Predicting the Introduction of New Technologies in the UK: the role of ICT investment and Innovation Spillovers

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Note

We would like to thank the data owner, the ONS, and the UK Data Service at the UK Data Archive; however the use of these data does not imply the endorsement of the data owner or the UK Data Service at the UK Data Archive in relation to the interpretation or analysis of the data.

This work uses research datasets which may not exactly reproduce National Statistics aggregates.

INTRODUCTION

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- We study the micro-evidence on innovation activity in the UK.
- Main research question is to assess whether, and how, investments in innovation activities and ICT not only affect the investing firm, **the internal effects**, but also generate knowledge spillovers affecting the innovation performance of other firms, the **external effects** for the introduction of
  - product,
  - process and
  - organizational innovations

Four Group of variables

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- This analysis is based four groups of variables
- investment in ICT, intangibles and innovation activities;
- introduction of innovation outcomes;
- firm characteristics, behaviour, motivations and cooperation relations; and
- knowledge spillovers, based on proximity in both geographic and production spaces.

DATA SOURCES-CIS

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- The Community Innovation Survey (CIS) provides the main source of information on business innovation in the UK. It is a voluntary postal survey carried out every two years covering both the production and the service sectors.
- Our data are derived from four releases of the CIS:
- CIS 4, which covers the period 2002-2004. 16,445 enterprises provided valid responses
- CIS 5 (period 2004-2006) consists of 14,872 responses
- CIS 6, which covers the period 2006-2008, 14,281 enterprises;
- CIS 7 covers the period 2008-2010 and includes data from 14,342 enterprises.

DATA SOURCES-ARD

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- Annual Respondents Database (ARD) is one of the most comprehensive surveys undertaken of business organisations in the UK, covering over 100 key economic variables, and approximately two-thirds of the UK economy.
- It is a census of large businesses, and a stratified sample of small and medium sized enterprises.
- Detailed variables for turnover, employment, costs, capital expenditures and the derivation of sales and profits are included.

DATA SOURCES-BERD

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- The Business Expenditure on Research and Development (BERD) is an annual survey providing information on Research and Development expenditure in the UK
- As the BERD data are collected annually and over larger samples, we used the BERD data to construct total annual measures of R&D expenditure, aggregated either at the sectorial level or at geographical level.
- Such data was used to construct measures of sectorial spillovers, as well as area spillovers for the R&D investment.

THE VARIABLES: INTANGIBLES

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- Internal R&D: defined as creative work within a firm to increase the stock of knowledge and its use to devise new and improved goods, services and processes;
- External R&D: the same activities, but purchased by the firm and performed by other companies
- Training: internal or external training for a firm's personnel specifically for the development and/or introduction of innovations; and
- ICT: the expenditure a firm invests on acquisition of advanced machinery, computer hardware and software for innovation

THE VARIABLES: GEOGRAPHIC SPILLOVERS

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- R&D and Training activity Geographic spillovers:
  - R&D and Training performed both in the same *Travel to work area*, (based on the radius of commuting to work patterns) and in the other 243 United Kingdom *Travel to work areas*.
  - This variable captures Marshallian knowledge externalities. The weights used are inversely proportional to the distance between areas.
- Local ICT expenditure Spillovers
  - ICT expenditure, external to the firm, but in the same TTWA

THE VARIABLES: SECTOR SPILLOVERS

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- Trade mediated spillovers:
- The R&D activity performed both in the same sector where a firm is operating and in the others.
- The effects of each sector's activity on a firm are weighted according to the inter-sector trades.
- They capture the effects of production specific knowledge externalities the Jacobian externalities
- We divided these spillovers into
  - R&D spillovers arising outside the ICT Sector
  - R&D sector spillovers arising inside the ICT Sector

THE FINAL OUTCOMES OF THE INNOVATION ACTIVITIES

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1. Goods or Services Innovation: new or significantly improved goods or services.
2. Process Innovation: new, or significantly improved, methods of the production or supply of goods or services.
3. Organizational innovations: new business practices, methods of organising work responsibilities and decision making, of organising external relationships with other firms or public institutions.

THE ECONOMETRIC MODEL

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The model is uses two stages of estimation:

1. **first stage**, four separate Tobit, one per type of intangible innovation activities.
2. **second stage** utilises the predicted values obtained from the first stage estimation, together with more covariates, for predicting , via a multi-Probit model, the outcomes of a firm's three possible innovation outcomes: product, process and organizational innovations.

THE MODEL SEQUENCE

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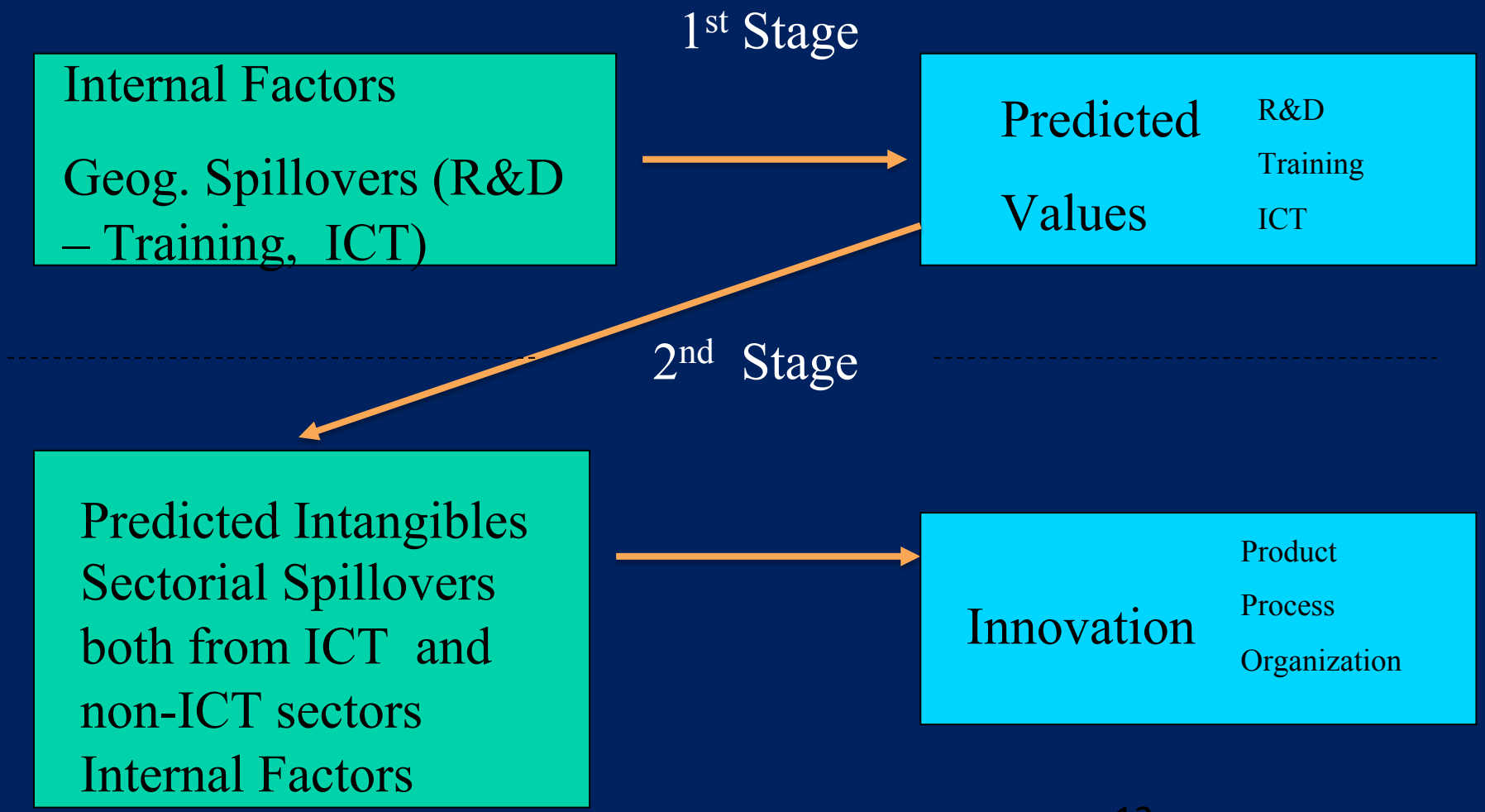

Related Literature

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- Focus on how to interpret causal relationships, as investment in ICT may at the same time be both cause and effect of economic growth.
- We deal with this endogeneity issue, due to simultaneity, of the possible direction of causality using a two stage approach.
- In the first stage with estimate "predicted Values" for ICT and Innovations intangibles and in the second stage we use these values to estimate their effects on the probability of introducing different innovation typologies.
- An alternative route has been to replace ICT variables by time-delayed ones, See Bloom et al., 2010, Brynjolfsson and Hitt, 1995, Hempell, 2005b, Tambe, 2011.
- Koutroumpis, 2009 and Röller and Waverman, 2001 also estimated structural models to separate these different effects through a simultaneous equation approach.
- Czernich et al., 2011 proposed a particularly interesting two stage approach by first estimating broadband penetration through a logistic diffusion equation and then using these predicted values as independent variables in the second stage assessing productivity growth ().

ESTIMATES OF THE 2nd STAGE: R&D and ICT

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- Predicted R&D positive with product + process innovations.
- Predicted training positive with organizational innovations.
- Predicted ICT expenditure positive with all innovations
- R&D-not ICT Spillovers: positive to all
- R&D-from ICT Spillovers: positive on process + product

Second Stage Pooled estimation Predicted Innovation Outcomes CIS (2004-2010)	New or sig improved processes	Goods and/or service Innovation	Organizational Innovation
Independent Variables			
Pred. Tot.R&D exp/Sales	0.0179*	0.0505***	0.000219
	(1.66)	(3.91)	(0.03)
Pred. Training exp/Sales	0.0347	-0.0584	0.227***
	(0.54)	(-0.91)	(4.34)
Pred. ICT exp/Sales	0.357***	0.449***	0.107**
	(4.98)	(3.48)	(2.00)
Subsidies over turnover	0.0194**	0.0294***	0.00158
	(2.13)	(4.68)	(0.17)
Log Total Employment	0.152***	0.112***	0.221***
	(8.45)	(6.43)	(16.43)
R&D sector spill net of ICT Sector	0.0488***	0.0133*	0.0270***
	(6.21)	(1.73)	(4.02)
R&D sector spill from the ICT Sector	0.0152***	0.0107**	0.00351
Observations	23828		

ESTIMATES OF THE 2nd STAGE: Motivations

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- Improve products positive with process and product negative on organizational.
- Improve process positive for process and organizational
- Increase profits positive with process and product
- Meet regulation negative on process and product positive on organizational ones..

Second Stage Pooled estimation Predicted Innovation Outcomes CIS (2004-2010)	New or sig improved processes	Goods and/or service Innovation	Organizational Innovation
Independent Variables			
Motive: Better products	0.546***	0.714***	-0.144*
	(4.55)	(8.82)	(-1.68)
Motive: Better production	0.670***	0.0112	0.195***
	(7.26)	(0.16)	(2.66)
Motive: Improve Profit	0.325***	0.365***	0.0907
	(2.80)	(4.18)	(1.01)
Motive: Meet Regulation	-0.299***	-0.332***	0.226***
	(-4.26)	(-5.12)	(3.82)
Motive: Expansion	0.0377	0.407***	0.305***
	(0.53)	(6.09)	(5.10)
	(9.92)		
Observations	23828		

ESTIMATES OF THE 2nd STAGE: Cooperation

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- Cooperation with own group, customers and suppliers is positive for the introduction of all types of innovations.
- This shows that all forms of innovations are a component of an integrated value chain whereby cooperation with customers and suppliers plays a significant and positive role.

Second Stage Pooled estimation Predicted Innovation Outcomes CIS (2004-2010)	New or sig improved processes	Goods and/or service Innovation	Organizational Innovation
Independent Variables			
Coop - Group	0.140**	0.126*	0.238***
	(2.23)	(1.90)	(3.57)
Coop - Suppliers	0.287***	0.243***	0.150**
	(4.49)	(3.72)	(2.29)
Coop - Customers	0.195***	0.333***	0.244***
	(3.08)	(5.35)	(3.87)
Coop - Other firms	-0.0346	0.00140	-0.0548
	(-0.44)	(0.02)	(-0.69)
Coop - Consultants	0.0219	0.0115	0.216***
	(0.28)	(0.14)	(2.69)
Coop - Universities	0.108	-0.0824	0.00838
	(1.20)	(-0.91)	(0.09)
Coop - Government	-0.0884	-0.134	-0.0731
	(-0.92)	(-1.37)	(-0.77)
Observations	23828		

ESTIMATES OF THE 1st STAGE Motivation & Geogr. Spillovers

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- R&D Geographic Spillovers: positive with ICT and negative Training
- Local ICT Spillovers marginally positive on ICT
- Training Geogr Spillovers positive on training negative on ICT
- Improve products positive with Int. R&D and training
- Improve prod. process positive for training and ICT expenditure
- Increase profits positive with all
- Meet regulation positive for training

Dependent Variables	Internal R&D / over Turnover	External R&D / over Turnover	Training Expenditure / over Turnover	ICT Expenditure / over Turnover
Independent Variables				
Motive: Better products	0.571**	0.353	0.259***	0.0277
	(2.06)	(1.27)	(3.03)	(1.13)
Motive: Better production	-0.0266	0.0227	0.181***	0.0859***
	(-0.13)	(0.11)	(2.66)	(3.60)
Motive: Improve Profit	1.046***	0.790**	0.250***	0.0457*
	(2.99)	(2.25)	(3.22)	(1.83)
Motive: Meet Regulation	-0.0490	-0.0887	0.122**	0.00919
	(-0.21)	(-0.51)	(2.21)	(0.52)
Motive: Expansion	0.838***	0.115	-0.0196	-0.0140
	(4.79)	(0.52)	(-0.31)	(-0.39)
R&D Geog. Spillover	0.0101	0.0108	-0.0467***	0.0120**
	(0.19)	(0.25)	(-3.06)	(2.00)
Local ICT expenditure Spillovers	-0.000621	-0.000174	0.000123	0.000117*
	(-1.47)	(-0.35)	(0.98)	(1.94)
Training Geog. Spillover	0.00525	-0.0205	0.0400**	-0.0169***
	(0.08)	(-0.42)	(2.41)	(-2.68)

ESTIMATES OF THE 1st STAGE Cooperation

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- Within Group has positive with Int.& Ext R&D
- Suppliers positive for all intangibles
- Customers positive for Internal R&D
- Competitors Negative for R&D (both Int and Ext) and positive for training
- Consultants: positive with Int and Ext R&D Training
- Universities positive with Int. and Ext R&D
- Governmentnot significant

Dependent Variables	Internal R&D / over Turnover	External R&D / over Turnover	Training Expenditure / over Turnover	ICT Expenditure / over Turnover
Independent Variables				
Coop - Group	0.381**	0.373**	-0.00689	-0.0182
	(2.07)	(2.42)	(-0.12)	(-1.26)
Coop - Suppliers	0.471***	0.532***	0.179***	0.104***
	(2.84)	(3.70)	(3.35)	(4.79)
Coop - Customers	0.553***	-0.00475	-0.0200	-0.0185
	(3.42)	(-0.03)	(-0.39)	(-1.22)
Coop - Other firms	-0.857***	-0.436**	0.115*	0.00194
	(-3.10)	(-2.05)	(1.78)	(0.12)
Coop - Consultants	0.757***	1.063***	0.105*	0.00759
	(3.54)	(7.34)	(1.70)	(0.60)
Coop - Universities	1.153***	0.630***	0.108	0.0119
	(3.66)	(3.96)	(1.63)	(0.75)
Coop - Government	-0.148	0.0895	0.0448	0.0169
	(-0.54)	(0.40)	(0.56)	(0.68)
Subsidies over turnover	0.00615	-0.0653**	-0.00277	-0.000825
	(0.33)	(-2.04)	(-0.35)	(-0.34)
Observations	23845			
t statistics in parentheses				
	* p<0.10	** p<0.05	*** p<0.01	

CONCLUSIONS

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- The Direct Internal Effects of ICT and R&D
  - A firm's investment in ICT has a direct positive impact on the probability of introducing Process, Products and Organizational Innovations.
  - Also a firm's R&D has a direct positive impact but only on Process and Product innovations.
- The Direct Sector Spillovers of R&D on Innovation
  - Sector Spillovers of R&D both in the ICT sector and in all other Sectors increase the probability of introducing process and product innovations.
  - Non- ICT R&D spillovers are positive also for organizational innovations

CONCLUSIONS

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The Indirect External Spillovers Effects of R&D and ICT on Innovation

- Geographic Spillovers of R&D diffuse in space affecting positively other firms ICT expenditure, but reducing their training intensity.
- Local ICT expenditure spillovers display positive Marshallian externalities on ICT expenditure, within each TTWA
- Both these Spatial spillovers have an indirect positive effect on Innovation though their positive direct impact on ICT

CONCLUSIONS

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The Indirect External Spillovers Effects of Training on Innovation

- Geographic Spillovers of Training also diffuse in space positively affecting other firms training expenditure and negatively their ICT one.
- These training spillovers have the opposite effects of R&D Geographic spillovers.
- Their indirect positive effect is only positive for organizational innovations.

CONCLUSIONS

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Direct and indirect effects of cooperation on Innovation.

- Cooperation within the group, with Customers and Suppliers highlights the relevance of the value chain in facilitating, directly, the introduction of all types of innovations.
- Cooperation within the group, Customers and Suppliers also has an indirect effect by positive affecting, some of the drivers of innovation: In particular
  - Group is positive on R&D, Suppliers positive on all R&D, Training and ICT
  - Customers is positive on Internal R&D, Consultants positive on R&D and Training and Universities positive on R&D
  - Only Cooperation with competitors lowers R&D, but it also has a positive impact on training, generating an indirect negative impact on Process and Product Innovations and a positive one on organizational innovations.

Thanks

Anglia Ruskin University

- Thank you
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FOCUS ON SPILLOVERS

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Spillovers are flows of innovation knowledge that is useful to different aspects of a firm's innovative activity.

Main Problems

1. Their definition.
2. The metrics used to quantify them.
3. The modalities of their diffusion through the economy.
4. The analysis of the direct impact that they have on the receiving firms.
5. The indirect, strategic impact that spillovers have on the profitability of other firms.

FIRM CHARACTERISTICS AND RELATIONAL VARIABLES

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- Geographic location: Travel To Work Areas, based on workers' commuting patterns;
- The output markets: where a firm sells : Regional, National, EU or International;
- Cooperation in innovation activities:
  - within the same business group,
  - with suppliers,
  - customers,
  - competitors,
  - consultants or commercial labs, or private R&D institutes,
  - Universities and Government or public research institutes.

FIRM CHARACTERISTICS MOTIVATIONAL

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- Factors motivating the decision to innovate: these include:
  - better products,
  - better production,
  - improving profit,
  - meeting regulatory requirements and
  - market expansion.
- Turnover, productivity, employment, age and industrial sector: based on ARD and BERD
- Financial Support: from Regional, National or EU public funding sources

FINDINGS: THE 2nd STAGE: FROM INTANGIBLES TO INNOVATIONS

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- The dependent variables capture the (non mutually exclusive) probabilities of introducing a:
  1. process innovation,
  2. product innovation
  3. organizational innovation.
- Our focus is on the effects of the intangible innovation and ICT activities, on these probabilities of innovation outcomes.
- The predicted values of total R&D training and ICT intensities are inputs for a tri-variate innovation function.
- We also explore the effects that sector spillovers in R&D activities have on the probabilities of introducing innovations.
- We separate R&D spillovers from ICT and non ICT sectors

CONCLUSIONS

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Motivation direct and indirect effects on Innovation.

- Aiming for Better Products is a direct driver for the probability of introducing both product and process innovation (but reduces organizational ones). This motive also has indirect positive effects through its positive impact on Internal R&D and Training.
- Aiming at Better Production Processes also has positive direct effects on both process and organizational innovations, and indirect effects by positive affecting ICT and Training expenditure.
- The motivation of Increasing Profits, has a positive direct impact on Process and Product innovations, and indirect positive ones on all intangibles, R&D, training, and ICT.
- The reason of Meeting regulations has a negative direct impact on Product and Process Innovations but a positive one for the organizational ones. The Indirect effects confirm this role, as it only affects positively training then leading, again to organizational innovations.
- The motive of Expansion drives innovation in products and organizations, directly and indirectly, through Internal R&D, affects positively both process and product innovations.