Product Innovation and Discontinuation in Manufacturing and Service Firms in Europe

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ABSTRACT

This study explores product innovation and discontinuation using the firm as a unit of analysis. A key objective of the paper is to compare the results between manufacturing and service firms. The results indicate that the factors affecting product innovation and discontinuation are similar for manufacturing and service firms, where innovation was significant for product/service discontinuation and process innovation was found to be important for innovations. Similarly monopoly power was important for innovation in both industry types. However, there were also some underlying differences, particularly in relation to firm age and economic geography effects. The conclusion of the paper is that it is not appropriate to assume that the process of product innovation and discontinuation will be identical across industry types.

Keywords: innovation, product, service, life-cycle

JEL Classification: 031, 032.

1. INTRODUCTION

Innovation is essential in determining the long term growth patterns of economies (OECD, 2005). The firm is viewed as the catalyst of innovation activities and is motivated to innovate in an effort to improve their productivity and market position relative to other market competitors. Baumol (2002) described innovation as a 'life and death matter for a firm' where maintaining or improving market share against competitors is crucial for the very survival of the firm. However, despite the importance of innovation for long term economic growth and for a firms success, the process of innovation was treated very much like a 'black box' (Fagerberg *et al.*, 2006) and was confined to what has become known in the literature as the Solow residual. However, over the most recent decades the process of innovation using the firm as a unit of analysis has been investigated by numerous scholars (Crepon *et al.*, 1998, Griffith *et al.*, 2008, Roper *et al.*, 2008; Doran and O'Leary, 2011).

A commonly employed framework to analyse firm innovation is the knowledge production function approach (Crepon et al., 1998 Griliches, 1998; Mairesse *et al.*, 2005; Parisi *et al.*, 2006; Griffith et al., 2008; Raffo *et al*., 2008; Mairesse and Robin, 2009), where innovation outputs are a result of firm inputs associated with the process of innovation. The origins of the concept of innovation emerging in the literature are largely dedicated to the work of Schumpeter (1934). Schumpeter (1934) argued that innovation comes about through new combinations made by an entrepreneur, resulting in a new product, a new process, opening of a new market, a new way of organising the business and new sources of supply. Schumpeter's idea of innovation is also embodied in his idea of creative destruction which is the process of where new products or processes replace existing ones. The literature has predominantly focused on how the 'new' activities [product and process innovations] are created within firms and its effect on firm outcomes (Crepon et al., 1998 Griliches, 1998;

Mairesse *et al.*, 2005; Chudnovky *et al.* 2006; Loof and Heshmati, 2006 Parisi *et al.*, 2006; Van Leeuwen and Klomp, 2006; Griffith *et al*., 2008; Masso and Vahter, 2008; Raffo *et al*., 2008; Hall *et al*., 2009; Mairesse and Robin, 2009). This focus in terms of Schumpeter's definition of creative destruction could be viewed as the creative aspect of his creative destruction concept. However, the destructive aspect of his concept has largely been ignored with no studies focusing on this aspect using the firm as a unit of analysis, albeit there have been studies conducted at an industry level examining the birth (entry) and death (exit) of firms (Dunne *et al.*, 1988, Audretsch and Mahmood, 1995, Doms *et al*., 1995; Agarwal and Gort, 1996, Agarwal, 1997; Agarwal and Audretsch, 2001). At the firm level of analysis, inherent in the creative destruction concept is a life span phenomenon due to the origin (creation) and death (destruction) of innovations. Hence, Schumpeter's concept is related to the idea of the product life cycle. This study postulates that examining the link between innovation and destruction using the firm as a unit of analysis will enhance our understandings of the product life cycle (PLC).

Klepper (1996) in a review of the empirical literature identified that industries with rich opportunities for product innovation reach a peak in the number of producers which falls over time and the focus of firms subsequently shifts from introducing product innovations to introducing process innovations. This phenomenon has broadly become understood as the PLC. Vernon (1966) introduced a spatial context to the PLC idea. He outlined that the location decision for production will shift from high cost locations to lower cost locations as the knowledge required to manufacture products becomes more standardised over time. Using such frameworks from the theoretical literature and evidence from the empirical literature on the PLC, five principle patterns are hypothesised to emerge in the analysis; (1) a replacement effect to occur within the firm with new and improved products having a significant effect on the likelihood of a firm discontinuing products (2) younger firms will be more likely to product innovate; (3) older firms will be more likely to discontinue products; (4) process innovation will be more significant at the end of the PLC and lastly, (5) a location effect, where product innovation is more likely to occur in more urban areas than in rural areas. A two-step production function approach is employed that firstly examines a firm's decision to innovate and secondly, a firm's decision to discontinue products/services.

There is a growing interest in the topic of understanding the innovation process of service firms. This is largely due to the fact that services account for 70 per cent of global output (GDP) in 2012 (World Economic Indicators, 2014). The services sector were long regarded as passive adopters of technology and technologically backward (Metcalfe and Miles, 2000), but they are increasingly being identified as firms that add value to goods (Bryson, 2010). The limited literature on innovation in service firms has identified the drivers of innovation to be distinctly different from that found in manufacturing studies (Mina *et al.*, 2014). The service literature has relied on the innovation studies of manufacturing firms to predict patterns and understandings of the innovation process in service firms (Menor *et al.*, 2002). This paper applies the theoretical lessons from the PLC literature to identify their relevance to the understanding of service life cycles (SLC).

The data used in this study is from 675 manufacturing firms and 1,784 service firms that took part in the third round of the Business Environment and Enterprise Performance Survey (BEEPS). The data is disaggregated across six countries: Germany, Spain, Ireland, Greece, Portugal and Slovenia. The sample is a collection of innovation-driven economies as categorised by the Global Competitiveness Report (GCR) based on their GDP per capita and the proportion of their total exports which are primary products (Schwab *et al*., 2009). In the next section, the theoretical context for the study is outlined. This is followed by a data and methodology section. The results are then discussed and a conclusion section concludes the paper.

2. LITERATURE REVIEW

Creative destruction is a concept from the work of Schumpeter (1934; 1942). Schumpeter's concept of innovation is also embodied in his idea of creative destruction where:

> "the fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets….[this process] incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism." (1942, p. 83)

The creative destruction concept refers to a process through which something new brings about the demise of whatever existed before it. Schumpeter (1942) referred to this process as the essential fact about capitalism where innovation is the catalyst for firms to attain an advantage over their competitors in the market place. Schumpeter's states that innovation consists of:

> "(1) the introduction of a new good – that is one with which consumers are not yet familiar – or of a quality of a good. (2) The introduction of a new method of production, that is one not yet tested by experience in the branch of manufacture concerned, which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially. (3) The

opening of a new market. (4) The conquest of a new source of supply of raw materials or half-manufactured goods. (5) The carrying out of a new organisation of any industry" (1934:66).

From the above definition, it is considered in the literature that the first element is related to the introduction of a new product. The rest are considered to refer to process innovations. The literature exploring innovation within the firm has primarily focused on the creative aspect of the creative destruction concept by examining the sources of innovation for firms. For instance, the conceptual model of the innovation value chain (IVC) (Hanson and Birkinshaw, 2007; Roper *et al*., 2008) focuses on knowledge sourcing, knowledge transformation and knowledge exploitation at the firm level. Similarly, the chain-link model of Kline and Rosenberg (1986) is a conceptual framework outlining how innovation occurs and conceptually outlines the continuous feedback and interaction from research sources, knowledge sources and market sources from the product idea to the commercial success of a product.

Innovation is central in the creative aspect of the term creative destruction as a market force. Both the IVC and the chain-link model focus on this creative aspect. This focus, albeit central to our understanding of economic growth, does not provide further understanding on the 'destructive' component of the creative destruction concept. For instance, it is well understood from the literature what types of firms are innovating and just as importantly, the types of firms that are not innovating. But, given that creative destruction is 'the essential fact about capitalism' (Schumpeter, 1942) the knowledge sourcing and production of products and processes *may* (must) also lead to knowledge disruption. Knowledge disruption is defined in this study as a re-evaluation by the firm of its existing product portfolio which may lead to a decision to discontinue a product or products and as such a 'replacement effect' within the firm's product portfolio emerges, where new products replace older products within the firm.

The author draws on Ropers *et al*. (2008) IVC framework for exploring this idea. The IVC outlines three stages. The first stage involves knowledge sourcing by the firm through internal R&D activities and external interaction with suppliers, competitors, customers and public institutions. The second stage consists of the firm drawing on the knowledge sourcing stage through creating tangible knowledge production outputs from knowledge inputs, commonly referred to in the literature either as product or process innovations. Finally, the third stage involves knowledge exploitation where innovation is not viewed as an end in the model but as a means to enhancing the firm's performance whether through tangible measures such as increased profit, productivity or through the growth of the firm.

A re-configured IVC framework is employed in this paper that includes a knowledge disruption stage leading to four stages as opposed to the three stages outlined in Roper *et al.* (2008). It is argued that knowledge sourcing and knowledge production activities by the firm may lead to a disruption of the 'existing state of production (affairs)' for firms and hence a knowledge disruption stage is included after the knowledge production stage and before the knowledge exploitation stage of Roper *et al.*'s (2008) IVC framework. For Schumpeter, the entrepreneur was the catalyst of creative destruction, where innovative entry was the disruptive force that created economic growth. In the attempts to measure the effect of creative destruction, predominantly the focus has been on the entry and exit of firms from sectors and markets. However, most innovations are incremental in nature, and hence most are not radical enough to completely disrupt whole industries (Veryzer, 1998). Therefore, it is argued in this paper that firms are constantly going through their own stages of creative destruction over time where they are creating products (knowledge transformation) and discontinuing them (knowledge disruption) and hence we outline the following hypothesis:

> **H1: Knowledge production (new and improved products) leads to knowledge disruption (discontinuation of products) and a 'replacement effect' of the firm's products occurs.**

Schumpeter (1942) closely aligned his idea of creative destruction with the business cycle. Klepper (1996), who surveyed the empirical literature on product life cycles identified six observed patterns or regularities with the product life cycle:

> "(1) The number of entrants often rises at the beginning of an industry but over time the number of entrants becomes small or zero….(2) the number of producers increases initially, reaches a peak, then declines despite continued industry growth….(3) eventually the rate of change of the market shares of the largest firms declines and the leadership stabilises….(4) The diversity of competing product variations and number of significant product innovations tend to reach a peak during the period of growth in number of producers, then decline….(5) Over time, producers devote increasing effort to *process* relative to *product* innovation….(6) During the period of growth in the number of producers, the most recent entrants account for a disproportionate share of product innovations." (1996: 564-565)

This idea has broadly become understood in the literature as the 'product-life cycle' (PLC). Klepper (1996) outlines that the last three regularities, (4) to (6) above, are in relation to the

PLC and innovation. Consequently, the focus by this paper in determining testable hypotheses takes these three regularities into account and in particular the focus is firstly on the relationship between the age of the firm and product innovation and secondly on the relationship between process and product innovation. Most studies in the literature have focused on examining the PLC and the exit and entry of firms to industries (Dunne et al., 1988, Audretsch and Mahmood, 1995, Agarwal and Gort, 1996, Doms et al., 1995, Agarwal, 1997). This study differs from the previous literature as it does not focus on attempting to track the PLCs within firms, and further it is not attempting to identify what stages of the PLC products may be currently at within firms. Rather, the focus is on exploring the link between product origin and product death and what factors (as well as product origin) may affect the likelihood of firms discontinuing products. Klepper (1996) envisages products to go through a life cycle which implicitly implies that products have an age life span. This life span is characterised by four stages: introduction; growth, maturity and decline. Following this, it is assumed in this study that younger firms are embodied with the production of younger products and older firms are embodied with the production of older products. In terms of age, from Kleppers (1996) three regularities (4) to (6), it is ascertained that the intensity of product innovations are related to the intensity of firm entry in the market and that the intensity of these measures is highest earlier on in the PLC. Hence, this implies that the propensity of product innovation should be higher with younger firms and product discontinuation should be higher amongst older firms. Huergo and Jaumandreu (2004) found that entrants present a high probability of innovating which slowly diminishes over the post-entry life cycle and that exit from the market by firms is associated with a relatively poor pre-exit innovative performance especially in process innovations. Hence, the following hypotheses are proposed:

H2: Younger firms are more likely to product innovate.

H3: Older firms are more likely to discontinue products.

The focus of this paper now turns to the relationship between process and product innovation. Utterback and Abernathy (1975) propose in their model of the PLC that firms compete predominately on product differentiation in the early stages of the PLC and consequently research and development investment is high to develop product features that they perceive customers to want. As the market matures, and the tastes and preferences of consumers become better understood by firms operating within the market, the focus of the firm changes to devoting efforts towards producing greater quantities of output at a lower cost. Hence, process innovations dominate the comparative innovation activities of firms in the latter stages of the PLC. The PLC provides a degree of structure of where the switch between product and process, as outlined by Utterback and Abernathy (1975) may occur and may be used as a benchmark for understanding the process innovation decisions of firms. Birou *et al.* (1998) found in a study that analysed functional level strategies (with respect to production, purchasing and logistics) and the PLC, that managers were most concerned about low costs in the maturity stage of their products. With respect to the PLC and the motivations of firms to focus more on process innovations, it is plausible following this discussion that the decision to process innovate is likely to happen in the latter stages of the PLC than in the early stages. However, the empirical literature is mixed on the relationship between product and process innovations. Martinex-Ros (2000) state that the drivers of product and process innovations are likely to be different as process innovations are more likely to be cost driven and product innovations are more oriented towards product differentiation. Martinez-Ros and Labeaga (2009) conclude that firms that engage in product innovations are more likely to engage in process innovations and simultaneously firms that engage in process innovations are more likely to engage in product innovations. Freeman and Soete (1997) and Mohnan and Hall (2013) outlined that product innovations may in turn lead to changes in processes of production. However, contrary to these other findings, Kraft (1990) found that firms which engage in process innovations are not more likely to engage in product innovation. Returning to Klepper's (1996) findings, he identified that firms devote increasing effort to process relative to product innovation over time. Hence, in terms of identifying a hypothesis for when innovations may occur – this study takes the theoretical and empirical expectations of Utterback and Abernathy (1975) and Klepper (1996), and the following hypothesis is proposed for examination:

H4: Process Innovation is more likely to be significant at the end of the PLC than at the beginning of the PLC.

We further draw on the geographical implications of the PLC (Vernon, 1966) which was later applied to regional and urban arguments for the location of production that later became known as the regional or urban hierarchy model (Tödtling, 1992, Oakey *et al.*, 1988, Roper, 2001). Vernon (1966) discussed this shift between product and process innovations by firms and the spatial implications of the PLC for international trade. He outlined that products are created and manufactured in developed countries and exported to less developed countries. As the knowledge required to manufacture the products becomes more standardised and more easily codified, production shifts to less developed countries where labour costs are lower. The focus of this paper is more on testing the regional and/or urban hierarchy effect of production for firms. The urban hierarchy model argues that there may be a hierarchy urban-periphery effect with innovation and the location of production. The early stage of product innovation may occur more often in urban areas where firms benefit from positive agglomerations which in turn aid the idea generation stage of innovation for firms where firms are close to customers, can get instant feedback on their new product and may also learn from their competitors that are going through a similar process. However, when the innovation diffuses, the product innovation may start to become standardised where the industry structure starts to shift to a more monopolistically competitive structure and hence, process innovation, scale and cost competitiveness become more important for firms. Therefore, there may be a shift to the periphery of urban regions or rural areas by firms in the later stages of a products 'life' - where costs of production may be lower. Following, the arguments of Vernon (1966), Tödtling (1992), Oakey *et al.*, (1988) and Roper (2001), it is expected that an urban effect will be associated with product innovation at the earlier stages of the PLC and a rural effect will be associated with product discontinuation at the latter stages of the PLC. Therefore, the final hypothesis of this paper is:

H5: Product innovation is more likely to occur in more urban areas and product discontinuation is more likely to occur in more rural areas.

The literature has focused primarily on PLC patterns and has completely overlooked Service Life Cycles (SLC's). Our understanding of innovation patterns has essentially been on the basis of technological innovation in manufacturing industries (Tether, 2003). The growth of services and there significant contribution to global economic output representing 70 per cent of global GDP (World Economic Indicators, 2014) means that we can no longer ignore innovation by service firms and obtaining a better understanding of service innovation may enhance our understanding, measuring and managing of innovation (Miles, 2005).

There are many case studies in the literature that show innovation to be important for service firms (Miles, 2005). Further studies suggest that some service industries have substantial R&D expenditures and that this investment is as sustained as those of firms in manufacturing industries (Miles, 2005). Tether (2005) using evidence from the community innovation survey (CIS) identified that the process of innovation by service industries was not dramatically different from the process of innovation by manufacturing industries. The differences identified were in relation to the level of innovation where the propensity to spend on R&D and to product and/or process innovate was lower. However, almost half of the surveyed service firms in the CIS2 reported undertaking innovative activities (Tether *et al.* 2001). Firms belonging to knowledge intensive service industries have been identified as: being among the most active innovators in the economy (Miles, 2005); play an important role in innovation systems (Leiponen, 2001; Miles, 2005); and are well linked to the public elements of innovation systems (Tether and Swann, 2003). In this study, we take an assimilation approach (Coombs and Miles, 2000) to understanding innovation by service firms. The assimilation approach views the process of innovation by service firms to be similar to that of innovation by manufacturing firms both in terms of theoretical methods and concepts[1]. Hence we explore the same hypotheses outlined earlier in relation to PLC's to that of SLC's for service firms.

In this literature review, the variables representing knowledge production, the age of the firm, the decision to process innovate and the location of the firm have been identified as key reasons why firms may discontinue products or services. In the analysis presented later in this paper, other variables identified as explaining innovation processes are also controlled for in

[1] There are other approaches to measuring innovation and for a discussion on these see Coombs and Miles (2000).

the models such as investment in human capital (Cohen and Levinthal, 1990; Romer, 1990; Blundel *et al.* 1990), investment in capital (Grilliches, 1998, Romer, 1990), firm size (Pavitt *et al.* 1987, Tether, 1998, Crepon *et al.* 1998) and sector (Pavitt, 1984). This allows us to identify the relative influence of PLC and SLC patterns on the decision to introduce and discontinue products. The data descriptive and empirical specifications (model and variables) are outlined in the next section.

3. DATA AND METHODOLOGY

The data used for the analysis in this paper is firm level survey data from the Business Environment and Enterprise Performance Survey (BEEPS). The BEEPS data is implemented by the European Bank for Reconstruction and Development (EBRD) and the World Bank. BEEPS data are collected by means of face to face interviews with managers. The purpose of the survey is to collect information on the quality of the business environment and how it affects the performance of enterprises. The data used for this paper stems from the third round of the BEEPS initiative completed in 2005. The key objective of this paper is a focus on PLC and SLC patterns at a firm level. The BEEPS survey is a unique dataset for studying the product and service life cycles as it specifically asks a question about product and service discontinuation in the firm.

[Insert Table 1 and 2 about here]

The sample size used for this paper is 675 manufacturing and 1,784 service firms from six innovation driven economies as defined by the GCR (2005). The firm data stems from a cross-sectional round of the BEEPS initiative taken in the 2004-2005 period. BEEPS data provides detailed information on performance and innovation indicators, the market environment, and the firm’s characteristics. In terms of innovation surveys, the Community

Innovation Survey (CIS) is the most widely used survey in recent innovation studies. However, the CIS does not have information on whether a firm has discontinued products/services. As far as the authors know, there is no other data (other than BEEPS) that asks firms whether they have discontinued a product/service or not. Table 2 outlines the variable definitions as specified in the BEEPS questionnaire.

[Insert Table 3, 4, 5 and 6 about here]

The firms are categorised by the ISIC Rev.3 technology intensity definition. The classification is based on direct R&D intensity and R&D embodied in intermediate and investment goods as proposed in Hatzichronoglou (1997). Following this approach four categories of manufacturing firms were introduced - high technology industries, medium to high technology industries, low to medium high technology industries and low technology industries; and two categories of service firms - Knowledge Intensive Services and Less Knowledge Intensive Services (Eurostat 2014,)[2] . We outline the type of industries that compose each industry grouping in Table 2. Table 3 and 4 outline the descriptive statistics for the sample of manufacturing and service firms, respectively. 23 per cent of manufacturing firms discontinued a product in the surveyed period. 65 per cent of manufacturing firms introduced a new product and/or upgraded an existing product line[3]. 60 per cent of manufacturing firms are in the small firm category and 22 and 18 per cent of firms are in the medium firm category and large firm category respectively. The average age of

[2] For more information on the specific composition of the technology groups go to Eurostat (2014).

[3] The product innovation variable employed in this study combines both new products introduced by the firm and upgraded products by the firm. According to Utterback and Abernathy (1975), much of the activities of firms in the early stages of the PLC are dominated by the firm attempting to identify the tastes and preferences of customers. It is plausible to assume that the process of upgrading products would occur more often in the early stages. Hence, the two measures of product innovation are combined for the purposes of this study.

manufacturing firms is 27. 65 per cent of manufacturing firms introduced a process innovation. In comparison, there is a lower intensity of product, process and product discontinuation in service firms. Noticeably, a much greater percentage of small firms comprise the sample of service firms relative to that in the composition of firms for the manufacturing sample. And the mean age is lower for the service firms relative to the mean age of manufacturing firms. Tables 5 and 6 compare a selection of key variables for the analysis by technological intensity. For the manufacturing sample, there is a greater innovation change experienced for medium to high technological firms in all innovation indicators. The same pattern can be described for knowledge intensive firms in the services sample. The correlation between the product/service and process innovation indicators is 38 per cent for manufacturing firms and 35 per cent for service firms. The monetary figures of R&D expenditure per worker by the firm are adjusted for exchange rates and purchasing power parities (PPPs) using Eurostat PPPs, price level indices and real expenditures for ESA aggregates (Eurostat, 2013).

One the principle focuses of this paper is on the disruptive stage of the innovation value chain (IVC). Equation (1) is a disruptive production function analysing the firm’s decision to discontinue a product/service line:

$$\gamma_{Di} = \begin{cases} 1 \; if \; \gamma_{0i}^{*} = G_i^{*}\alpha_0 + \mathrm{A}_i\alpha_1 + \mathrm{AT}_i\alpha_2 + X_{0i}\alpha_0 + z_{0i} > 0 \\ 0 \; if \; \gamma_{0i}^{*} = G_i^{*}\alpha_0 + \mathrm{A}_i\alpha_1 + \mathrm{AT}_i\alpha_2 + X_{0i}\alpha_o + z_{0i} \leq 0 \end{cases} \qquad (1)$$

Where γ_{0i}^{*} is a latent decision variable measuring the decision of a firm to discontinue a product/service and γ_{Di} is the corresponding observed binary variable being 1 for firms discontinuing a product/service and 0 for firms not discontinuing a product/service. A_{ι} and AT_{ι} are measures of Age and an interaction variable of Age and the technological intensity of the firm. ε_{0i} is the error term for equation (1).

G_i^* is the knowledge input by the firm following the knowledge transformation stage of the IVC – this is the product innovation step outlined in equation (2).

$$\gamma_{Ii} = \begin{cases} 1 \; if \; \gamma_{0i}^* = \mathrm{A}_{\iota}\alpha_1 + \mathrm{AT}_{\iota}\alpha_2 + X_{0i}\alpha_0 + \epsilon_{0i} > 0 \\ 0 \; if \; \gamma_{0i}^* = \mathrm{A}_{i}\alpha_1 + \mathrm{AT}_{i}\alpha_2 + X_{0i}\alpha_o + \epsilon_{0i} \leq 0 \end{cases} \tag{2}$$

It is possible that there is endogeneity between the γ_{Di} and γ_{Ii}. Following Griffith et al. (2008), by using the predicted values in (2) we instrument the knowledge transformation input of firms G_i^* and take care of the possible endogeneity that may be present between the knowledge and disruptive production functions. This will account for the likely characteristics not accounted for in the models that can increase the knowledge input potential of firms by controlling for the likelihood that γ parameters in (1) would be biased upward, because G_i^* and ε_{0i} would be positively correlated. Taking the predicted values from the probit model of the innovation transformation stages allow correction for this as long as z_{0i} are independent of ϵ_{0i}. For more information on this approach see Griffith et al. (2008). We do not allow for feedback effects and we follow a two-step estimation procedure by firstly estimating equation (2) and using the predicted values from this first step and using them in the second step in estimating equation (1)[4]. The results of the innovation and disruption production equations are outlined in the next section.

4. RESULTS

The results from the two equations are presented in Tables 7 and 8. Our analysis of the econometric outputs is framed in terms of the five hypotheses outlined in the literature review section.

[Insert Table 5 and 6 about here]

The first hypothesis attempts to measure Schumpeter's (1942) creative destruction concept at the level of the firm. We find that knowledge production has a significant and positive effect on the decision to discontinue a product and service line in both manufacturing and service firms (at the 1 per cent level). Hence, we assert from our empirical finding that firms do go through their own stages of creative destruction over time where they are creating products/services (knowledge transformation) and discontinuing them (knowledge disruption). It is also the case that R&D expenditure per worker is also significant in the knowledge production stage (at the 1 per cent level) in both industries. The theoretical concepts of a firm sourcing knowledge, producing knowledge and disrupting knowledge holds for the adapted innovation value chain outlined in the literature review section earlier. Hence, the evidence suggests knowledge sourcing effects knowledge production and

[4] The literature also highlights the probable endogeneity that may exist between R&D spend (knowledge sourcing) and the introduction of new products (knowledge production) also known in the literature as the first step in the CDM model (Crepon et al. 1998). The CDM model is the most widely used approach in the literature to study innovation in firms (Chudnovsky et al., 2006, Griffith et al., 2008, Lööf and Heshmati, 2006, Van Leeuwen and Klomp, 2006, Mairesse and Robin, 2009, Doran and O'Leary, 2011). In this paper, the possible endogeneity between R&D spend and new products is controlled for using the same method where the predicted values are estimated from a knowledge sourcing equation of R&D spend per worker as a function of firm size, whether the firm operates in international markets proxied by whether it exports its goods or not and by country dummies. The predicted instruments are then inserted into the equation 2 as a measure of R&D spend per worker.

knowledge production effects knowledge disruption within the firm and critically this is the case for both manufacturing and service firms.

It is now established that new products/services being introduced in the firm matters and has an influence on the death of existing products/services within the firm. Further objectives of this paper were to examine the factors (other than product/service origin) that influence PLC's and SLC's within firms. Our second and third objective relates to the effect of the age of the firm and the PLC/SLC through measuring the relationship between the age of the firm and the decision to introduce innovations and the decision of the firm to discontinue a product/service. For manufacturing firms, we find from our analysis that younger firms are significantly (at the 5 per cent level) more likely to introduce products. The age of the firm does not have a significant effect on the likelihood of a firm discontinuing a product line. The results for service firms run contrary to the expected hypothesis – as older service firms are more likely to service innovate and less likely to discontinue a service. The analysis also controlled for the significance of age by the technological/knowledge intensity of firms by the employment of interaction variables[5]. There is no significance between age and the technological/knowledge intensity of firms found for the disruption stage in manufacturing and service firms and for the production stage for service firms. However, despite younger manufacturing firms being more likely to introduce product innovations, older manufacturing firms belonging to the low to medium and medium to high technological industries are more likely to introduce innovations relative to older firms in the low technological industry category. Hence, higher technological intensity incumbent firms appear to be better able to

[5] Interaction effect for age and technology sectors follows INTEFF command as proposed by Norton *et al.* (2004). Norton *et al.* (2004) argued that computing the marginal effect of a change in two variables is more complicated in nonlinear models and requires the use of the INTEFF command in STATA. The INTEFF command computes the correct marginal effect for the interaction between two variables and also computes the correct standard errors. For more on this command please see Norton *et al.* (2004)

compete in the area of product innovations and respond to changing market preferences and conditions. Surprisingly, firms in higher technological groupings are less likely to introduce product innovations relative to firms in the low technological category (firms in the high technology category are an exception). This may be due to the broad definition of product innovation taken in this paper.

The fourth hypothesis tests the relationship between process innovation and product/service innovation at the beginning of the PLC/SLC and at the end of the PLC/SLC. Process innovation is found to be significant only at the beginning of the PLC/SLC. Hence, it is not possible to support the claims of Klepper (1996) and Utterback and Abernathy (1975) that process innovation is more relevant towards the end of a PLC than at the beginning of the PLC. However, our results do support the views of Swann (2009) and Mohnen and Roller (2005) who suggested that the introduction of one type of innovation may necessitate the introduction of a different type of innovation and hence product/service and process innovation may be necessary complements. Doran (2012) identified that there is a substantial degree of complementarity among different forms of innovation. Furthermore, Mohnen and Hall (2013) highlighted that new products may lead to new production processes or technology for production. Therefore, in contrary to the ideas outlined in Utterback and Abernathy (1975), the firm may be forced to consider process innovations when introducing new products/services and it could equally be argued that as new technologies for production become available to the firm, the capacity to expand their production of different products/services may emerge.

Lastly, we tested the relationship between product innovation, product discontinuation and location. Following the economic geography implications of the PLC (Vernon, 1966;

Tödtling, 1992, Oakey *et al.*, 1988, Roper, 2001) the expectation was firms located in more densely populated urban areas were more likely to product innovate (being close to the market is important for ideas) and firms located in less densely populated areas would be more likely to discontinue products (cost of production is more important towards the end of the PLC). Surprisingly, economic geography was found not to be important in explaining the likelihood of a manufacturing firm introducing new products. However, manufacturing firms located in smaller cities with a population of 50,000 to 250,000 were more likely to discontinuing products, relative to firms located in the capital and cities with a population over one million. Location was found to be important in explaining innovation patterns for service firms – service firms located in smaller cities of a population less than 250,000 were less likley to introduce new services relative to service firms located in the capital city or cities with a population greater than one million people. The economic geography effect appears to hold for service firms but is not as significant for manufacturing firms.

Within the models, other traditional variables used in innovation studies were controlled for. And despite these variables not being to the forefront of the objectives within this paper, it is interesting nonetheless to discuss the importance of these variables on the decision to introduce product innovations and the decision to discontinue products. Unsurprisingly, firms with a greater percentage of employees with a third level education and firms that have a greater proportion of their employees that undergo training are more likely to introduce product innovations. Absorptive capacity asssociated with human capital stock of the firm has long been identified in the literature as important for innovation (Griliches, 1998, Romer, 1990; Hong *et al.*, 2012). However, the marginal effect of the human capital measure employed in this paper is weak and only significant at the 10 per cent level. Domestic firms are more likely to introduce product and service innovations. Smaller manufacturing firms relative to larger manufacturing firms are more likely to discontinue products and manufacturing firms with a greater spending on capital investment are more likely to discontinue products. However, service firms with a greater spending on capital investment are less likely to discontinue services. Firms with a greater degree of monopoly power also matters: both manufacturing and service firms with more monopoly power are more likely to innovate and manufacturing firms with more market power are less likely to discontinue products. This latter results goes against the predictions of Arrow (1962) who hypothesised that competition will encourage innovation. In turn, Schumpter (1942) argued that firms in monopolistic positions are more likely to innovate as they have the essential resources required to invest in innovation. Perhaps, Schumpter's ideas may be stretched to explaining the fact that manufacturing firms are less likely to discontinue products because their resources enable them to produce products less susceptible to market challenges from competitors. The latter results on firm size, capital investment and monopoly power on product discontinuation are new to the literature with no other study previously conducted in the literature that focuses on explaining what type of firms discontinue products/services.

5. CONCLUSION AND DISCUSSION

The purpose of this paper was to explore PLC and SLC patterns using product/service innovation and product/service discontinuation in a structural production function approach at the firm level. The majority of PLC studies have focused on examining patterns at the industry level (Agarwal and Gort, 1996, Agarwal and Audretsch, 2001, Audretsch and Mahmood, 1995). The focus at the firm level in this respect and in particular on the examination of the destructive element of Schumpeter's (1942) creative destruction concept and a focus on service life cycles is novel to the literature. In this paper, an extended version of the innovation value chain by Roper *et al.* (2008) was explored that included a disruptive stage and examined Schumpeter's (1942) idea of creative destruction. The study took a snapshot of a cross-sectional sample of firms to analyse the factors that affected product origin and product death in firms. A key aspect was to explore whether there was a creative destruction effect where products/services were discontinued as a result of new product/service creations. Innovation was found to have a significant and positive effect on product discontinuation for both manufacturing and service firms. Hence, there appears to be an evolutionary replacement effect in the portfolio of products/services at the firm level. This is an important finding since discontinuing products/services is as natural to the firm as creating products/services. Hence, from the perspective of the firm - the event of a product/service being discontinued does not necessarily mean the firm will not survive. In fact, 23 per cent of manufacturing firms and 11 per cent of service firms in this sample discontinued a product/service in the previous three years from when the survey was taken and they were still in operation.

In the literature, product innovation has also been identified in some studies as having a negative effect on productivity (Raffo *et al.*, 2008 for Argentinian firms and Duguet, 2006 for incremental innovation). It has been hypothesised that these negative effects are a result of time lags due to learning effects (Mohnen and Hall, 2013) or perhaps as a result of natural product life cycle disruptions (Roper et al., 2008). Given that innovation is found in this study to have a positive effect on discontinuing products/services, it is likely that this may have a displacement effect within the firm resulting in the short term negative effects that are being identified in the literature between innovation and productivity in firms.

This study identified that firm age was more significant at the beginning of the PLC for manufacturing firms and was significant at the beginning and end of the SLC for service firms. The adaptability of the firm to changing market conditions is assumed first to increase and then decrease with age (Agarwal and Gort, 1996). Indeed, younger firms were identified as being more likely to innovate suggesting that they are more adaptable to changing market conditions. But, older firms appear to be more dominant in SLC's and older manufacturing firms in more technologically intensive industries are more likely to innovate relative to older firms in low technology intensive industries. This result implies that firms in low technology intensive industries are less resilient to changing market conditions than their counterparts in low-medium or medium-high technologically intensive industries.

The rise of a dominant standard design over the PLC/SLC does not appear to hold either. Process innovation was found to have a significant effect at the beginning of the PLC. Hence, firms do not appear to be just focusing on the tastes and preferences of firms and later focusing on just process innovation. Process innovation is a compliment to product and service innovation which goes against the PLC theoretical literature (Klepper, 1996; Utterback and Abernathy, 1975) and this finding is further supported by previous empirical findings (Freeman and Soete, 1997; Doran, 2012; Mohnen and Hall, 2013). However, it should be noted that firms may be producing more than one product at a time and hence the association being identified between product/service innovation and process innovation may be complicated by the scale of production within the firm of various products/services.

This last point brings the discussion to remarks on the data constraints of this study and future research suggestions. Firstly, manufacturing firms in the low technological category were more likely to introduce innovations relative to the other higher technological categories. It is expected that there would be a correlation and causation between innovation and higher technological intensive firms. It is plausible that this finding is a result of the broad measure of product innovation used within the study. Hence, it is suggested that future research should distinguish between new to market and new to firm innovation. Also given the point raised at the conclusion of the previous paragraph the relevance of these new innovations to the overall production capacity of products within the firm should be identified and the links between different product innovations and their requirements for different process innovations. Similarly, if this approach was applied at the end of the PLC/SLC to the discontinuation of products/services and process innovations – greater clarity would emerge from our understandings of PLC/SLC patterns and the relative importance of innovation, firm age and process innovations in explaining the underlying patterns that emerge.

As this study importantly points out, SLC's and PLC's have similar patterns where innovation was significant for product/service discontinuation and process innovation was found to be important for innovations. Similarly monopoly power was important for innovation in both industry types. However, there were also some underlying differences particularly in relation to firm age and economic geography effects. It is not appropriate to assume that the process of innovation in manufacturing firms will be identical to the process of innovation in service firms. Further, an assimilation view of the process of innovation in service firms was taken in this study. However, as Coombes and Miles (2000) point out, modifications to conventional surveys and other instruments for measuring innovation in service firms that take into account the non-technical characteristics of services such as their intangibility and involvement of human capital and client interaction are required.

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Table 1: Variable Descriptions

Dependent variables – innovation and discontinuation indicators	
Product	=1 if the firm 'developed successfully a major new product line or service over the last 3 years and if the firm upgraded an existing product line or service over the last 3 years', 0 otherwise.
Discontinued product	=1 if firm has 'discontinued a major new product line or service over the last 3 years', 0 otherwise.
Independent variables	
Firm Indicators	
Research and development	Positive spending on R&D including wages and salaries of R&D personnel, R&D materials, R&D education and R&D related training divided by the number of full time employees in 2003.
Process	=1 if the firm 'acquired a new production technology in the last 36 months' and/or if the firm has had a major reallocation or completely new organisational structure, 0 otherwise.
Age of firm in year surveyed	Years since firm first began operations in this country.
Log of Employment (Size)	How many full-time employees did your business have three years ago?
Small Firm	=1 if the firm has 2-49 employees, 0 otherwise.
Medium Firm	=1 if the firm has 50-249 employees, 0 otherwise
Large Firm	=1 if the firm has 250-9999 employees, 0 otherwise.
Capital intensity	Positive spending on new buildings, machinery and equipment divided by the number of full time employees in surveyed year.
Education Category (%)	What percentage of the workforce have a third level qualification?
Professional (%)	What percentage of the workforce are in the professional category?
Training (%)	What percentage of your staff receive training?
Percentage of Exports	What percentage of the firms main product are exported?
Domestic	=1 if majority of firm is Irish owned (greater than 50 per cent), 0 otherwise
Part of multi plant group	=1 if the firm has many establishments (separate operating facilities) in this country, 0 othewise.
Location and Markets	
Capital	=1 if firm is located in a Capital City, 0 otherwise.
City pop 250k-1million	=1 if firm is located in a city with a population between 250k-1 million, 0 otherwise.
City pop 50k-250k	=1 if firm is located in an urban area with a population between 50k-250k million, 0 otherwise.
City pop less than 50k	=1 if firm is located in a village or town with a population of less than 50k, 0 otherwise.
Sector Indicators	
Low tech	=1 if the firm is categorised as low tech by the OECD, 0 otherwise.
Low to medium tech	=1 if the firm is categorised as low to medium tech by the OECD, 0 otherwise.
Medium to high tech	=1 if the firm is categorised as medium to high tech by the OECD, 0 otherwise.
High tech	=1 if the firm is categorised as high tech by the OECD, 0 otherwise
Monopoly Power	=1 if the firm raised its price by 10% and customers would continue to buy from them at the same quantities or slightly lower quantities, 0 if customers would continue to buy at much lower quantities or or from other competitors instead.
Other Measures	
Pressure from domestic competitors	=1 if pressure from domestic competitors was fairly important or very important for product/service or process innovation, 0 otherwise.

Table 1: Continued

Pressure from foreign competitors	=1 if pressure from foreign competitors was fairly important or very important for product/service or process innovation, 0 otherwise
Pressure from customers	=1 if pressure from customers was fairly important or very important for product/service or process innovation, 0 otherwise.
Subsidies	=1 if the firm over the last 36 months has received subsidies from European Union/regional or local sources, 0 otherwise.
<u>Country</u>	
Germany	=1 if the firm is located in Germany, 0 otherwise.
Spain	=1 if the firm is located in Spain, 0 otherwise.
Ireland	=1 if the firm is located in Ireland, 0 otherwise.
Greece	=1 if the firm is located in Greece, 0 otherwise.
Portugal	=1 if the firm is located in Portugal, 0 otherwise.
Slovenia	=1 if the firm is located in Slovenia, 0 otherwise.

Source: Business Environment and Enterprise Performance Survey 2005

Table 2: NACE REV.2 Technology Intensity Definition

MANUFACTURING

Low technology Industries

Manufacture of furniture; wood and of products of wood, paper and paper products; printing and reproduction of recorded media (excluding 18.2); Food products, beverages and tobacco, textiles, wearing apparel, leather and related products.

Medium-Low technology industries

Building and repairing of ships and boats; repair and installation of machinery and equipment; manufacture of rubber and plastics products, other non-metallic mineral products and basic metals; fabricated metal products (except machinery and equipment and weapons and ammunition); coke, refined petroleum products; reproduction of recorded media (18.2).

Medium-High technology industries

Manufacture of chemicals and chemical products (excluding pharmaceuticals); weapons and ammunition; machinery and equipment, n.e.c.; motor vehicles; trailers and semi trailers; other transport equipment (excluding ships, boats, air and spacecraft and related machinery); medical and dental instruments and supplies.

High technology industries

Manufacture of Aircraft and spacecraft and related machinery; basic pharmaceuticals products and pharmaceutical preparation; computer, electronic and optical products.

SERVICES

Knowledge Intensive Services

Water transport, air transport; publishing activities, motion picture, video and television programme production, sound recording and music publishing activities, programming and broadcasting activities, telecommunications, computer programming, consultancy and related activities, information service activities; financial and insurance activities; legal and accounting activities, activities of head offices; management consultancy activities, architectural and engineering activities; technical testing and analysis, scientific research and development, advertising and market research, other professional, scientific and technical activities, veterinary activities; employment activities; security and investigation activities; Public administration and defence, compulsory social security, education, human health and social network activities, arts, entertainment and recreation.

Less Knowledge Intensive Services

Wholesale and retail trade; repair of motor vehicles and motorcycles; land transport and transport via pipelines; warehousing and support activities for transportation, postal and courier activities; accommodation and food service activities; real estate activities and leasing activities; travel agency, tour operator reservation service and related activities; services to buildings and landscape activities; office administrative, office support and other business support activities; activities of membership organisations, repair of computers and personal and household goods, other personal service activities; activities of households as employers of domestic personnel; undifferentiated goods – and services – producing activities of private households for own use, activities of extraterritorial organisations and bodies.

Source: Eurostat Indicators of High Tech Industry and Knowledge Intensive Services, January, 2014.

Table 3: Descriptive Statistics of Continuous and Binary Variables for Manufacturing

Variables	Mean	Std. Dev.	Min	Max
Continuous Variables				
Log of R&D per Worker	1.44	4.88	-8.18	11.91
Full Time Employees	159.25	484.86	1	6300
Age of the Firm	27.19	23.61	4	180
Log of Capital Investment	6.055	4.04	-8.18	13.81
% of Professional Workers	7.635	13.33	0	100
% of Staff Receiving Training	20.86	29.73	0	100
% of Staff with a University Education	17.52	25.62	0	100
Binary Variables				
Discontinued a product (%)	23.25	42.27	0	1
Product (%)	65.18	47.67	0	1
Process (%)	65.62	47.52	0	1
Small Sized Firms (%)	60.00	49.03	0	1
Medium Sized Firms (%)	22.22	41.60	0	1
Large Sized Firms (%)	17.77	38.26	0	1
Low Tech Firms (%)	56.14	49.65	0	1
Low to Medium Tech Firms (%)	18.07	38.50	0	1
Medium to High Tech Firms (%)	25.78	43.77	0	1
Monopoly Power (%)	38.52	48.69	0	1
Domestic Firms (%)	85.62	35.10	0	1
Multi-plant Firms (%)	25.18	43.43	0	1
National Subsidies (%)	11.26	31.63	0	1
Regional Subsidies (%)	9.92	29.92	0	1
EU subsidies (%)	7.25	25.96	0	1
Capital City (%)	15.40	36.12	0	1
City with population 250k to 1 million (%)	8.88	28.47	0	1
City with population 50k to 250k (%)	16.14	36.82	0	1
City with population under 50k (%)	56.59	49.60	0	1
Pressure from Domestic Competitors (%)	70.37	45.69	0	1
Pressure from Foreign Competitors (%)	52.14	49.99	0	1
Pressure from Customers (%)	81.33	38.99	0	1
Germany (%)	29.48	45.62	0	1
Spain (%)	15.85	36.54	0	1
Ireland (%)	22.37	41.70	0	1
Greece (%)	14.66	35.40	0	1
Slovenia (%)	7.25	25.96	0	1
Portugal (%)	10.37	30.51	0	1

Source: Business Environment and Enterprise Performance Survey 2005

Table 4: Descriptive Statistics of Continuous and Binary Variables for Services

Variables	Mean	Std. Dev.	Min	Max
Continuous Variables				
Log of R&D per Worker	-0.225	1.75	-2.33	6.65
Full Time Employees	57.31	336.23	1	8500
Age of the Firm	17.72	16.00	4	200
Log of Capital Investment	4.56	4.72	-8.26	12.87
% of Professional Workers	10.11	21.67	0	100
% of Staff Receiving Training	11.82	21.99	0	100
% of Staff with a University Education	11.89	23.97	0	100
Binary Variables				
Discontinued a product (%)	11.71	32.16	0	1
Product (%)	39.74	48.95	0	1
Process (%)	42.60	49.46	0	1
Small Sized Firms (%)	84.97	35.73	0	1
Medium Sized Firms (%)	9.24	28.97	0	1
Large Sized Firms (%)	5.77	23.33	0	1
Low Knowledge Intensive Firms (%)	36.72	48.21	0	1
High Knowledge Intensive Firms Firms (%)	63.28	48.22	0	1
Monopoly Power (%)	42.37	49.42	0	1
Domestic Firms (%)	92.21	26.81	0	1
Multi-plant Firms (%)	25.18	43.43	0	1
National Subsidies (%)	4.37	20.45	0	1
Regional Subsidies (%)	5.38	22.57	0	1
EU Subsidies (%)	2.35	15.16	0	1
Capital City (%)	21.35	40.99	0	1
City with population 250k to 1 million (%)	12.21	32.76	0	1
City with population 50k to 250k (%)	19.22	39.41	0	1
City with population under 50k (%)	42.37	49.42	0	1
Pressure from Domestic Competitors (%)	71.18	45.30	0	1
Pressure from Foreign Competitors (%)	28.53	45.17	0	1
Pressure from Customers (%)	75.44	43.05	0	1
Germany (%)	35.65	47.91	0	1
Spain (%)	17.66	38.14	0	1
Ireland (%)	13.45	34.13	0	1
Greece (%)	11.55	31.96	0	1
Slovenia (%)	5.33	22.46	0	1
Portugal (%)	16.37	37.00	0	1

Source: Business Environment and Enterprise Performance Survey 2005

Table 5: Descriptive Statistics of Selected Variables by Industry Type for Manufacturing

Variables	Low Tech	Low-Medium Tech	Medium Tech	High Tech
Product Innovation	59%	69%	76%	70%
Process Innovation	61%	69%	72%	75%
Discontinued Products	20%	21%	32%	25%
Large Firm	12%	23%	29%	23%
Mean Age of Firm	26	28	30	15

Source: Business Environment and Enterprise Performance Survey 2005

Table 6: Descriptive Statistics of Selected Variables by Industry Type for Services

Variables	Low Knowledge Intensive	High Knowledge Intensive
Product Innovation	37%	41%
Process Innovation	39%	48%
Discontinued Products	11%	12%
Large Firm	3%	7%
Mean Age of Firm	3	7

Source: Business Environment and Enterprise Performance Survey 2005

Table 7: Drivers of Product Innovation and Discontinuation for Manufacturing Firms.

	INNOVATION	*DISCONTINUATION*
Independent Variables		
Firm Characteristics		
Innovation effort	0.0713***	-
	(0.017)	-
Innovation	**-**	**0.536*** **
	-	**(0.121)**
Process Innovation	**0.273*** **	**-0.015**
	(0.045)	**(0.052)**
Log of Capital per worker	0.008*	0.011**
	(0.005)	(0.005)
Professional (%)	0.002	-
	(0.002)	-
Training (%)	0.002*	-
	(0.01)	-
University education	-	0.000
	-	(0.001)
Log of full time employees (2003)	-	-0.002
	-	(0.014)
Small Firm	0.068	-
`	(0.109)	-
Medium Firm	-0.017	-
	(0.086)	-
Age of the firm	**-0.002** **	**-0.000**
	(0.001)	**(0.001)**
Low-Medium Tech	**-0.198** **	**-0.052**
	(0.095)	**(0.058)**
Medium-High Tech	**-0.194***	**0.0200**
	(0.104)	**(0.066)**
High-Tech	**-0.423**	**0.106**
	(0.243)	**(0.219)**
Age*L/M Tech	**0.007*** **	**0.001**
	(0.003)	**(0.001)**
Age*M/H Tech	**0.007** **	**-0.000**
	(0.003)	**(0.001)**
Age*High Tech	**0.013**	**-0.007**
	(0.009)	**(0.007)**
Domestic	0.123*	-0.029
	(0.080)	(0.050)
Part of multi-plant	0.027	-0.041
	(0.052)	(0.036)
Monopoly Power	**0.083** **	**-0.097** **
	(0.041)	**(0.032)**
Location and Markets		
City pop 250k-1m	**-0.120**	**-0.051**
	(0.096)	**(0.061)**
City pop 50k-250k	**-0.094**	**0.098***
	(0.076)	**(0.064)**
City under 50K	**0.011**	**-0.013**
	(0.058)	**(0.045)**
No of Observations	*675*	675
LR Chi^2	263.37	120.69
	(0.000)	(0.000)

Log Likelihood	-304.56	-305.76

Notes

1. The above model reports marginal effects.
2. The Innovation predictor is instrumented by predicted values from the knowledge production function (new products)
3. The reference categories are low tech industries in each of the industry analyses (interaction variables), capital city and large firms.
4. Significant at 1 per cent level is ***, significant at the 5 per cent level is ** and significant at the 10 per cent level is *.
5. This model is significant where Prob>chi^2 = 0.000
6. Country dummy and subsidies are not reported.
7. Interaction effect for age and technology sectors follows INTEFF command as proposed by Norton *et al.* (2004)

Table 8: Drivers of Product Innovation and Discontinuation for Service Firms.

	INNOVATION	*DISCONTINUATION*
Independent Variables		
Firm Characteristics		
Innovation effort	0.032***	-
	(0.013)	-
Innovation	**-**	**0.316*** **
	-	**(0.061)**
Process Innovation	**0.289*** **	**0.005**
	(0.026)	**(0.023)**
Log of Capital per worker	0.009***	-0.003*
	(0.003)	(0.001)
Professional (%)	0.001	-
	(0.001)	-
Training (%)	0.001	-
	(0.01)	-
University education	-	0.000
	-	(0.000)
Log of full time employees (2003)	-	0.002
	-	(0.005)
Small Firm	0.056	-
`	(0.072)	-
Medium Firm	0.036	-
	(0.072)	-
Age of the firm	**0.002***	**-0.002****
	(0.001)	**(0.001)**
High Knowledge Intensive (HKI)	**-0.017**	**-0.009**
	(0.041)	**(0.021)**
Age*HKI	**-0.002**	**0.000**
	(0.002)	**(0.001)**
Domestic	0.137***	0.027
	(0.043)	(0.021)
Part of multi-plant	0.014	-0.003
	(0.034)	(0.016)
Monopoly Power	**0.071*** **	**-0.018**
	(0.026)	**(0.013)**
Location and Markets		
City pop 250k-1m	**-0.043**	**-0.021**
	(0.044)	**(0.019)**
City pop 50k-250k	**-0.067***	**-0.011**
	(0.037)	**(0.018)**
City under 50K	**-0.066****	**-0.007**
	(0.033)	**(0.016)**
No of Observations	*1784*	1784
LR Chi^2	457.04	259.43
	(0.000)	(0.000)
Log Likelihood	-970.24	-514.69

Notes

1. The above model reports marginal effects.
2. The Innovation predictor is instrumented by predicted values from the knowledge production function (new products)
3. The reference categories are low knowledge intensive services in each of the industry analyses (interaction variables), capital city and large firms.

4. Significant at 1 per cent level is ***, significant at the 5 per cent level is ** and significant at the 10 per cent level is *.
5. This model is significant where Prob>chi^2 = 0.000
6. Country dummy and subsidies are not reported.
7. Interaction effect for age and technology sectors follows INTEFF command as proposed by Norton *et al.* (2004)

Figures for Norton *et al.* Interaction Effect INTEFF command

Figure 1: Results of Marginal Effects for Low-Medium Tech Firms*Age for Product Innovation

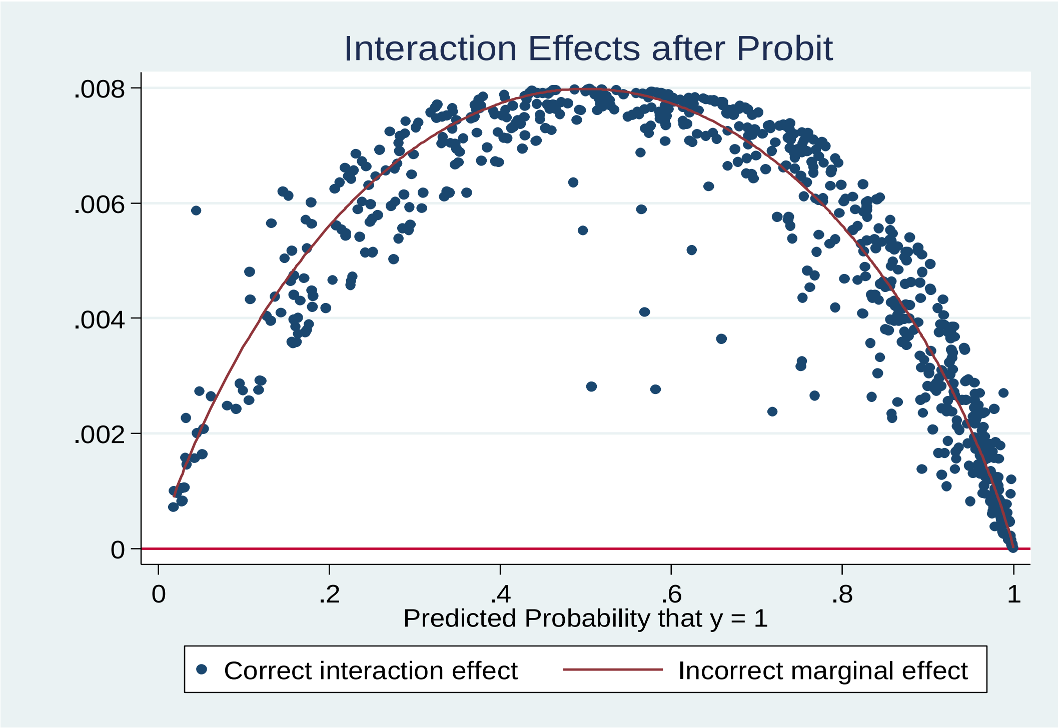

Figure 2: Result of Z statistic of Marginal Effects for Low-Medium Tech Firms*Age for Product Innovation.

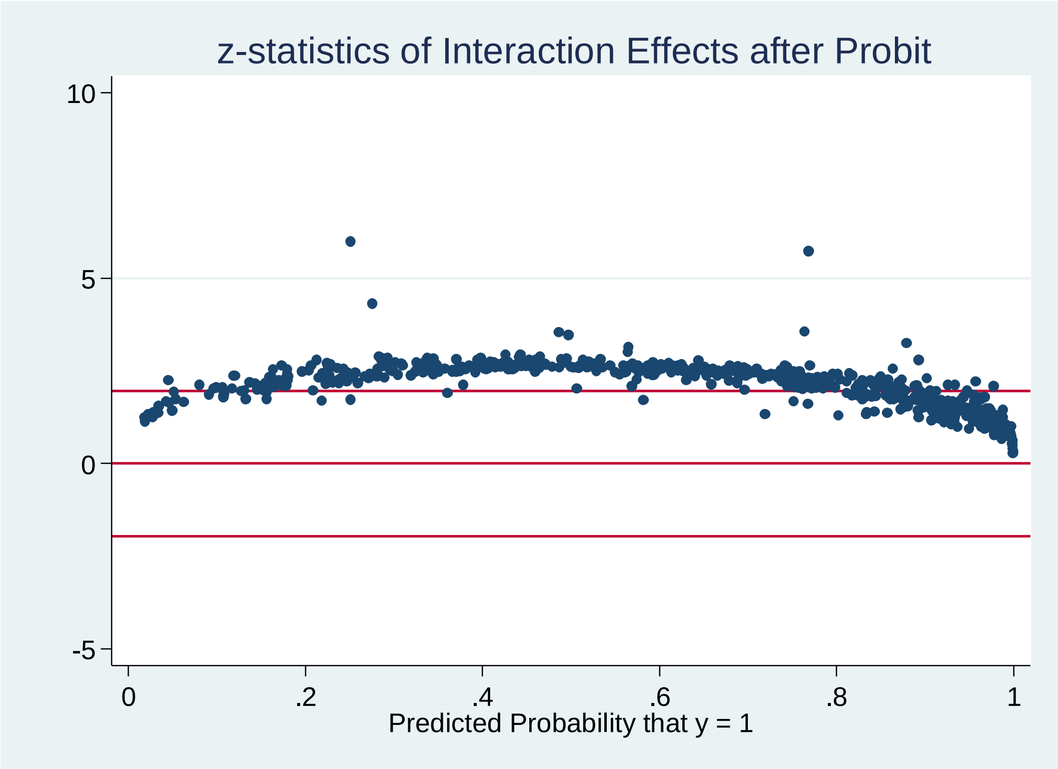

Figure 3: Result of Marginal Effects for Medium-High Tech Firms*Age for Product Innovation

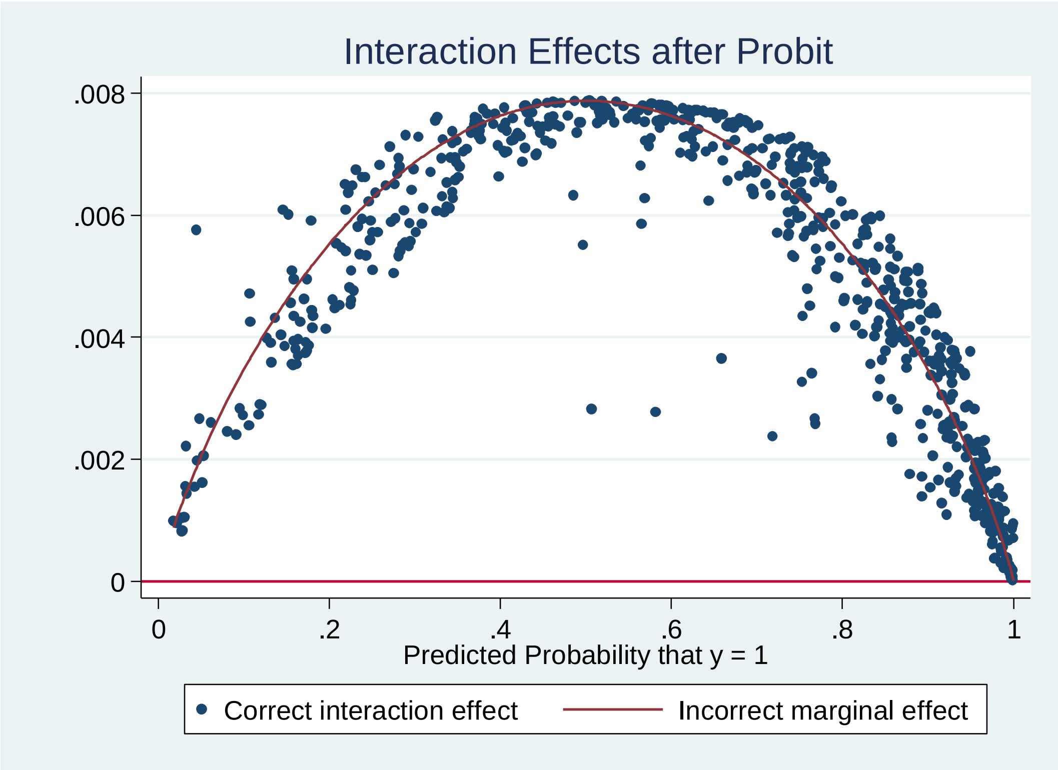

Figure 4: Result of Z statistic for Marginal Effects for Medium-High Tech Firms*Age for Product Innovation

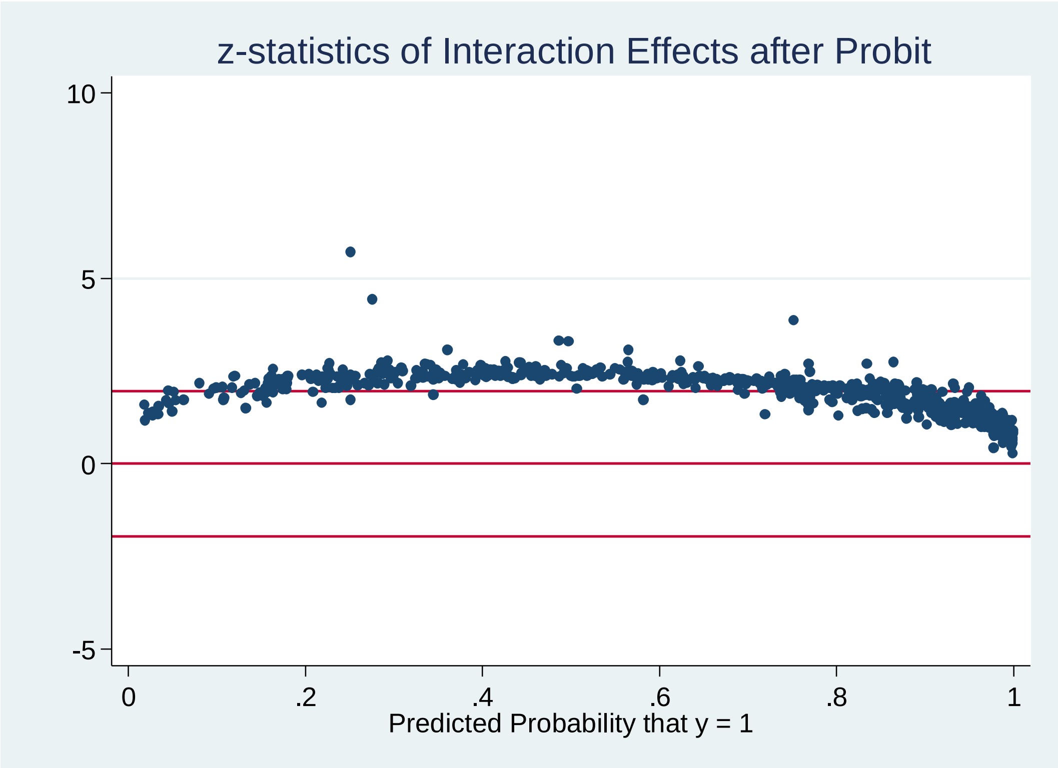

Figure 5: Results of Marginal Effects for Low-Medium Tech Firms*Age for Discontinued Products

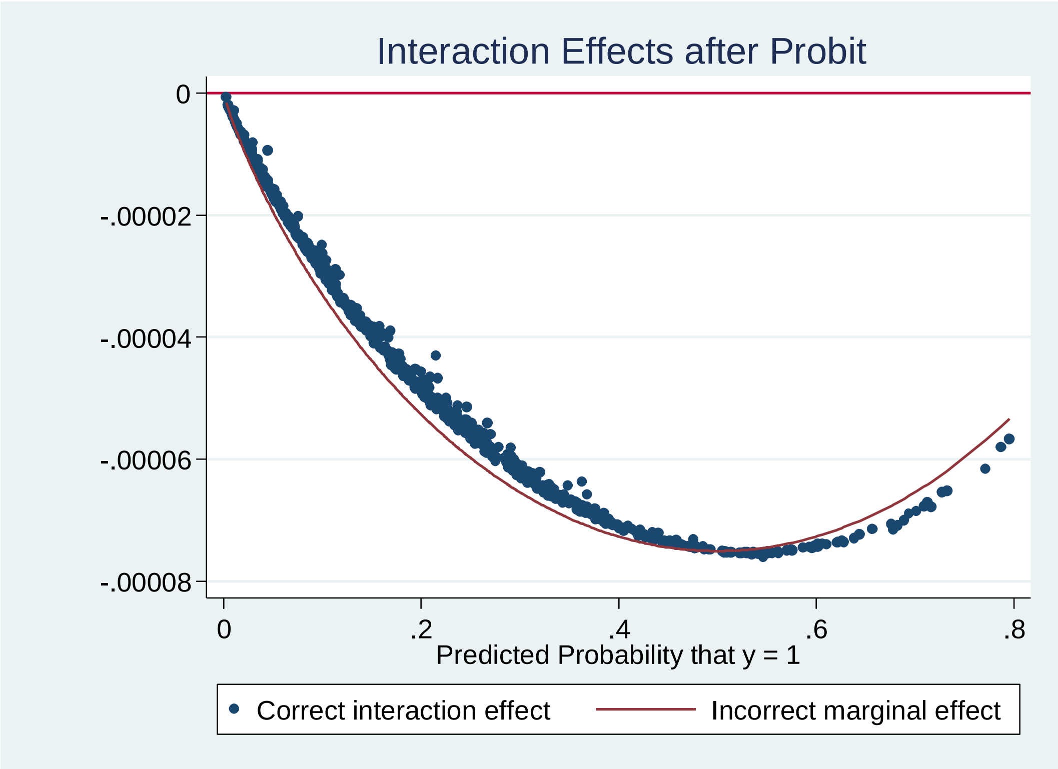

Figure 6: Result of Z statistic of Marginal Effects for Low-Medium Tech Firms*Age for Discontinued Products

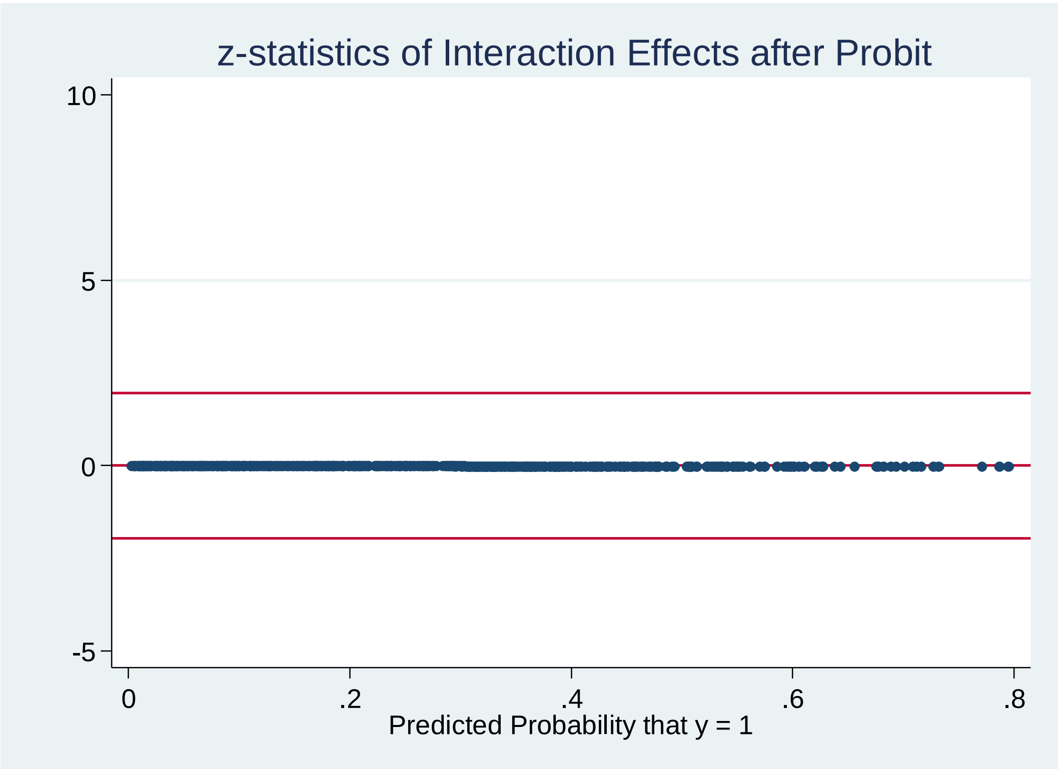

Figure 7: Result of Marginal Effects for Medium-High Tech Firms*Age for Discontinued Products

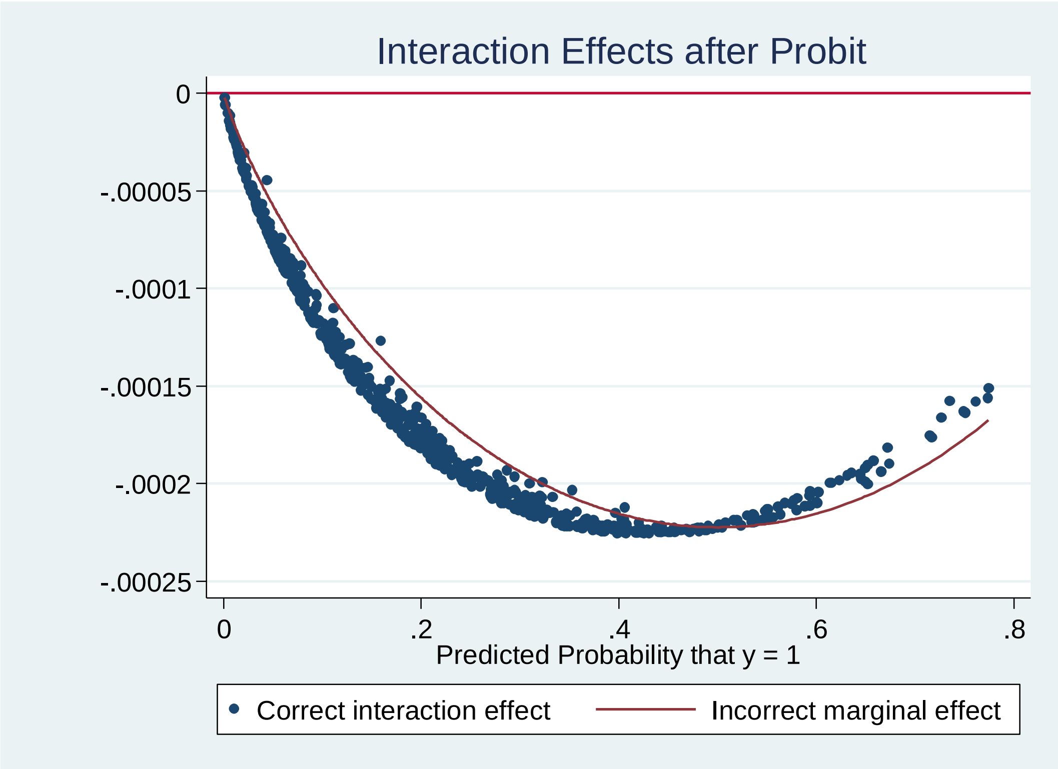

Figure 8: Result of Z statistic for Marginal Effects for Medium-High Tech Firms*Age for Discontinued Products

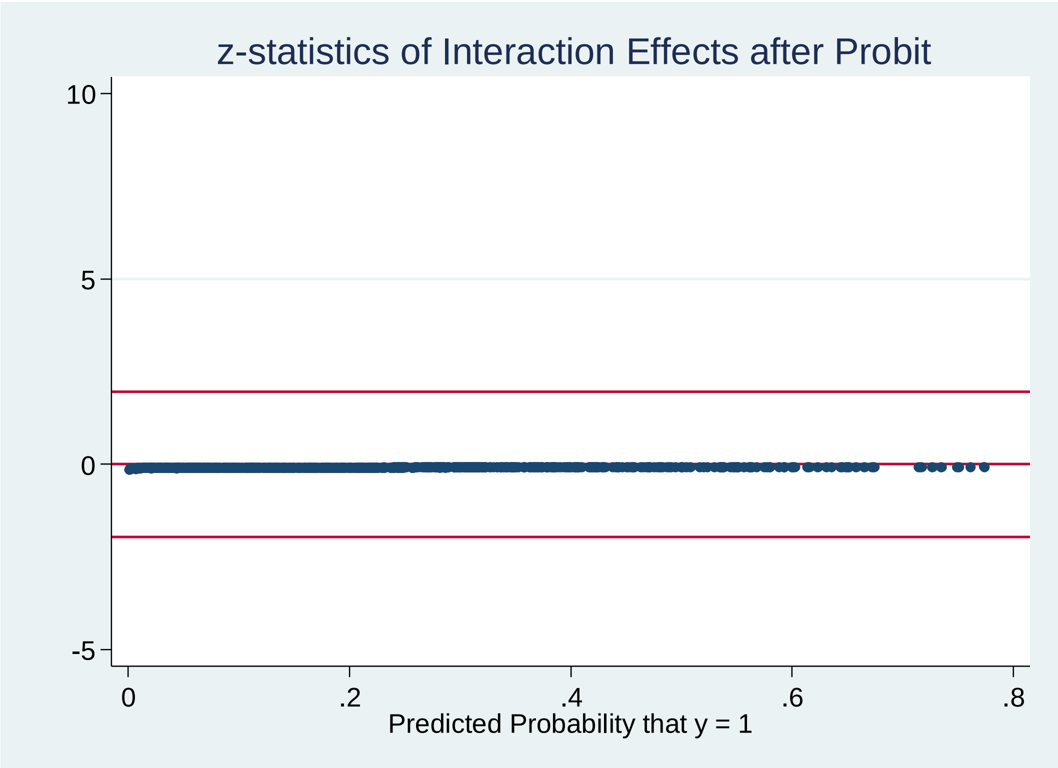

Figure 9: Result of Marginal Effects for High Knowledge Intensive Firms*Age for Product Innovation

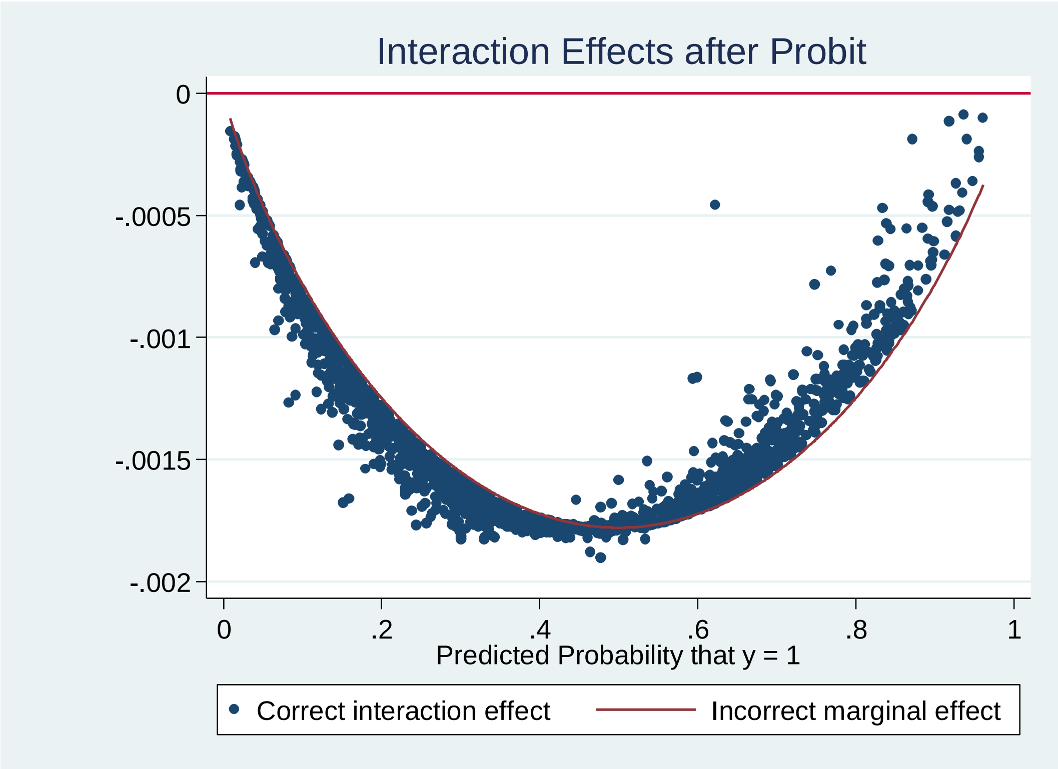

Figure 10: Result of Z statistic for Marginal Effects for High Knowledge Intensive Firms*Age for Product Innovation

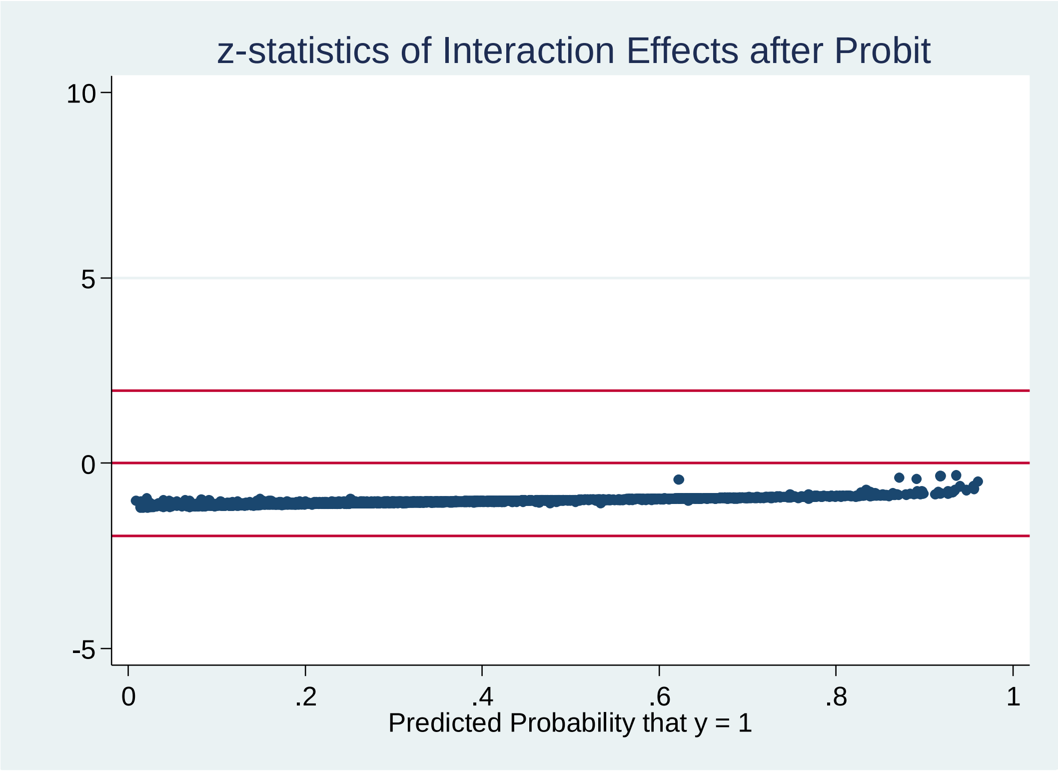

Figure 9: Result of Marginal Effects for High Knowledge Intensive Firms*Age for Discontinued Product

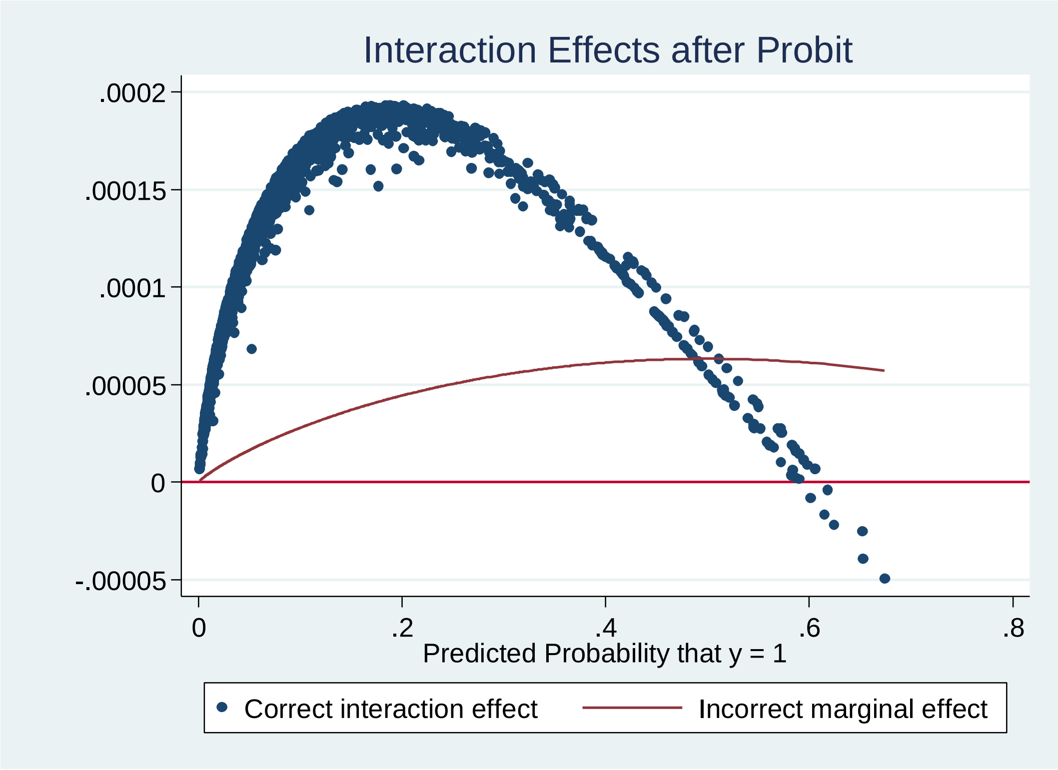

Figure 10: Result of Z statistic for Marginal Effects for High Knowledge Intensive Firms*Age for Discontinued Product