as likely to engage in new to firm innovation. A similar result applies to new to market innovation, with the exception that firms in *Financial Intermediation* are less likely to innovate in this way. Interestingly, these results indicate that the high-technology sectors, which have been the focus of Irish innovation policy, are clearly not more likely to decide to innovate than a range of medium or low-technology manufacturing and service sectors.

Turning to cost, knowledge and market factors[vii] it can be noted that for new to firm innovation, firms which report a lack of qualified personnel, uncertain demand for innovations and excessive perceived risk are more likely to decide to innovate. Similarly, for new to market innovation, firms which report a lack of finances from sources outside their enterprise, uncertain demand for innovative goods or services or a need to meet market regulation are more likely to innovate.

While these results may appear counter-intuitive, they may be explained by innovating firms being more likely to encounter these problems than non innovating firms. Therefore, innovating firms are more likely to report problems such as these. Alternatively, it may be that firms which experience these conditions are forced to innovate. For example, a firm which lacks access to external sources of funds may have to innovate in order to overcome financial pressure. Firms which report excessive perceived risk are also more likely to introduce new to firm innovation. This perceived risk may come from the actions of competitors that increase the need for a firm to innovate.

It can also be observed that for new to firm innovation, difficulty in finding cooperation partners reduces the likelihood of a firm innovating. This result tallies with findings that interaction with external agents increases the probability of innovation (Freel 2003; McCann and Simonen 2005; Jordan and O'Leary 2008; Roper, Du and Love 2008).

Firms which report no need to innovate due to an absence of demand for innovations are less likely to decide to engage in both new to firm and new to market innovation. This suggests that firms respond to market conditions when considering whether to engage in innovation and supports the market pull perspective of Kline and Rosenberg (1986). Interestingly firms with previous failed or abandoned innovations are more likely to engage in innovation. This could be due to firms learning from previous mistakes (Drucker, 1985).

[table 2 around here]

Table 3 presents a series of probit estimations of Equation (2) for new to firm innovation. It can be observed that a complementary relationship exists among external interaction agents. For example, firms are more likely to interact within their own group if they already interact with suppliers, customers and universities. A similar result is present for the other external agents, although the nature and strength of the complementary relationship varies for each. These results are broadly consistent with the findings of Jordan and O'Leary (2008) and Roper, Du and Love (2008).

Overall, it appears that firms which source knowledge from market agents such as suppliers, customers and, to a lesser extent, competitors and consultants, also tend to interact with other market agents. On the other hand, businesses which source knowledge from universities and government research institutes do not tend to interact with market agents apart from consultants. It appears as if the decision to source knowledge internally through R&D only tends to be associated with interaction with government research institutes. This slightly surprising result may be explained by the measurement of R&D as the incidence of formal spending so that informal R&D activity by many businesses is not analysed.

As might be expected knowledge sourcing within a firm's own group is more likely for firms that are foreign-owned. However, knowledge sourcing from suppliers, consultants and government research institutes is more likely for Irish-owned firms. Turning to sectors, it appears that knowledge sourcing activity does not vary significantly. The exceptions are interaction with consultants, which is less likely, compared to the reference sector for firms in *Wholesale, Transport, Storage and Communication* and *Computer, Architecture and Engineering Services* and knowledge sourcing with universities which is less likely for firms in *Wholesale, Transport, Storage and Communication* and *Financial Intermediation.* Finally, firms are more likely to conduct formal R&D if they are in *Wholesale, Transport, Storage and Communication, Financial Intermediation* and *Computer, Architecture and Engineering Services.*

Table 4 deals with new to market innovation. Just as in Table 3 a set of complementary relationships between external interaction agents is evident. Overall, the results are quite similar. It appears that interaction with suppliers for the purposes of this slightly more risky form of innovation is now also associated with interaction with universities and government research institutes. Additionally, it is notable that knowledge sourcing from universities is more associated with high-technology sectors while interaction with government research institutes is now less likely from firms in *Financial Intermediation* and *Computer, Architecture and Engineering Services.* Overall these results suggests that knowledge sourcing activities are fairly similar regardless of whether the business is introducing products that are new just to itself or new to its market. This may reflect the routine nature of innovation in most businesses where internal and external knowledge sourcing takes place as a matter of course.

[table 3&4 around here]

Tables 5 and 6 present the results of the three stage least squares estimations of Equation (3) and (4) for new to firm and new to market innovation. In Table 5 productivity is endogenous with all other variables being treated as exogenous. It can be observed that productivity, measured as the natural log of overall firm turnover per worker, has a significantly positive effect on the level of innovation turnover per worker for new to market innovation. This suggests that feedback effects are present, with more productive firms being more innovative. Higher productivity may result from greater cumulative experience and learning from past mistakes from both new and existing products. This echoes the finding in Table 2 that firms with previous innovation failures are more likely to decide to innovate. The presence of feedbacks support Kline and Rosenberg's (1986) assertion that innovation does not cease once the good is first brought to market but that innovation is systemic.

It is striking that none of the external knowledge sources have a positive effect on new to market innovation. The finding that R&D spending is positive and significant suggests that the magnitude of formal spending on R&D is what is important. It also appears that smaller firms are more likely to engage in this form of innovation. Turning to sectors, firms in *All Other Manufacturing* and *Financial Intermediation* have lower levels of innovation performance than those in *High-Tech Manufacturing.* This implies that firms in either of the high-technology sectors and *Wholesale, Transport, Storage and Communication* are superior innovation performers.

For new to firm innovation it is noteworthy that neither productivity, nor external interaction exerts any significant positive effect. R&D spending again has a positive effect but there are no sectoral differences. Interestingly, foreign-owned firms are more likely to perform better. The absence of a positive and significant productivity coefficient may be explained by firms with higher levels of productivity focussing their innovation effort on the riskier new to market innovation. Interaction with government research institutes, which relates to public knowledge sourcing from other than universities, is the only significant variable. Surprisingly, this form of cooperation is estimated to reduce the turnover per worker from new to firm innovation. This surprising result might reflect an orientation of government research institutes towards technological and radical innovation at the expense of new to firm innovation. It merits further investigation.

[table 5 around here]

Results from the three stage least square estimation of Equation (4) are displayed in Table 6. This equation for the final stage of the innovation value chain treats the natural log of innovation turnover per worker as endogenous. It can be observed that innovation turnover per worker has a positive and significant effect on productivity for both new to firm and new to market innovations. This once more emphasizes that innovation and productivity are interdependent in the innovation system. In addition, as expected, the acquisition of capital investment for innovation also has positive effects on productivity.[viii] In these estimations employment has a positive effect indicating that larger firms are more productive than smaller firms. In addition, for firms engaging in new to market innovation, foreign-owned firms are more productive. [ix]

It is notable that for new to firm innovation businesses in the *Wholesale, Transport, Storage and Communication* and *Financial Intermediation* sectors have higher levels of productivity than those in the reference sector. This might be explained by productivity being measured as turnover rather than value added per worker. However, for new to market innovation, this result is extended to businesses in *All Other Manufacturing*. This signifies that businesses in *High-technology Manufacturing* and *Computer, Architecture and Engineering Services* have lower levels of turnover per worker than those in *All Other Manufacturing.* It was seen in Table 2 that businesses in the high-technology sectors are not more likely to decide to introduce this form of innovation. There is no evidence that these sectors, which have been the focus of Irish innovation policy, are superior performers.

These results are broadly consistent with empirical studies of the innovation value chain for other European countries using similar techniques. Janz, Lööf and Peters (2003), for a sample of German and Swedish firms, who use an identical measure of productivity to this paper, also report that more productive firms have higher levels of innovation output and more innovative firms have higher levels of productivity. Loof and Heshmati (2002) find that higher levels of innovation output result in increased productivity growth while Klomp and Van Leeuwen (2006) find that more innovative firms are more productive and that higher levels of productivity result in more innovation output.

[table 6 around here]

6. Conclusions

This paper models the innovation value chain for a sample of Irish firms from the 2004-6 Community Innovation Survey (CIS) using three stage least squares techniques. The innovation value chain framework has been increasingly employed in the literature to analyse the inter-relationships between external interaction, innovation and productivity as part of the innovation system. In a regional context there has been less attention to the endogeneity between innovation and productivity. External interaction may influence innovation, but so also might productivity.

The key finding is that innovation performance has a strong positive influence on productivity, for both new to firm and new to market innovation and that productivity influences innovation performance, but only for new to market innovation. This suggests that feedback effects are crucial, with more productive firms being more innovative and more innovative firms being more productive. It points to the main methodological contribution of the paper, which is the importance of estimating the innovation transformation and exploitation stages of the innovation value chain in a simultaneous setting. The results support Kline and Rosenberg's (1986) assertions about the systemic nature of innovation.

It is notable that in explaining innovation performance none of the external knowledge sources have a positive effect. This is a similar finding to studies using single equation estimations of innovation performance, measured as innovation intensity and success, which exclude productivity as an independent variable (Roper, 2001, Love and Roper, 2001 and Roper Du and Love, 2008). Indeed, an OLS estimation of external interaction agents, R&D and firm specific factors on innovation turnover per worker for this data set reveals the same result, with none of the external interaction agents being significant (See Appendix Table A2). Moreover, although not strictly comparable, the explanatory power of this estimation is considerable lower than in Table 5, with an R^2 of only 12% to 13% compared to 33% to 57%.

If external interaction is not important this begs the question as to what explains innovation performance. This paper shows that productivity plays a key role. The successful transformation of new products into positive sales performance is determined by leveraging the cumulative learning and experience built up in the business as a whole. The results again indicate the importance of estimating innovation performance simultaneously with productivity. The finding that external interaction does not matter in this set-up suggests that the implications often drawn from estimations of binary innovation production functions as to its importance have been over-stated (Roper, 2001, Jordan and O'Leary, 2008 and Roper, Du and Love 2008). It is not enough to engage in external interaction. What matters is using the knowledge gained through interaction for the benefit of the business. These results serve a reminder that in-house productive effort is vital.

For the knowledge sourcing stage of the innovation value chain, the results point a dichotomy whereby firms which source knowledge from market agents such as suppliers and customers also tend to interact with other market agents. On the other hand firms which source knowledge from universities and government research institutes are more likely to interact with these non-market agents and consultants. This dichotomy may reflect the science-push focus of Irish innovation policy with its concentration on business-university interaction in high-technology businesses (Jordan and O'Leary, 2008). Firms in these sectors are more likely to interact with universities, especially for new to market innovation, and are not more likely to interact with suppliers and customers.

By offering comprehensive coverage the CIS facilitates innovation analysis for a range of manufacturing and services sectors, which is especially relevant from a policy perspective. It is notable first that there are no great sectoral differences in terms of the likelihood of innovating. When it comes to explaining innovation turnover per worker, firms in either of the high-technology sectors are found to be superior performers. However, for productivity they are found to be inferior performers.[x] This result may reflect the greater emphasis on science-push innovation by these businesses and a greater difficulty in leveraging innovation into improved business productivity in these sectors. However, further research is necessary in order to test this hypothesis.

As the first application of the innovation value chain to Ireland using simultaneous estimation techniques, this papers findings are generally in line with the international literature. However there are two measurement issues which, if addressed in future CIS surveys may greatly facilitate understanding and policy relevance. These are first, that the CIS data set does not provide measures of the human capital stock in the business, which is widely regarded as important measures of absorptive capability. This omission makes it difficult to delve deeper into the contribution of human capital in the business, which is warranted given the main findings of the paper. It also impedes full evaluations of the efficacy of public investment in higher education on innovation and productivity. Second, a longitudinal data set would facilitate more comprehensive analysis of the nature of feedback effects between productivity and innovation performance. Knowledge of how firms incorporate past learning into performance would be especially important for a fuller understanding of these effects.

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Table 1: Descriptive Statistics for the Irish Community Innovation Survey: 2004-2006

Variable	Mean	Standard Deviation
Company Specific Factors		
Employment[1]	124	525
Irish Owned (0/1)	0.74	n/a
Sector		
High-Tech Manufacturing (%)	14	n/a
All Other Manufacturing (%)	30	n/a
Wholesale, Transport, Storage and Communication (%)	35	n/a
Financial Intermediation (%)	8	n/a
Computer, Architecture and Engineering Services (%)	13	n/a
Product Innovation		
New to Firm Innovations (0/1)	0.25	0.43
New to Market Innovations (0/1)	0.22	0.42
Either New to Firm or Market Innovators (0/1)	0.33	0.47
Knowledge Sourcing		
Research and Development (0/1)	0.25	n/a
Research and Development Expenditure per Worker (€)	6014[2]	18884
Group (0/1)	0.09	n/a
Supplier (0/1)	0.11	n/a
Customer (0/1)	0.09	n/a
Competitor (0/1)	0.03	n/a
Consultant (0/1)	0.06	n/a
University (0/1)	0.05	n/a
Government Research Institute (0/1)	0.03	n/a
Innovation Turnover and Capital		
Innovation Turnover per Worker - New to Firm (€)	76,580[2]	206,676
Innovation Turnover per Worker - New to Market (€)	102,441[2]	345,652
Innovation Capital Investment per Worker (€)	6,952[2]	49,064
Productivity		
Turnover per Worker[1]	620,502[2]	3,512,599

Note 1: From CSO Central Business Register
2: Innovators only.

Source: Community Innovation Survey: 2004-2006

Table 2: Probit Estimation of Equation (1) - The Innovation Decision[1]

Variables	New to Firm	New to Market
Employment	0.00001	0.0001
	(0.0001)	(0.00001)
Irish owned	-0.0966***	-0.1115***
	(0.0256)	(0.0242)
R&D	0.3000***	0.3092***
	(0.0313)	(0.0303)
Sector[3]		
All Other Manufacturing (%)	-0.0426	-0.0197
	(0.0296)	(0.0272)
Wholesale, Transport, Storage and Communication (%)	-0.0030	-0.0243
	(0.0327)	(0.0293)
Financial Intermediation (%)	-0.0506	-0.0996***
	(0.0358)	(0.0245)
Computer, Architecture and Engineering Services (%)	0.0391	0.0159
	(0.0392)	(0.0337)
Cost Factors		
Lack of funds within enterprise or groups	-0.0053	0.0085
	(0.0142)	(0.0132)
Lack of finance from sources outside your enterprise	-0.0137	0.0275**
	(0.0149)	(0.0137)
Innovation costs to high	0.0089	-0.0179
	(0.0136)	(0.0130)
Knowledge Factors		
Lack of qualified personnel	0.0414***	0.0062
	(0.0148)	(0.0138)
Lack of information on technology	-0.0208	0.0005
	(0.0199)	(0.0180)
Lack of information on markets	0.0241	0.0089
	(0.0180)	(0.0159)
Difficulty in finding cooperation partners for innovation	-0.0287**	0.0037
	(0.0150)	(0.0137)
Market Factors		
Market dominated by established enterprises	0.0109	-0.0090
	(0.0128)	(0.0127)
Uncertain demand for innovate goods of services	0.0447***	0.0364***
	(0.0146)	(0.0137)
Need to meet market regulation	-0.0070	0.0299***
	(0.0134)	(0.0120)
Excessive perceived economic risk	0.0307**	0.0039
	(0.0160)	(0.0146)
Reasons not to Innovate		
No need due to prior innovations	0.0030	-0.0173
	(0.0123)	(0.0118)
No need because of no demand for innovations	-0.0504***	-0.0527***
	(0.0117)	(0.0114)
Previous Innovation Failures	0.0833***	0.1057***
	(0.0296)	(0.0286)
No. of obs.	1974	1974
Wald Chi2	418.71	471.13
	0.0000	0.0000
Pseudo R2	0.2166	0.2773
Log-likelihood	-872.15	-757.79

Note 1: Marginal effects are provided for ease of interpretation.

Note 2: *** significant at 99%, ** significant at 95%, * significant at 90%.

Note 3: High-Tech Manufacturing is the reference category.

Table 3: Probit Estimation of Equation (2) – Knowledge Sourcing for New to Firm Innovation[1]

Variables	Group	Supplier	Customer	Competitor	Consultants	University	Gov. Research Institutes	R&D
External Knowledge Sources								
Group	n.a.	0.4643***	0.2600***	0.0072	0.0033	0.1536***	0.0389	0.1172
		(0.0767)	(0.0718)	(0.0145)	(0.0271)	(0.0575)	(0.0310)	(1.2500)
Supplier	0.3598***	n.a.	0.3603***	0.0409	0.0819**	0.0148	-0.0136	0.1672
	(0.0661)		(0.0622)	(0.0266)	(0.0401)	(0.0209)	(0.0107)	(-0.2400)
Customer	0.2178***	0.3985***	n.a.	0.0589*	0.0713*	-0.0007	0.0153	0.1406
	(0.0630)	(0.0678)		(0.0319)	(0.0385)	(0.0158)	(0.0204)	(0.8100)
Competitor	0.0163	0.2303*	0.2782**	n.a.	0.0822	0.0083	0.0255	0.1360
	(0.0606)	(0.1290)	(0.1238)		(0.0618)	(0.028)	(0.0345)	(1.2800)
Consultant	-0.0345	0.1861**	0.1479*	0.0371	n.a.	0.0740*	0.1128**	0.2701
	(0.0385)	(0.0889)	(0.0776)	(0.0292)		(0.0439)	(0.0560)	(-1.0400)
University	0.2644***	0.0426	-0.0207	0.0006	0.0885*	n.a.	0.0549	0.2110
	(0.0931)	(0.0731)	(0.0484)	(0.0131)	(0.0515)		(0.0396)	(0.0900)
Government Research Institutes	0.0898	-0.0873	0.0931	0.0083	0.2116**	0.1000	n.a.	0.0799***
	(0.0965)	(0.0577)	(0.1016)	(0.0205)	(0.0951)	(0.0663)		(2.8900)
Internal Knowledge Production								
R&D	0.1196**	0.0388	-0.0635	0.0226	-0.0101	0.0441	0.0141	n.a.
	(0.0596)	(0.0870)	(0.0824)	(0.0197)	(0.0441)	(0.0298)	(0.0217)	
Employment	0.0001	0.0001	-0.0001	-0.00001	0.0001	0.0001*	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(-0.6800)
Irish owned	-0.2654***	0.1070**	0.0260	-0.0048	0.0410**	0.0100	0.0204*	0.1224***
	(0.0533)	(0.0483)	(0.0446)	(0.0127)	(0.0213)	(0.0166)	(0.0124)	(5.300)
Sector[3]								
All Other Manufacturing (%)	0.0232	0.0603	-0.0391	0.0092	-0.0303	-0.0171	0.0166	0.1259
	(0.0512)	(0.0671)	(0.0479)	(0.0171)	(0.0206)	(0.0149)	(0.0183)	(1.4900)
Wholesale, Transport, Storage and Communication (%)	0.0184	0.0741	0.0425	0.0204	-0.0488***	-0.0517***	n.a.	0.21747*
	(0.0576)	(0.0777)	(0.0657)	(0.0251)	(0.0202)	(0.0166)		(-1.8500)
Financial Intermediation (%)	0.1854*	-0.0898	-0.0643	0.1134	-0.0247	-0.0362***	-0.0047	0.0995*
	(0.1072)	(0.0637)	(0.0558)	(0.0785)	(0.0250)	(0.0130)	(0.0166)	(1.8600)
Computer, Architecture and Engineering Services (%)	0.0908	-0.0103	0.0169	-0.0136	-0.0330*	-0.0043	-0.0119	0.1603***
	(0.0672)	(0.0641)	(0.0560)	(0.0109)	(0.0183)	(0.0169)	(0.0116)	(-4.1900)
Inverse Mills Ratio	0.2824	0.3112	-0.6355**	0.0774	-0.2696	-0.0020	-0.0549	1.3839***
	(0.2755)	(0.3722)	(0.3182)	(0.0832)	(0.1737)	(0.1237)	(0.0980)	(-6.9500)
No. of obs.	490	490	490	490	490	490	453	490
Wald Chi2	251.96	232.02	222.16	77.45	134.57	144.49	76.97	570.47
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R2	0.5026	0.4289	0.4363	0.3517	0.3864	0.4198	0.3663	0.8555
Log-likelihood	-124.66	-154.47	-143.51	-71.38	-106.85	-99.83	-66.57	-48.17

Note 1: Marginal effects are provided for ease of interpretation.
Note 2: *** significant at 99%, ** significant at 95%, * significant at 90%.
Note 3: High-Tech Manufacturing is the reference category.

Table 4: Probit Estimation of Equation (2) – Knowledge Sourcing for New to Market Innovation[1]

Variables	Group	Suppliers	Customers	Competitors	Consultants	University	Gov. Research Institutes	R&D
External Knowledge Sources								
Group	n.a.	0.3853***	0.2150***	0.0091	0.0764**	0.1191**	0.0468	0.0799
		(0.0741)	(0.0654)	(0.0145)	(0.0386)	(0.0485)	(0.0293)	(0.0613)
Supplier	0.3522***	n.a.	0.3407***	0.0962***	0.0687**	0.0796**	-0.0196	0.0253
	(0.0662)		(0.0622)	(0.0375)	(0.0350)	(0.0404)	(0.0126)	(0.0842)
Customer	0.2111***	0.3888***	n.a.	0.0285	0.0636*	0.0072	0.0069	-0.0014
	(0.0679)	(0.0692)		(0.0210)	(0.0334)	(0.0251)	(0.0166)	(0.1006)
Competitor	0.0030	0.4244***	0.1451	n.a.	0.0716	0.0186	0.0626	-0.1119
	(0.0729)	(0.1351)	(0.0963)		(0.0523)	(0.0397)	(0.0494)	(0.2471)
Consultant	0.1418*	0.2022***	0.1487**	0.0389	n.a.	0.0383	0.0477	0.0406
	(0.0857)	(0.0958)	(0.0766)	(0.0299)		(0.0389)	(0.0371)	(0.1189)
University	0.1866**	0.2022**	0.0199	-0.0001	0.0329	n.a.	0.1379**	0.0453
	(0.0886)	(0.0913)	(0.0595)	(0.0125)	(0.0322)		(0.0628)	(0.0907)
Government Research Institutes	0.1078	-0.1403***	0.0663	0.0472	0.0962	0.2612***	n.a.	0.0677
	(0.0997)	(0.0504)	(0.0850)	(0.0400)	(0.0612)	(0.0921)		(0.0653)
Internal Knowledge Production								
R&D	0.1204	0.0784	-0.0803	-0.0214	-0.0054	0.0632*	0.0362*	n.a.
	(0.0780)	(0.0968)	(0.0960)	(0.0328)	(0.0456)	(0.0386)	(0.0222)	
Employment	0.0001	0.0001	-0.0001*	-0.0001	0.00001	0.0001**	-0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Irish owned	-0.3538***	0.0810	0.0687	-0.0100	0.0448**	0.0111	0.0179	0.5899***
	(0.0575)	(0.0578)	(0.0467)	(0.0139)	(0.0203)	(0.0253)	(0.0137)	(0.1229)
Sector[3]								
All Other Manufacturing (%)	0.0581	0.0585	-0.0290	0.0167	-0.0424**	-0.0383*	0.0124	0.0222
	(0.0667)	(0.0714)	(0.0517)	(0.0195)	(0.0188)	(0.0218)	(0.0173)	(0.0681)
Wholesale, Transport, Storage and Communication (%)	0.0806	0.2183	-0.0127	0.0078	-0.0527***	-0.0642***	0.0041	-0.2465
	(0.0823)	(0.0970)	(0.0625)	(0.0205)	(0.0181)	(0.0195)	(0.0220)	(0.1815)
Financial Intermediation (%)	0.2756	-0.2013***	-0.0112	0.2141*	-0.0019	-0.0570***	-0.0211**	0.0930***
	(0.1363)	(0.0369)	(0.0910)	(0.1256)	(0.0338)	(0.0162)	(0.0107)	(0.0401)
Computer, Architecture and Engineering Services (%)	0.2050**	-0.0095	-0.02740	0.0095	-0.0448***	0.0094	-0.0246**	-0.6057***
	(0.0920)	(0.0766)	(0.0558)	(0.0230)	(0.0164)	(0.0312)	(0.0123)	(0.1972)
Inverse Mills Ratio	0.3603	0.2626	-0.6347	-0.0328	-0.3148*	-0.0009	-0.0847	-4.8870***
	(0.3985)	(0.4441)	(0.3635)	(0.0986)	(0.1773)	(0.2020)	(0.1144)	(1.2670)
No. of obs.	441	441	441	441	441	441	441	441
Wald Chi2	223.18	222.2	181	86.94	155.58	151.06	96.65	486.05
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R2	0.4428	0.4288	0.3814	0.3788	0.4482	0.4176	0.3814	0.8518
Log-likelihood	-140.43	-148.01	-146.8	-71.28	-95.75	-105.31	-78.61	-42.28

Note 1: Marginal effects are provided for ease of interpretation.
Note 2: *** significant at 99%, ** significant at 95%, * significant at 90%.
Note 3: High-Tech Manufacturing is the reference category.

Table 5: Three Stage Least Squares Estimation of Equation (3) – Innovation[1]

Log of Innovation Turnover per Worker	New to Firm	New to Market
Constant	6.8970	2.4621
	(7.0626)	(3.403)
Turnover per Worker[2]	0.2259	0.6271**
	(0.6237)	(0.3136)
External Knowledge Sources		
Group	-0.2027	0.0252
	(0.2225)	(0.1544)
Supplier	0.2175	0.2007
	(0.2066)	(0.1548)
Customer	-0.0805	0.0191
	(0.1849)	(0.1592)
Competitor	0.1041	0.0748
	(0.2621)	(0.2290)
Consultant	0.0188	0.0581
	(0.2183)	(0.1842)
University	0.1404	0.0237
	(0.2363)	(0.1793)
Government Research Institutes	-0.4293*	-0.0038
	(0.2760)	(0.2126)
Internal Knowledge Production		
R&D Expenditure[2]	0.0728*	0.0528*
	(0.0466)	(0.0330)
Employment[2]	-0.0233	-0.1297**
	(0.0769)	(0.0601)
Irish owned	-0.7781*	-0.4316
	(0.4638)	(0.3384)
Sector[3]		
All Other Manufacturing	0.0738	-0.3419**
	(0.1968)	(0.1668)
Wholesale, Transport, Storage and Communication	0.3994	-0.2117
	(0.5017)	(0.3269)
Financial Intermediation	0.1555	-0.7169**
	(0.4284)	(0.3001)
Computer, Architecture and Engineering Services	-0.0780	-0.2820
	(0.2121)	(0.1971)
Inverse Mills Ratio	0.9988	1.2495
	(0.9952)	(1.001)
Obs	490	441
R-sq	0.3288	0.5675
Chi2	84.76	134.84
	0.0000	0.0000

Note 1: *** significant at 99%, ** significant at 95%, * significant at 90%.

2: These variables are in logs.

3: High-Tech Manufacturing is the reference category.

Table 6: Three Stage Least Squares Estimation of Equation (4) – Productivity[1]

Log of Turnover per Worker	New to Firm	New to Market
Constant	6.2363	5.7134
	(1.6180)	(1.6889)
Innovation Turnover per Worker[2]	0.5641***	0.5814***
	(0.1451)	(0.1457)
Innovation Capital Investment per Worker[2]	0.0234***	0.0303**
	(0.0106)	(0.0136)
Employment[2]	0.0956***	0.1355***
	(0.0289)	(0.0348)
Irish Owned	-0.1600	-0.3667**
	(0.1398)	(0.1653)
Sector[3]		
All Other Manufacturing (%)	0.0921	0.3284***
	(0.1035)	(0.1145)
Wholesale, Transport, Storage and Communication (%)	0.4334***	0.6797***
	(0.1349)	(0.1365)
Financial Intermediation (%)	0.3885***	0.8058276***
	(0.1498)	(0.1870)
Computer, Architecture and Engineering Services (%)	-0.0982	0.0111
	(0.1144)	(0.1504)
Inverse Mills Ratio	-0.2620	-0.0116
	(0.3651)	(0.4117)
Obs	490	441
R-sq	0.6338	0.6593
Chi2	223.17	297.87
	0.0000	0.0000

Note 1: *** significant at 99%, ** significant at 95%, * significant at 90%.

2: These variables are in logs.

3: High-Tech Manufacturing is the reference category.

Appendix

Table A1: Summary Statistics of the Irish Community Innovation Survey 2004-2006.

Technology Push and Market Pull Factors (%)	**N/A**	**Low**	**Medium**	**High**
Lack of funds within enterprise or groups	47.62	19.91	17.93	14.54
Lack of finance from sources outside your enterprise	56.84	20.16	13.78	9.22
Innovation costs to high	49.65	16.97	20.36	13.02
Lack of qualified personnel	48.78	23.71	19.55	7.95
Lack of information on technology	51.87	29.43	14.79	3.9
Lack of information on markets	51.27	28.37	15.5	4.86
Difficulty in finding cooperation partners for innovation	59.22	23.96	11.14	5.67
Market dominated by established enterprises	48.23	19.71	19.66	12.41
Uncertain demand for innovate goods of services	47.06	20.01	21.78	11.14
Need to meet market regulation	53.14	24.47	12.21	10.18
Excessive perceived economic risk	50.81	24.06	17.27	7.85
No need due to prior innovations	55.52	20.92	14.44	9.12
No need because of no demand for innovations	51.52	21.18	15.6	11.7
Previous Innovation Activity			**No**	**Yes**
Previous Innovation Failures			80.7	19.3

Table A2: OLS Estimation of Equation (3) Omitting Productivity

Log of Innovation Turnover per Worker	**New to Firm**	**New to Market**
Constant	9.4749	9.4120
	(0.7503)	(0.8725)
External Knowledge Sources		
Group	-0.2380	0.0488
	(0.2240)	(0.2352)
Supplier	0.2560	0.3162
	(0.2104)	(0.2339)
Customer	-0.0852	0.0521
	(0.2154)	(0.2349)
Competitor	0.1104	0.1367
	(0.3054)	(0.3322)
Consultant	0.0110	0.0711
	(0.2507)	(0.2801)
University	0.1680	0.0317
	(0.2535)	(0.2727)
Government Research Institutes	-0.4474	-0.0155
	(0.3193)	(0.3207)
Internal Knowledge Production		
R&D Expenditure[2]	0.0856***	0.0879***
	(0.0300)	(0.0331)
Employment[2]	-0.0014	-0.0618
	(0.0568)	(0.0664)
Irish owned	-0.9359***	-1.0290***
	(0.1591)	(0.1882)
Sector[3]		
All Other Manufacturing	0.1109	-0.2029
	(0.1958)	(0.2146)
Wholesale, Transport, Storage and Communication	0.5662***	0.3148
	(0.2140)	(0.2509)
Financial Intermediation	0.2789	-0.3769
	(0.2818)	(0.3569)
Computer, Architecture and Engineering Services	-0.1170	-0.4608*
	(0.2161)	(0.2557)
Inverse Mills Ratio	1.1161	1.9350
	(1.0361)	(1.2240)
Obs	490	441
R-sq	0.1165	0.1335
F-test	4.17	4.36
	0.0000	0.0000

Note 1: *** significant at 99%, ** significant at 95%, * significant at 90%.

2: These variables are in logs.

3: High-Tech Manufacturing is the reference category.

ENDNOTES

[i] Innovation intensity is defined as innovation turnover per worker while innovation success is measured as the percentage of total turnover accounted for by new products.

[ii] Three stage least squares is preferred to two stage least squares because it corrects for errors identified in the co-variance matrix. For a discussion on the use of three stage least squares see Greene (2008).

[iii] It is not possible to test this here as value added is not available from the CIS.

[iv] The NACE Rev 1 codes selected are: *High-Tech Manufacturing* (24, 29, 30 - 35); *All Other Manufacturing* (10-14; 15-37 excluding high-tech, 40-41), *Wholesale, Transport, Storage and Communication* (51, 60-64), *Financial Intermediation* (65-67) and *Computer, Architecture and Engineering Services* (72, 74.2, 74.3). The definition of high-technology is taken from the OECD classification (see European Commission, 2003).

[v] This includes Computer and Related Activities (NACE Rev 1) which is a high-technology industry (European Commission, 2003). Forfás consider it as part of Ireland's ICT sector (National Competitiveness Council, 2009). See Jordan and O'Leary (2005) and (2008) for a full discussion.

[vi] Again, this differs from Jordan and O'Leary (2008) which considers both formal and informal linkages as external interaction.

[vii] See Appendix Table A1 for descriptive statistics for these measures.

[viii] This result coincides with Mansury and Love (2008) who find higher levels of capital investment result in increased levels of productivity.

[ix] This finding that Irish owned firms have lower productivity than foreign owned firms may reflect the well documented presence of transfer pricing by foreign multi-national businesses in the manufacturing sector based in Ireland which results in the overstatement of turnover in these businesses (O'Leary, 2003).

[x] Using turnover rather than value added per worker makes comparisons of manufacturing and services difficult as manufacturing may sell to services sectors. This difficulty is not present in comparing different manufacturing sectors. Thus, the key finding being alluded to here is that relative to *All Other Manufacturing,* firms in *High-tech Manufacturing* are found to have lower levels of turnover per worker.