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Article

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Economics and Business Letters

11(2), 53-69, 2022

Intensity of competition and firm innovative behavior

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Received: 12 July 2021
Revised: 3 December 2021
Accepted: 3 January 2022

Abstract

Using a novel firm-reported measure of the intensity of competition and two distinct forms of innovation (product and process) from the European Commission Flash Eurobarometer 433 dataset, this paper comprehensively identifies the impact of competitive pressure on firm innovation for four broad sectors of the economy. A logit model by innovation type is used to estimate the impact of the intensity of competition on the firm's decision to innovate. Firm reported intensity of competition is found to have a positive impact on product innovation. Significant heterogeneities exist in the impact of minor and major degrees of competition across innovation types and sectors supporting Arrow's (1962) perspective on this relationship.

Keywords: Innovation; Competition; Europe; Flash Eurobarometer
JEL Classification Codes: D4, D22, L1, L2, O31

1. Introduction

Innovation is a key driver of firm growth (Im et al., 2015). The determinants of firm innovation have been widely explored in the literature (Bhattacharya and Bloch, 2004; Roper et al., 2008). External competition has been found to encourage firms to reinvent their product/service market offerings or commercialise new ideas (Theeke, 2016). There is significant interest in the role of external competition as a driver of innovative behaviour (Tabacco, 2015; Lefouili, 2015; Im et al., 2015; Theeke, 2016; Cornett et al., 2019), but evidence predominantly focuses on product/service innovation (Cornett et al., 2019; Crowley and Jordan, 2017) rather than other distinct forms of innovation like process innovation (Gunday et al., 2011). Despite this, Lee et al. (2019) finds that process innovation positively influences product innovation within firms and Calvino (2019) finds that process innovation has a positive impact on the employment

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Citation: O'Leary, D., Doran, J., and Power, B. (2022) Intensity of competition and firm innovative behavior, *Economics and Business Letters,* 11(2), 53-69.

DOI: 10.17811/ebl.11.2.2022.53-69

ISSN: 2254-4380

growth of firms. By considering both product and process innovation, this paper significantly advances our knowledge of the competition-innovation relationship.

Theoretical perspectives differ on the nature of the relationship between competition and firm innovation (Im et al., 2015). Schumpeter (1943) suggests a negative relationship arguing that innovation is driven by large dominant firms to strengthen their market position and that there is less incentive for R&D activities if the rewards from commercialisation are eroded through competition. Hence, highly competitive markets breed less innovation. Earlier writers like Salop (1977), Dixit and Stiglitz (1977), Romer (1990) and Aghion and Howitt (1990) agreed that competition discouraged innovation. Contrastingly, Arrow (1962) suggests a positive relationship between competition and firm innovation maintaining that dominant firms have a financial incentive to preserve the status quo which innovation disrupts. According to this perspective, competitive pressure incentivises firms to engage in R&D and commercialise their ideas. Porter (1991) supports this view.

Empirical investigations of the relationship between competition and firm innovation have used industry level measures of competition (vis. Herfindahl Indexes) and firm level indicators of innovation performance (e.g. patents and R&D). This research frequently produces mixed findings. Im et al. (2015) and Aghion et al. (2005) found evidence for an inverted-U shaped relationship between competition and innovation. Separate studies by Negassi et al. (2019) and Beneito et al. (2017) support this finding across different industries. However, other studies find evidence for a U-shaped relationship (Cornett et al., 2019). Specifically, Cornett et al. (2019) find lower levels of industry competition are associated with decreasing levels of innovation as industry competition increases, but high levels of competition are associated with increasing levels of innovation as firms attempt to pull away from competitors. Though rare, some studies have found no evidence of a relationship between competition and innovation (Tabacco, 2015).

A key challenge when empirically testing this relation is the measurement of competition intensity as product market competition cannot be observed directly (Cornett et al., 2019). While other studies have used imperfect proxies such as the number of firms in the industry (Tirole, 1998), Lerner indexes (Aghion et al., 2005; Im et al., 2015) and industry concentration measures (Cornett et al., 2019; Gu, 2016; Aslan and Kumar, 2016), our empirical approach differs. Rather than assuming homogeneity in the effect of competition on firms within industries, we use a self-reported indicator of competitive intensity at the firm level to assess competition. Advantageously, this captures whether firms are actually experiencing competitive pressure and does not assume that all firms in a sector are facing the same level of competition. This firm-reported measure of competition has not been used, to the best of our knowledge, in previous studies to explore the competition-innovation relationship.

Empirical studies on this topic predominately focus on single sectors (Hombert and Matray, 2018; Hashmi, 2013). The Structure Conduct Performance paradigm expounded by Bain (1956) and modern approaches by Porter (2008) highlight how the intensity of competition varies for firms occupying different market positions, particularly given their different exposure to market forces (Wang et al., 2015). Additionally, the innovation behaviour of firms can vary across sectors due to heterogeneric sources of technological change throughout sectors (De Jong and Vermeulen, 2006). Doran and Jordan (2016) find that drivers of innovation differ across sectors and even specify that the 'pooling' of sectors together could potentially produce biased inferences. The empirical findings of Nylund et al. (2019) confirm sectoral differences exist in firm innovation behaviour. Thus, we explicitly model for variations in the impact of competitive pressure on innovative firm behaviour across four board sectors in the economy. Consequently, this assists in identifying the source of the contradictory findings to date masked in other studies.

Table 1. Definition of Variables and Descriptive Statistics.

Variable	Definition	N	Mean / %	Std Dev	Min	Max
Intensity of Competition						
Major Competition	=1 if the market being dominated by established competitors is a major problem; 0 otherwise.	12892	24.84%	n.a.	0	1
Minor Competition	=1 if the market being dominated by established competitors is a minor problem; 0 otherwise.	12892	36.95%	n.a.	0	1
No Competition	=1 if the market being dominated by established competitors is not a problem; 0 otherwise.	12892	38.22%	n.a.	0	1
Product Innovation	=1 if the firm introduced a new or significantly improved good or service innovation between 2013 and 2015; =0 otherwise.	12892	0.4061	0.4911	0	1
Process Innovation	=1 if the firm introduced a new or significantly improved process innovation between 2013 and 2015; =0 otherwise.	12892	0.3906	0.4879	0	1
R&D expenditure	=0 if 0% of turnover; =1 if less than 1% of turnover; =2 if between 1-5% of turnover; and =3 if more than 5% of turnover is invested into research and development activities.	12892	1.7131	1.0177	1	4
Size	The natural logarithm of the number of employees.	12892	2.6231	1.7139	0	11.1411
Group membership	=1 if a member of a group of companies under one parent company; =0 otherwise.	12892	0.2361	0.4247	0	1
Age						
Young firms	Established after 1st of January 2015; =0 otherwise.	12892	0.92%	n.a.	0	1
Established firms	Established between 1st of January 2010 and 1st of January 2015; =0 otherwise.	12892	12.64%	n.a.	0	1
Mature firms	Established before 1 January 2010; =0 otherwise.	12892	86.43%	n.a.	0	1

Sector						
Manufacturing (NACE code C)	Manufacturing (NACE code C).	12892	13.42%	n.a.	0	1
Retail (NACE code G)	Wholesale and retail trade; repair of motor vehicles and motorcycles (NACE code G).	12892	29.98%	n.a.	0	1
Services (NACE codes H to N)	H - Transporting and storage; I - Accommodation and food service activities; J - Information and communication; K - Financial and insurance activities; L - Real estate activities; M - Professional, scientific and technical activities; N - Administrative and support service activities.	12892	42.68%	n.a.	0	1
Industry (NACE codes D to F)	D - Electricity, gas, steam and air conditioning supply; E - Water supply, sewerage, waste management and remediation activities; F – Construction.	12892	13.92%	n.a.	0	1
Country	Country dummies were included for the following regions: Belgium (3.68%), Bulgaria (3.52%), Czech Rep. (3.54%), Denmark (3.35%), Germany (3.61%), Estonia (3.49%), Ireland (3.65%), Greece (3.73%), Spain (3.54%), France (3.72%), Croatia (3.67%), Italy (3.51%), Rep. of Cyprus (1.50%), Latvia (3.72%), Lithuania (3.58%), Luxembourg (1.34%), Hungary (3.64%), Malta (1.40%), Netherlands (3.71%), Austria (3.46%), Poland (3.58%), Portugal (3.51%), Romania (3.65%), Slovenia (3.57%), Slovakia (3.39%), Finland (3.73%), Sweden (3.68%), UK (3.38%), Switzerland (2.74%), and United States (3.40%).					

Source: European Commission (2016)

2. Data

We use the Flash Eurobarometer 433 survey which gathered data in 2016 on firms located in 28 EU countries including Switzerland and America to explore the relation between intense competition and forms of innovation (N=18,000). The modal number of observations per country was 500 with an associated minimum number of observations of 200. There were 500 observations on businesses in 20 of the 30 countries. Firms employing at least one person across manufacturing (13.4%), industry (30%), services (13.9%) and retail (46.7%) sectors were included. Micro (40.3%), small (34.4%), medium (19.9%) and large sized firms (5.5%) were represented in the sample defined in accordance with the EU SME definition of the firm (EC, 2016). Quota sampling methods were applied to ensure geographic and sectoral representativeness (see Bozic and Botric 2017; Grigorescu et al. 2020).

The data contains standard measures of two distinct forms of innovation over the period 2013 to 2015. Firms were asked to report whether they introduced new or significantly improved (i) goods or services, and (ii) processes[1]. The data contains a binary indicator for each innovation type j taking a value of '1' if the firm introduced an innovation over that period and '0' otherwise. These measures are similar to those adopted in other studies e.g. Doran and Ryan (2014) and Crowley and Jordan (2017). Our self-reported measure of the intensity of competition facing firms captures whether respondents perceived the "market [as being] dominated by established competitors" as (i) not a problem; (ii) a minor problem; or (iii) a major problem for the commercialisation of the company's goods or services. Our analysis distinguishes between the following four distinct sectors: manufacturing is defined as broad NACE Rev 2 code C; industry as NACE Rev 2 codes D to F; retail as code G; and services as codes H to N. Our model also controls for R&D, firm size, group membership and country. The definitions and descriptive statistics of our variables are displayed in Table 1. There is largely no difference in the proportions of firms engaging in the different types of innovation. About 40% of the firms surveyed engage in product and process innovation. Almost two fifths (38.2%) reported that the intensity of competition (e.g. market dominance by established players) was not a problem, while slightly less viewed it as being a minor problem (37%) in comparison to approximately a quarter of the firms surveyed who viewed it as a major problem (24.8%).

3. Methods

Equations (1) and (2) display the innovation production functions to be estimated. Equation (2) is an extended version of Equation (1) and includes interaction terms between our novel competition intensity indicators and our sectoral dummies to explore sectoral differences in competition intensity on innovation. Each equation is estimated separately for each innovation type j.

$$IO_{ji} = \alpha_0 + \alpha_1 ComMin_i + \alpha_2 ComMaj_i + \alpha_3 Sector_i + \alpha_4 Z_i + \varepsilon_i \tag{1}$$

$$IO_{ji} = \alpha_0 + \alpha_1 ComMin_i + \alpha_2 ComMaj_i + \alpha_3 Sector_i + \alpha_4 Z_i + \alpha_5 ComMin_i * Sector_i + \alpha_6 ComMaj_i * Sector_i + \varepsilon_i \tag{2}$$

where IO_{ji} takes a value of '1' if firm i has introduced innovation type j between 2013 and 2015. The two innovation types j are product and process innovation. $ComMin_i$ and $ComMaj_i$ indicates that firm i perceived market dominance by established competitors as a 'minor' or 'major' problem respectively when commercialising goods or services. The base category is that firms experienced no competitive pressure in this context. $Sector_i$ is a series of dummies capturing the four distinct sectors. Manufacturing is the reference category. The terms

[1] Where goods and services innovations are both a form of product innovation.

$\alpha_5 ComMin_i * Sector_i$ and $\alpha_6 ComMaj_i * Sector_i$ are interaction terms between our competition intensity indicators and our sectoral dummies. Coefficients $\alpha_1$and α_2 identify the direct competition effect. If these coefficients are negative and significant ($\alpha_1 < 0, \alpha_2 < 0$), they provide support for Schumpeter's view of competition. However, if they are positive and significant ($\alpha_1 > 0, \alpha_2 > 0$), they provide support for Arrow's view of competition. If these coefficients are of opposing signs (e.g. if $\alpha_1 > 0$ and $\alpha_2 < 0$) or in instances such as when $\alpha_1 > 0$ and $\alpha_2 > 0$ but $\alpha_2 < \alpha_1$ they provide evidence of nonlinearities. The coefficient vector α_3 shows the sector effects. Coefficient vectors α_5 and α_6 assess the extent to which the observed competition effect varies across sectors. If coefficients α_5 and α_6 are significant this suggests that the impact of competition on innovation varies across the sectors. The Z vector includes standard controls included in innovation models such as R&D, firm size, firm age, and country dummies (see Tang 2006; Crowley and McCann 2018). Equation (1) is estimated using logit estimation techniques. The standard errors are clustered within countries. Marginal effects are calculated as the partial derivative (dy/dx) based on Karaca-Mandic et al. (2012) and Ai and Norton (2003)[2].

4. Results

Table 2 presents the estimates of equations (1) and (2) for both product and process innovation. Columns I and III display the results of the reduced model given by equation (1) and Columns II and IV display the results of the complete model given by equation (2) for patents and process innovation respectively[3]. Focusing initially on the results in Table 2 for product innovation, we find that the coefficients α_1 and α_2 on our firm-reported measures of competition intensity for estimates of equations (1) and (2) are positive and significant indicating a positive effect of competition intensity on product innovation and providing some initial support for Arrow's (1962) perspective using this novel measure. There are however potential signs of non-linearities in the relationship between competitive intensity and product innovation. While $\alpha_1$and α_2 are both positive, $\alpha_2 < \alpha_1$. This suggests a concave or an inverted U-shaped curve supporting Im et al. (2015) and Aghion et al. (2005). Diminishing impacts on product innovation eventually set it.

The coefficients on α_1 and α_2 display a similar pattern in the estimates of equation (1) for process innovation presented in Column III. While significant and positive in the reduced equation, α_1 and α_2 are not significant in the estimates of the extended equation (2) displayed in Column IV indicating that competitive pressure reported by firms is not a key driver of process innovation in manufacturing firms (the base category) supporting Tabacco (2015) for this sector. This is to be expected due to the proprietary nature of this form of innovation. Strong business ties and cooperation is often required to ease the transfer of information regarding certain innovative activities (Cheng and Yang, 2017). Process innovations involve knowledge that is generated inhouse to improve cost efficiency or the production process in the delivery of products and services. It represents knowledge that is not diffused rapidly across markets. This is emphasised by the results of Scuotto et al. (2017) which show the importance of investing in *in-house* means of innovating organizational processes.

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[2]This method of calculating the marginal effects enables the most accurate method of interpretation of the non-linear model. It allows for the produced results to be interpreted in terms of percentage change rather than log likelihood.

[3]The associated marginal effects between the competition intensity and sector for the product and process innovation types *j* based on the estimates of equations (1) and (2) are presented in Table A2 in the supplementary appendix.

Table 2. Logit Estimates of competition effects.

VARIABLES	Product Innovation		Process Innovation	
	I	II	III	IV
No competition (Reference)				
Minor Competition ($ComMin_i$)	0.333***	0.384***	0.201***	-0.0834
	(0.0453)	(0.0999)	(0.0390)	(0.118)
Major Competition ($ComMaj_i$)	0.314***	0.230**	0.174***	-0.146
	(0.0495)	(0.110)	(0.0436)	(0.148)
Retail (NACE categories G)	0.0375	-0.0958	-0.198***	-0.496***
	(0.0705)	(0.0936)	(0.0705)	(0.0926)
Services (NACE categories H/I/J/K/L/M/N/R)	-0.769***	-0.711***	-0.252***	-0.467***
	(0.0755)	(0.106)	(0.0740)	(0.115)
Industry (NACE categories D/E/F)	-0.775***	-0.685***	-0.361***	-0.476***
	(0.0868)	(0.125)	(0.0805)	(0.133)
Manufacturing (Reference)				
Minor competition x Retail		0.179		0.475***
		(0.118)		(0.130)
Minor competition x Services		-0.192*		0.276**
		(0.112)		(0.130)
Minor competition x Industry		-0.191		0.207
		(0.130)		(0.160)
Major competition x Retail		0.236*		0.421**
		(0.125)		(0.178)
Major competition x Services		0.0579		0.436**
		(0.147)		(0.177)
Major competition x Industry		-0.0722		0.120
		(0.145)		(0.257)
No R&D expenditure (Reference)				
R&D expenditure as percentage of turnover <1%	0.671***	0.676***	0.923***	0.930***
	(0.0518)	(0.0518)	(0.0614)	(0.0615)
R&D expenditure as percentage of turnover 1-5%	1.224***	1.226***	1.306***	1.311***
	(0.0581)	(0.0567)	(0.0728)	(0.0736)
R&D expenditure as percentage of turnover >5%	1.896***	1.899***	1.508***	1.509***
	(0.0717)	(0.0719)	(0.105)	(0.106)
Natural logarithm of employees	0.0343**	0.0336*	0.165***	0.165***
	(0.0175)	(0.0176)	(0.0171)	(0.0171)
Group Membership	0.169***	0.168***	0.304***	0.302***
	(0.0459)	(0.0459)	(0.0579)	(0.0575)
Young Firms (Reference)				
Established Firms	0.255	0.239	0.274	0.254
	(0.220)	(0.221)	(0.236)	(0.236)
Mature Firms	0.149	0.131	0.151	0.130
	(0.211)	(0.211)	(0.222)	(0.222)
Constant	-0.522**	-0.501**	-1.502***	-1.290***
	(0.231)	(0.243)	(0.255)	(0.248)
Observations	12,892	12,892	12,892	12,892
Chi Squared	0.0000	0.0000	0.0000	0.0000
Pseudo R-Squared	0.1134	0.1142	0.1131	0.1121

Note: *** p<0.01, ** p<0.05, * p<0.1. Country dummies are also included but not displayed here for brevity. Standard errors are in parentheses. Likelihood ratio (LR) tests were performed to examine whether the addition of the interaction terms in models II and IV resulted in a statistical significant improvement in model fit. The null hypothesis that α_5 and α_6 equalled zero was rejected for both product innovation (Chi-square = 15.17, p-value=0.0189) and process innovation (Chi-square = 17.23, p-value=0.085).

From the above and just focusing on the main effects, our findings indicate a heterogeneous impact of firm assessed competitive pressures on innovation types. This deserves further examination but first we consider sectoral effects on innovation. We find that services firms and industry are significantly less likely to engage in product innovation relative to manufacturing (the base category) and retail businesses given the negative and significant coefficients on these sectoral dummies in Columns I and II. Retail, services and industry sectors are significantly less likely to engage in process innovation relative to manufacturing firms given the negative and significant coefficients on all three sectoral dummies in Columns III and IV.

The coefficients on the interaction effects in the extended product innovation equation displayed in Column II show that services firms facing minor competition (captured by *Minor competition* x *Services*) are significantly less likely to engage in product innovation relative to firms in manufacturing and in the other sectors who face minor competition given the negative and significant coefficient on this interaction variable and the insignificance of similar interaction coefficients for retail and industry firms who face minor competition. Retailers facing major competition (captured by *Major competition x Retail*) are significantly more likely to engage in product innovation relative to firms in other sectors who face major competition (e.g. manufacturing or otherwise) given the positive and significant coefficient on this interaction variable. Similarly, the coefficients on the interaction effects in the extended process innovation equation displayed in Column IV show that retail and services firms facing minor or in fact major competition are significantly more likely to engage in process innovation relative to firms in the manufacturing and industry sectors who face minor or major competition. Thus, our findings build on those of others (Im et al. 2015; Aghion et al. 2005) through indicating a heterogeneous impact of firm assessed competitive pressures across sectors on innovation types.

Finally, the coefficients on our control variables indicate that larger firms, firms with greater intensity of R&D and firms which are members of a group are also more likely to engage in product and process innovation.

We illustrate the predicted probabilities of product or process innovating calculated based on our estimates in Table 2 in Figures 1 and 2 to examine our findings further.[4] Chi-square tests were conducted to explore the significant differences in the predicted probabilities. The results of these tests of difference are provided in Table 3 below. The predicted probabilities are adopted to ease the interpretability of the results. They show the change in probability of innovating for a discrete change in the level of competition intensity (Horbach et al., 2012).

Figure 1 presents the aggregate impact of competition intensity on product and process innovation. As found above for the estimates of the reduced form equations any degree of competition increases the likelihood of both innovation types compared with no competitive pressures supporting Arrow (1962) and Im et al. (2015).[5] While the probability of innovating whether product or process is less for major than minor competition no significant differences were found in the impact of minor and major competition on the probability of product innovation (Chi-square test statistic= 0.14, p-value = 0.7075, see Table 3) and process innovation (Chi-square test statistic= 0.38, p-value = 0.5398, see Table 3). Thus, there is less support for a tipping point when examining the predicted probabilities.

[4] The predicted probabilities are provided in Table 3A in the supplementary appendix for product and process innovation by different levels of competition intensity and by sector.

[5] The results of the chi-squares tests in Table 3 support this for product and process competition. For example, for product innovation a test of the null hypothesis of no difference in the predicted probabilities for no competition and minor competition (e.g H_0: $\beta_{\text{No Competition}} - \beta_{\text{Minor Competition}} = 0$) was rejected (Chi-square test statistic= 54.06, p-value = 0.0000), and similarly for no competition and major competition (Chi-square test statistic= 40.18, p-value = 0.0000).

Figure 1. Predicted Probability of the Impact of Competition on Innovation

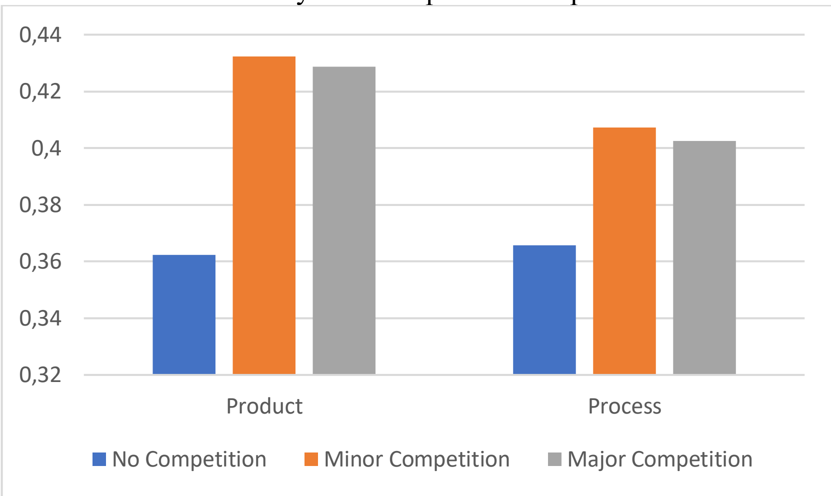
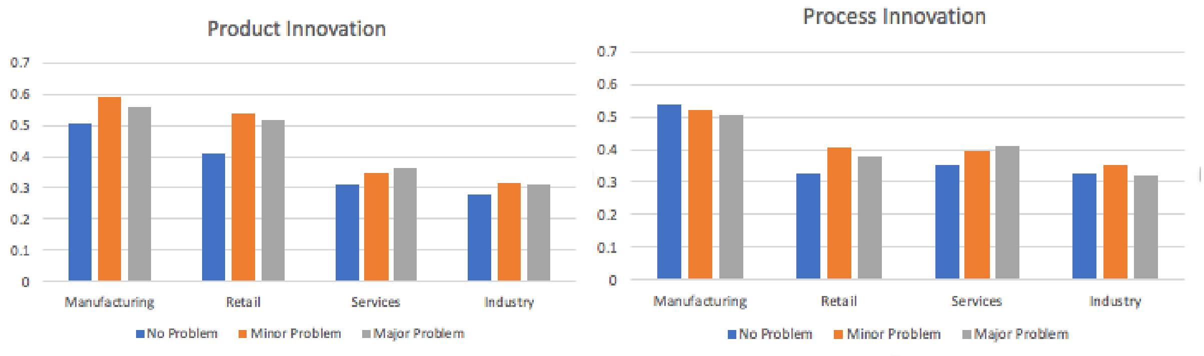


Figure 2. Predicted Probability of the Impact of Competition on Innovation by Sector.



Similarly in Figure 2, we consider the predicted probabilities of product and process innovation by sector and level of competition intensity. As above, we find competitive pressure tends to have a positive impact on innovation compared with no competitive pressure supporting Arrow (1962) save for process innovation in manufacturing and industry firms where there is no significant difference in the probability of process innovating by competitive intensity (see Table 3). Manufacturing firms have a higher probability of engaging in process innovation as found above when compared to the probability of process innovating in the other sectors. While manufacturing firms are more likely to product innovate when faced with competitive pressures (minor or major) there is no significant difference in the impact of minor and major competitive pressures on the probability of engaging in product innovation for manufacturing firms[6]. Similarly, there is also no significant difference in the probabilities of product and process innovating for minor and major competitive pressures for retailers and services firms. This is despite the greater effect of major competitive pressures than minor ones on innovation in services firms. Finally, for industry minor competitive pressure can increase the probability of firms engaging in product innovation compared with no competition. There is nonetheless no significant difference between the effects of major and no competition and minor and major competition on the probability of product innovating in this sector (see Table 3). In summary, while similar patterns can be observed across sectors there is evidence of heterogeneity in the impact of competition on product and process innovation across the sectors when the extent of competitive pressures are assessed by firms within these sectors.

[6] A test of the null hypothesis of no difference in the predicted probabilities β between $\beta_{\text{Manufacturing}\times\text{No Competition}}$ and $\beta_{\text{Manufacturing}\times\text{Minor Competition}}$ and between $\beta_{\text{Manufacturing}\times\text{No Competition}}$ -$\beta_{\text{Manufacturing}\times\text{Major Competition}}$ were rejected a but $\beta_{\text{Manufacturing}\times\text{ Minor Competition}}$ -$\beta_{\text{Manufacturing}\times\text{Major Competition}}$= 0 could not be rejected, see Table 3.

Table 3. Chi-square Tests of Difference in the Predicted Probabilities β.

Null Hypothesis	Product Innovation Chi Squared	Product Innovation P Value	Process Innovation Chi Squared	Process Innovation P Value
$\beta_{\text{No Competition}} - \beta_{\text{Minor Competition}} = 0$	54.06	0.0000	26.42	0.0000
$\beta_{\text{No Competition}} - \beta_{\text{Major Competition}} = 0$	40.18	0.0000	15.94	0.0001
$\beta_{\text{Major Competition}} - \beta_{\text{Minor Competition}} = 0$	0.14	0.7075	0.38	0.5398
$\beta_{\text{Manufacturing}\times\text{No Competition}} - \beta_{\text{Manufacturing}\times\text{Minor Competition}} = 0$	14.74	0.000	0.50	0.480
$\beta_{\text{Manufacturing}\times\text{No Competition}} - \beta_{\text{Manufacturing}\times\text{Major Competition}} = 0$	4.41	0.036	0.98	0.323
$\beta_{\text{Manufacturing}\times\text{Minor Competition}} - \beta_{\text{Manufacturing}\times\text{Major Competition}} = 0$	1.59	0.207	0.16	0.688
$\beta_{\text{Retail}\times\text{No Competition}} - \beta_{\text{Retail}\times\text{Minor Competition}} = 0$	41.08	0.000	37.68	0.000
$\beta_{\text{Retail}\times\text{No Competition}} - \beta_{\text{Retail}\times\text{Major Competition}} = 0$	22.41	0.000	14.96	0.000
$\beta_{\text{Retail}\times\text{Minor Competition}} - \beta_{\text{Retail}\times\text{Major Competition}} = 0$	1.29	0.256	1.63	0.202
$\beta_{\text{Services}\times\text{No Competition}} - \beta_{\text{Services}\times\text{Minor Competition}} = 0$	8.79	0.003	16.48	0.000
$\beta_{\text{Services}\times\text{No Competition}} - \beta_{\text{Services}\times\text{Major Competition}} = 0$	10.77	0.001	17.00	0.000
$\beta_{\text{Services}\times\text{Minor Competition}} - \beta_{\text{Services}\times\text{Major Competition}} = 0$	1.30	0.255	1.65	0.199
$\beta_{\text{Industry}\times\text{No Competition}} - \beta_{\text{Industry}\times\text{Minor Competition}} = 0$	4.19	0.041	1.04	0.309
$\beta_{\text{Industry}\times\text{No Competition}} - \beta_{\text{Industry}\times\text{Major Competition}} = 0$	2.38	0.123	0.02	0.879
$\beta_{\text{Industry}\times\text{Minor Competition}} - \beta_{\text{Industry}\times\text{Major Competition}} = 0$	0.07	0.788	1.06	0.303

5. Conclusions

The presence of firm-reported competition significantly increases the likelihood of product innovation supporting the positive competition-innovation view of Arrow (1962) rather than the negative view of Schumpeter (1943). However, it appears that major competition has a lower impact relative to minor competition for inducing innovation providing some tentative evidence for either a diminishing or negative relationship between competition and innovation. After a certain tipping point we find that this difference is insignificant even when examined across sectors. Use of self-assessed measures of competitive pressures and allowing for variations across sectors are shown to be helpful in reconciling conflicting empirical evidence in this area. There is evidence of heterogeneity in its effect particularly for process innovation in manufacturing and industry sectors. Further research could explore whether the results differ depending on the type of market dominance. For example, whether the source of this market dominance or intense competition is from indigenous or foreign owned businesses.

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Appendix A

Table A1. Correlation Matrix.

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Product Innovation	1																											
2	Minor Competition	.1	1																										
3	Process Innovation	.4	.1	1																									
4	No Competition	-.1	-.6	-.1	1																								
5	Major Competition	.1	-.4	.0	-.5	1																							
6	Manufacturing	.1	.0	.1	.0	.0	1																						
7	Retail	.1	.0	.0	-.1	.1	-.3	1																					
8	Services	-.1	.0	.0	.1	-.1	-.3	-.6	1																				
9	Industry	-.1	.0	.0	.0	.0	-.2	-.3	-.3	1																			
10	No Competition x Manufacturing	.0	-.2	.1	.3	-.1	.6	-.1	-.2	-.1	1																		
11	No Competition x Retail	.0	-.3	-.1	.4	-.2	-.1	.5	-.3	-.1	-.1	1																	
12	No Competition x Services	-.1	-.4	-.1	.6	-.3	-.2	-.3	.5	-.2	-.1	-.2	1																
13	No Competition x Industry	-.1	-.2	.0	.3	-.1	-.1	-.2	-.2	.6	-.1	-.1	-.1	1															
14	Min Competition x Manufacturing	.1	.3	.1	-.2	-.1	.6	-.2	-.2	-.1	-.1	-.1	-.1	-.1	1														
15	Min Competition x Retail	.1	.5	.0	-.3	-.2	-.1	.5	-.3	-.1	-.1	-.1	-.2	-.1	-.1	1													
16	Min Competition x Services	.0	.6	.0	-.3	-.2	-.2	-.3	.5	-.2	-.1	-.1	-.2	-.1	-.1	-.2	1												
17	Min Competition x Industry	.0	.3	.0	-.2	-.1	-.1	-.1	-.2	.6	-.1	-.1	-.1	-.1	-.1	-.1	-.1	1											
18	Maj Competition x Manufacturing	.1	-.1	.1	-.1	.3	.5	-.1	-.2	-.1	.0	-.1	-.1	.0	.0	-.1	-.1	.0	1										
19	Maj Competition x Retail	.1	-.2	.0	-.2	.5	-.1	.5	-.3	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	-.1	1									
20	Maj Competition x Services	.0	-.2	.0	-.3	.6	-.1	-.2	.4	-.1	-.1	-.1	-.2	-.1	-.1	-.1	-.1	-.1	-.1	-.1	1								
21	Maj Competition x Industry	.0	-.1	.0	-.1	.3	-.1	-.1	-.2	.5	.0	-.1	-.1	.0	.0	-.1	-.1	.0	.0	-.1	-.1	1							
22	R&D expenditure <1%	.0	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1						
23	R&D expenditure 1-5%	.2	.0	.2	-.1	.0	.1	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0	.1	.0	.0	.0	-.2	1					

Note: Values above greater than the absolute value of 0.02 are significant at $p<0.05$; Min = Minor and Maj = Major. The correlations are rounded to 1 decimal place.

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
24	R&D expenditure > 5%	.2	.0	.2	.0	.0	.1	-.1	.1	-.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	-.1	-.1	1				
25	Firm Size	.1	.1	.2	-.1	.0	.2	-.1	.0	.0	.1	-.1	.0	.0	.1	.0	.0	.0	.1	-.1	.0	.0	.1	.1	.0	1			
26	Group Membership	.1	.0	.1	.0	0	.1	.0	.0	-.1	.0	.0	.0	-.1	.0	.0	.0	.0	.0	.0	.0	.0	.1	.1	.1	.4	1		
27	Young Firms	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1	
28	Established Firms	.0	.0	.0	.0	.0	-.1	.0	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	-.2	-.1	.0	1
29	Mature Firms	.0	.0	.0	.0	.0	.1	.0	-.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2	.1	-.2	-1

Note: Values above greater than the absolute value of 0.02 are significant at p<0.05; Min = Minor and Maj = Major. The correlations are rounded to 1 decimal place.

Table A2. Marginal Effects based on the Logit Estimates (dy/dx).

VARIABLES	**Product Innovation**		**Process Innovation**	
	I	II	III	IV
No competition (Reference)				
Minor Competition ($ComMin_i$)	0.0685***	0.0788***	0.0408***	-0.0169
	(0.00949)	(0.0206)	(0.00784)	(0.0240)
Major Competition ($ComMaj_i$)	0.0646***	0.0472**	0.0354***	-0.0297
	(0.0102)	(0.0225)	(0.00880)	(0.0300)
Retail (NACE categories G)	0.00770	-0.0197	-0.0404***	-0.101***
	(0.0145)	(0.0192)	(0.0143)	(0.0187)
Services (NACE categories H/I/J/K/L/M/N/R)	-0.158***	-0.146***	-0.0512***	-0.0949***
	(0.0150)	(0.0216)	(0.0150)	(0.0233)
Industry (NACE categories D/E/F)	-0.159***	-0.141***	-0.0735***	-0.0967***
	(0.0173)	(0.0254)	(0.0162)	(0.0269)
Manufacturing (Reference)				
Minor competition x Retail		0.0367		0.0964***
		(0.0243)		(0.0266)
Minor competition x Services		-0.0394*		0.0561**
		(0.0231)		(0.0266)
Minor competition x Industry		-0.0392		0.0420
		(0.0268)		(0.0325)
Major competition x Retail		0.0486*		0.0856**
		(0.0256)		(0.0361)
Major competition x Services		0.0119		0.0885**
		(0.0303)		(0.0358)
Major competition x Industry		-0.0148		0.0245
		(0.0298)		(0.0523)
No R&D expenditure (Reference)				
R&D expenditure as percentage of turnover <1%	0.138***	0.139***	0.188***	0.189***
	(0.0105)	(0.0105)	(0.0115)	(0.0114)
R&D expenditure as percentage of turnover 1-5%	0.252***	0.252***	0.266***	0.266***
	(0.0110)	(0.0107)	(0.0132)	(0.0133)
R&D expenditure as percentage of turnover >5%	0.390***	0.390***	0.307***	0.307***
	(0.0131)	(0.0131)	(0.0195)	(0.0196)
Natural logarithm of employees	0.00705*	0.00690*	0.0335***	0.0335***
	(0.00360)	(0.00362)	(0.00353)	(0.00352)
Group Membership	0.0348***	0.0346***	0.0618***	0.0614***
	(0.00939)	(0.00937)	(0.0116)	(0.0115)
Young Firms (Reference)				
Established Firms	0.0524	0.0490	0.0558	0.0516
	(0.0454)	(0.0455)	(0.0478)	(0.0477)
Mature Firms	0.0306	0.0269	0.0307	0.0263
	(0.0434)	(0.0434)	(0.0450)	(0.0449)
Observations	12,892	12,892	12,892	12,892

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Country dummies are also included but not displayed here for brevity.

Table A3. Marginal effects of the interaction terms between sector and competition for product and process innovation.

Innovation Type	Sector	No Competition	Minor Competition	Major Competition
Product Innovation	Manufacturing	0.507***	0.590***	0.557***
	Retail	0.413***	0.539***	0.518***
	Services	0.308***	0.345***	0.364***
	Industry	0.281***	0.318***	0.311***
Process Innovation	Manufacturing	0.538***	0.521***	0.507***
	Retail	0.324***	0.403***	0.379***
	Services	0.354***	0.393***	0.413***
	Industry	0.327***	0.351***	0.322***

Note: *** p<0.01, ** p<0.05, * p<0.1, no asterisks to indicate insignificance. The full set of coefficients available upon request from author.