Revisiting the Effect of R&D intensity on innovation Performance: An Instrument Variable Approach

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Abstract: The literature on innovation performance makes clear the important role of R&D in innovation performance. Studies that have investigated this relationship have generally assessed the effect of R&D investment on innovation performance. It is important to note that innovation performance and R&D investment are known to be closely associated with the possibility of reverse causality. Regressing innovation performance on R&D expenditure therefore poses an important statistical challenge of endogeneity. In the presence of endogeneity regression parameter estimates are biased and inconsistent and therefore hypothesis testing may be misleading. Using data from different sectors of OECD economies sourced from the OECD data base, instrumental variable analysis is conducted through a two stage least square using the number of R&D personnel as instrument. Again, the literature assumes that innovation is an increasing function of R&D. However, considering R&D is combined with other factors, some of which are fixed, the possibility that R&D will experience diminishing returns cannot be overlooked. This means that the dominant linear relationship authors specify in these studies may not be wholly accurate. We captured this effect by modeling a quadratic relationship to reflect the diminishing returns to innovation performance. The findings of the study show that the number of R&D persons exhibit a nonlinear inverted U-shaped relationship with innovation performance. The policy implication of the findings of the study is that R&D activities must be commensurate with the size of other organizational factors to ensure that changes in R&D activities solicit a favourable response from innovation performance.

Keywords: R&D intensity, innovation performance, instrumental variable, OLS regression.

1. Introduction

The relationship between R&D intensity of firms and innovation performance is one of the most researched topics in innovation literature. The focus of investigation in this area of study has been how changes in R&D spending of firms affect innovation performance of firms. The fundamental assumption of these studies is that innovation performance of firms is a linear function of R&D intensity (Teng & Yi, 2017; Savrul & Incekara, 2015). The R&D intensity of firms is seen as an indication of the capacity of firms to be able to absorb external knowledge. The overall R&D capacity of firms help in the design of technique for efficient resource use (Lin, et al., 2021). The R&D intensity has been a source of competitiveness that allows firms to improve their innovation performance. Studies that investigate the link between R&D Intensity and innovation performance of firms have generally found R&D intensity to influence the performance of innovation. There are however, isolated instances of studies that have shown that R&D intensity is not a source of innovation performance. The transition into knowledge economy has made it imperative for firms to engage in R&D activity as a channel to improve innovation performance. It is widely known, both theoretically and empirically that R&D intensity and innovation performance of firms have served as a channel to economic growth (Zhylinska, et al., 2020; Afonso, 2016; European Commission , 2005; Aghion & Howitt, 1998). The interest in R&D intensity and innovation performance is the results of the desire of firms and economies to experience growth. It is for this reason that governments and firms commit a lot of resources to the course of increasing R&D intensity and ensuring innovation performance. The literature on the relationship between innovation and R&D has investigated different dimensions of this linkage, all with the aim of understanding the role of R&D in improving innovation performance. An important area of focus for studies in this area have been the role of policies in effectively transmitting R&D activities to improving innovation performance (Bloom, et al., 2002). The general position of the literature has been that governments policies stimulate private R&D to improve innovation perfomance (Chen, et al., 2021). Other authors have considered dimensions such as the additionality effect of R&D tax credit in private R&D expenditure of firms. In this area of study there is no consensus among authors. Whereas some authors have shown that R&D tax credit stimulates private R&D expenditure of firms (Castellacci & Lie, 2015), there are a number of other authors who suggest that R&D tax credit does not solicit increased private R&D expenditure (Marinoa, et al., 2016). Some other studies have argued that R&D tax credit crowds out private R&D expenditure and therefore the natural link between R&D expenditure and innovation performance is broken. A typical explanation for the break in the link between R&D and innovation performance has ranged from firm specific factors, issues with minimum threshold of R&D as well as the role of government policies instrument for innovation performance-R&D tax credit and subsidies.

The literature account on innovation performance places much emphasis on sectorial difference and how that influences innovation performance. The inconsistencies in the effect of R&D on innovation performance has been attributed to differences in the sectors investigated. It is known that innovation perfomance in some sectors are more responsive to changes in R&D expenditure of firms (Malerba, 2005; Castellacci & Lie, 2015). Other aspects of the organisation that have been cited as a reason why there are incosistencies in the effect of R&D on innovation performance have been the diversity in the composition of R&D staff. For example Garcia, Zouaghi and Garcia, (2017) have shown that the R&D team characteristics is important in influencing how R&D affects innovation perfomance. There are a litany of reasons cited in the literature to explain why R&D have not always improved innovation perfomance as expected. Other reasons cited in the empirical literature for the differences in the effect of R&D expenditure on innovation performance make the argument that the relationship between R&D activities of firms are moderated by some other factors which are either internal or external to the firm. These moderating factors could make a lot of difference in the outcome of the relationship between R&D and innovation (Zhu, et al., 2019).

One area that needs to be given attention to determine the source of and resolve these inconsistencies in the effect of R&D expenditure on innovation performance is the statistical approach in modeling the relationship. A large portion of the empirical literature that has been devoted to analysing the relationship between R&D investment and innovation peformance have been relational studies that apply regression analysis mainly (Leung & Sharma, 2021; Kim, et al., 2011; Mairesse & Mohnen, 2005). Intuitively, the relationship between R&D investment and innovation performance of firms could be argued to be endogenous. Whereas authors have regressed innovation performance on R&D expenditure, we argue that innovation perfomance of firms can also explain R&D expenditure of firms. Higher innovation means that firms will have more resources to invest in R&D. This is a recipy for endogenous regression models which biases upwards the effect of R&D on innovation performance. The other aspect of modelling the relationship between R&D expenditure of firms and innovation performance that is yet to be given attention in the innovation literature is the role of diminishing returns to R&D investment. The status quo is that increasing R&D investment proportional increase innovation performance. This is a simplistic view of the relationship. A more deeper and realistic view is to consider integrating into the model diminishing returns to R&D investment to capture the effect increasing R&D investment in the face fixed firm resources. In this study therefore, an attempt is made to determine the effect of R&D investment on innovation performance instrumenting R&D investment with number of business enterprise researchers and integrating diminishing returns to the number of business enterprise researchers.

2. Literature Review

The literature review focuses on the relationship between R&D investments of firms and its effect on the innovation performance of firms. The literature focuses on data analysis techniques as well as the outcome of the studies.

2.1 R&D and Innovation Performance

Studies on the relationship between R&D investments on firms and innovation performance have generally suggested that the causal effect is from R&D to innovation (Vershinin, 2021; Prokop & Stejskal, 2019). That is to say that R&D investment determines the innovation outcomes of firms. There is empirical evidence that indicates R&D intensity of firms can be connected to innovation performance. However, evidence from the literature has shown that in some instances countries with high R&D intensity have not gained much in terms on innovation performance (Savrula & Incekara, 2015). The authors further stressed that some environmental factors influence the effect of R&D investment on innovation performance. This is an indication of the possibility of having a high error term in an innovation regression if care is not. There are large number of environmental factors that affect factors that determine innovation performance and predisposes these innovation influencing factors to the problem of endogeneity and therefore biases the effect of the influencing factors upwards. Studies on the effect of R&D on innovation performance have used both country level and firm level data and the findings have generally been invariant to the data type. Findings of these studies have shown that innovation performance generally increases with increasing R&D investments. In a study by Mairesse and Mohnen (2005), the authors used data from the third community innovation survey (CIS 3) on French manufacturing firms covering the periods 1998 to 2000. The authors, using tobit regression revealed that R&D intensity of firms is positive and significantly related with innovation performance. The findings of Mairesse and Mohnen (2005) also revealed that sectoral differences matter. They showed that innovation performance of low technology sectors is more responsive to changes in R&D than the case in high technology sectors. The strong relationship

between R&D intensity of firms and their innovation performance has been widely documented in the extant literature. This has been argued by several authors to be an indication that R&D intensity of firms is a strong determinant of innovation. However, Mairesse and Mohnen (2005) argues that part of the reason for this strong relationship is as a result of the endogeneity of R&D investment in innovation performance model. There is also evidence of causality moving from innovation to R&D (Harris & Moffat, 2011) breaking the traditional relationship between R&D and innovation with causality from R&D. The reverse causality identified by Harris and Moffat (2011) is confirmed in a study by Guloglu and Tekin (2012) where a granger causality test revealed that innovation performance granger cause R&D expenditure. These are not isolated cases where R&D has been confirmed to be indogenous in an innovation performance model. In a study to determine the relationship between R&D, innovation and productivity, Baum, et al. (2017), using community innovation survey for Swedish manufacturing and service sector data showed that R&D is endogenous in determining innovation performance of firms. Eventhough the issue of endogeneity in the relationship between R&D and innovation has been generally overlooked, evidence from the empirical literature suggests that authors admit its presence and the consequence of biasing R&D coefficients and rendering OLS inconsistent in the determination of the effect of R&D on innovation performance (Carboni & Medda, 2021;Medda & Piga, 2014)

Another aspect of the relationship between R&D and innovation perfomance that has been given little attention is dimishing return to R&D. Firms investment in R&D do not solicit the needed increases in innovation perfomance. The concept of diminishing returns explains the reduction in the effect of an input variable on an output as an increasing amount of the input varaible is exerted on other fixed input factors. In the R&D innovation perfomance model, R&D investments are conbined with other firm input factors that may be fixed at a point in time and therefore could explain why firms may experience slow growth in innovation in spite of increased R&D investment. In a study by Barbero, et al. (2021), the authors used data envelopment analysis to investigate the efficiency in the use of innovation inputs to translate into innovation outcomes. The findings of the study showed that in most countries the transmission of innovation inputs into to innovation outputs have not always shown evidence of increasing returns to innovation inputs or constant returns, but rather decreasing returns to innovation inputs is a common phenomenon in most countries. The literature on innovation has made clear that innovation is a network of activities and interactions in an organisation (Palmberg, 2006; Metcalfe, 1995). This is an indication that innovation inputs are in interaction among themselves and other organisational factors to generate innovation performance outcomes. Increasing investment in some innovation inputs without doing the same with the other inputs will mean applying more of some resources to a limited amount of other resources. This is what leads to diminishing returns. The carrying capacity of some resources is limited relative to other resources and therefore increasing some innovation inputs without a commensurate increase in the complementary input for innovation increasingly reduces the effect of increased innovation inputs on innovation outcomes. The issue of R&D activities translating into innovation and the associated diminishing returns to R&D is not a new phenomenon even though largely neglected. The presence of fixed factors in the innovation activity processes predisposes increased R&D activities to diminishing returns (Houser, 1998). In the view of the author, diminishing return to R&D is the source of reduction in innovative activity when subsidies propel expansion in R&D intensity in the Schumpeterian growth model. Firms, governments, and policy makers in general are quick at finding means to increase the R&D capacity of firms, but very little is normally done to improve other complementary resources for innovation activities in organisation. It is well known that R&D tax credit and subsidies are policies designed to improve the R&D capacity of firms but hardly are there policies that looks at resource requirements of other segments of the organization which may not be directly in line with R&D activities of firms but without which R&D activities are stalled. Findings from the literature show that the inability of firm resources to respond to increasing internal and external R&D decreases return to R&D and explains why increasing R&D capacity of firms have on some occasions have not generated the expected innovation outcomes (Lokshin, et al., 2008).

From the review of the literature, two important issues about the relationship between R&D activities and innovation performance are raised, the fact that the relationship between R&D and innovation performance raises the problem of endogeneity and the fact that such a relationship is affected by diminishing returns. This will mean that the usual OLS approach adopted in such an estimation is biased and not consistent. Besides, the relationship between R&D and innovation cannot be linear but nonlinear to capture the effect of diminishing returns to R&D. Integrating these two important but largely neglected assumptions into our model, we formulate the following hypotheses for testing:

H_A: There is a significant relationship between R&D intensity of firms and innovation performance.

H_B: There is an inverted U relationship between R&D intensity and innovation performance.

3. Methodology

In this study, we seek to model the relationship between R&D intensity and innovation performance. Data for the study is sourced from the OECD database. The data is a country level data on four OECD countries, Czech Republic, Poland, Slovakia, and Hungary. Data sourced from the OECD database include foreign direct investment from the OECD countries to these sampled countries. Included in the data sourced from the OECD database include patent count as a measure of innovation performance, R&D expenditure of firms, GDP, imports, and exports to and from the sampled countries respectively and the number of R&D personnel of the firm. The data spans from 2003 to 2012. The choice of this data span is because of the unavailability of data for some variables.

In analysing the relationship between R&D intensity and innovation performance, multiple regression has generally been the technique employed in the extant literature, specifically panel OLS linear regression or simple OLS depending on the type of data being used (Lokshin, et al., 2008; Mairesse & Mohnen, 2005) and probit regression (Lööf, 2017) depending on whether the dependent variable is dichotomous. In this study we depart a bit from what is generally done by authors. In this study, we use instrumental variable analysis to estimate the relationship between R&D intensity and innovation performance. The use of instrumental variable analysis is to deal with neglected problem of endogeneity in the relationship between R&D and innovation performance. In estimating the relationship between R&D and innovation performance, the study further assumes diminishing returns to R&D and therefore adopts nonlinear regression model. The model is implemented through a two stage least squares. The study models an OLS regression with the endogenous variable as a predictor. We argue in this study that R&D intensity is endogenous in an innovation performance model because it is correlated with the error term. The basis for taking this position is that several organizational factors contribute to the creation of innovation besides R&D. These influencing factors cannot be captured fully in a regression model. Consequently, it swells the error term and correlates with R&D causing the problem of endogeneity. Evidence from the literature confirms the reverse causality between innovation performance and R&D of firms (Guloglu & Tekin, 2012; Harris & Moffat, 2011), an important source of endogeneity. Central to this study is to effectively capture the causal effect of R&D on innovation performance. By this the study deals with the problem of endogeneity which biases the effect of R&D on innovation upwards and renders the OLS inconsistent. The study also adopts a more realistic approach to estimating the effect of R&D on innovation performance. In modelling the relationship, we recognized the fact that R&D could experience diminishing return as the scale of R&D rises. The intuition is that there are large number of activities and resource requirements apart from R&D investment that need to be present in some required and commensurate quantities to combine with R&D investment to improve innovation performance. If firms increase R&D investment without a commensurate increase in activities and resources in other areas necessary to improve innovation performance, continuous increase in R&D investment will yield smaller and small levels of innovation performance. Thus, rather than a linear relationship, in this study we model the relationship between R&D and innovation performance as a nonlinear relation to accurately capture diminishing returns to R&D.

Equation 1 is an OLS regression that links innovation performance measured by patent count to R&D intensity and some other control variables and a crisis dummy to take care of periods with economic crises that can potentially affect innovation performance.

$Inn_{it} = \beta_0 + \beta_1 R\&D_{it} + \beta_2 Trade\_Opennes_{it} + \beta_3 FDI\_spill_{it} + \beta_4 GDP_{it} + \beta_5 FDI\_OECD_{it} + \beta_6 Crisis\_Dummy_{it} + \varepsilon_{it}$ (1)

Where Inn is innovation performance, R&D is R&D intensity, Trade_openness is trade openness, FDI_spill is knowledge spillover from FDI, GDP is gross domestic product, FDI_OECD is FDI from OECD countries to the four sampled countries.

In equation 1, we argue that R&D intensity is not independent of the error term. That is $Cov(R\&D, \varepsilon) \neq 0$. This means that $E\ [\hat{\beta}_{OLS}] \neq \beta$ and therefore R&D is endogenous. The expectation that as N $\quad \infty$, $\hat{\beta}_{OLS} = \beta$ is violated making the estimates inconsistent.

To deal with the problem of endogeneity and be able to assess the causal effect of R&D intensity on innovation performance, a two stage least square estimation is employed. The first stage of the two stage least square is presented as equation 2. At this stage an instrument is determined. The basis for determining the instrument is that $Cov(R\&D, R\&D\_pers) \neq 0$ and $Cov(Inn, R\&D\_pers) = 0.$ Theoretically, the size of a firms R&D personnel cannot directly influence innovation unless through the research activities of the firm also known as

the intensity of R&D. This makes the number of R&D personnel a good variable to be used as an instrument for R&D intensity.

$$R\&D_{it} = \beta_0 + \beta_1 R\&D\_pers_{it} + \beta_2 Trade\_Opennes_{it} + \beta_3 FDI\_spill_{it} + \beta_4 GDP_{it} + \beta_5 FDI\_OECD_{it} + \beta_6 Crisis\_Dummy_{it} + \varepsilon_{it} \quad (2)$$

R&D_pers is the number of R&D personnel.

In equation 2, the study presents the equation for the first stage of the two stage least squares. In this model R&D intensity is regressed on the instrument (number of R&D personnel) and the control variables.

Equation 2 allows us to derive an unbiased estimate of R&D intensity and the regressors. We then use the coefficients from equation 2 to predict R&D intensity as shown in equation 3.

$$\widehat{R\&D}_{it} = \hat{\alpha}_0 + \hat{\alpha}_1 R\&D\_pers_{it} + \hat{\alpha}_2 Trade\_Opennes_{it} + \hat{\alpha}_3 FDI\_spill_{it} + \hat{\alpha}_4 GDP_{it} + \hat{\alpha}_5 FDI\_OECD_{it} + \hat{\alpha}_6 Crisis\_Dummy_{it} \quad (3)$$

$\widehat{R\&D}$ is an unbiased estimate of R&D intensity and there is no correlation between $\widehat{R\&D}$ and ε. In equation 3 $\widehat{R\&D}$ is a linear combination of the instrument, R&D_pers and control variables. These regressors are independent of the error term, ε. This means that $\widehat{R\&D}$ is also independent of the error term and therefore an unbiased estimate of R&D intensity. Now that we have an unbiased estimate of R&D intensity, the second stage model of the two stage least square can be fomulated.

$$Inn_{it} = \beta_0 + \beta_1 \widehat{R\&D}_{it} + \beta_2 Trade\_Opennes_{it} + \beta_3 FDI\_spill_{it} + \beta_4 GDP_{it} + \beta_5 FDI\_OECD_{it} + \beta_6 Crisis\_Dummy_{it} + v_{it} \quad (4)$$

Where v is the error term.

In equation four innovation performance is regressed on an unbiased estimate of R&D intensity and control variables.

To integrate into model 4 diminishing returns to R&D intensity the estimate of R&D intensity, $\widehat{R\&D}$ must enter the regression model as a polynomial with degree 2 as shown in equation 5.

$$Inn_{it} = \beta_0 + \beta_1 \widehat{R\&D}_{it} + \beta_2 \widehat{R\&D}^2_{it} + \beta_3 Trade\_Opennes_{it} + \beta_4 FDI\_spill_{it} + \beta_5 GDP_{it} + \beta_5 FDI\_OECD_{it} + \beta_7 Crisis\_Dummy_{it} + v_{it} \quad (5)$$

4. Results and Discussions

This section of the study presents the results of the data analysis, the interpretation of the results and the discussions of the results. The results are presented in two parts, one on the effect of R&D intensity on innovation performance and the other on the role of diminishing returns to R&D intensity and its effect on innovation performance.

Table1: Effect of R&D intensity on Innovation Performance

Independent/Dependent Var	Model 1	Model 2	Model 3	Model 4
	Innovation	R&D intensity	Innovation	Innovation
C	3.340665**	-2.869330**	0.057493	-0.835411
	(1.491236)	(0.897769)	(0.911517)	(0.950995)
R&D_int	1.386520***		0.389302**	0.358556*
	(0.176130)		(0.169887)	(0.192644)
R&D_int^2				-1.758413*
				(1.063033)
R&D_pers		0.471293***		
		(0.065816		
Trade_openness	-0.787448***	0.911667***	1.094313***	1.128933***
	(0.305776)	(0.134937)	(0.119743)	(0.142609)
FDI_spill	-0.071242	-0.053085	0.613037***	-0.679735***
	(0.135321)	(0.085637)	(0.070819)	(0.081527)
GDP	1.18E-07***	-2.85E-09	1.18E-08***	111E-08***
	(2.66E-09)	(1.69E-09)	(1.69E-09)	(1.84E-09)
FDI_OECD	8.18E-07	-178E-07	1.20E-08***	8.16E-07*
	(6.06E-07)	(3.84E-07)	(4.50E-07)	(4.21E-07)

	Model 1	Model 2	Model 3	Model 4
Crisis_Dummy	0.356754**	-0.310360***	-0.046283	-0.090233
	(0.163604)	(0.095334)	(0.095953)	(0.153200)
R-squared	0.813098	0.995392	0.928033	0.919069
Adjusted R-squared	0.779116	0.994554	0.914948	0.901366
F-statistics	23.92724	1188114	70.92379	51.91439
Prob(F-statistic)	0.000000	0.000000	0.000000	0.000000

*Standard errors in parentheses; *P< 0.1, **P<0.05, ***P<0.01 Both dependent and independent variables are in logs except crisis dummy.*

Table 1 presents the results on the effect of R&D intensity on innovation performance. Model 1 presents an OLS estimation of the effect of R&D intensity on innovation performance. The results suggest the model is significant and R&D intensity also significantly explains the variation in innovation performance. A percentage point change in R&D intensity leads to a 1.38 percentage change in innovation performance in the same direction. Models 2 presents the first stage of the two stage least square where R&D intensity is regressed on the instrument, number of R&D personnel. The results show that the number of R&D personnel is positive and highly significant and a coefficient of 0.47. The high significant level is an indication from model 2 that number of the number of R&D personnel is a strong instrument. In testing the hypothesis that R&D intensity significantly explains innovation, model 3 presents instrumental variable estimate of the relationship and the second stage of the two stage least square. The results from model 3 confirm the hypothesis that there is a significant relationship between R&D intensity and innovation performance. The results suggest that increasing R&D intensity by one percentage points results in an increase in innovation performance by 0.3 percentage points. This contrasts with model 1 where the OLS estimates that increasing R&D intensity by one percentage point leads to an increase in innovation performance by 1.38 percentage points. This confirms the belief that OLS estimates are biased upwards and inconsistent. A comparison between the adjusted R-squares in model 1 and model 3 indicates that the instrumental variable model in model 3 presents a better modeling of the relationship than what is shown in model 1. The findings of the study provide evidence that instrumental variable approach models the relationship between R&D intensity and innovation performance better than OLS.
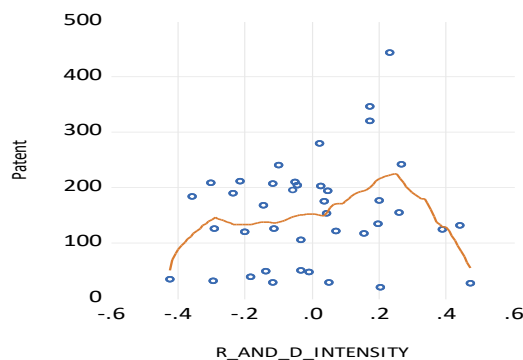

Figure 1: Scatter Plot of Relationship between R&D intensity and Innovation Performance

Model 2 tests the hypothesis that the relationship between R&D intensity and innovation performance is an inverted U shaped. The results of the analysis confirm the hypothesis that the relationship between R&D intensity and innovation performance is an inverted U shape. Both the first degree and second-degree polynomial are significant with the first-degree polynomial being positive and the second-degree polynomial being negative. Figure 1 presents a scatter plot of the relationship between R&D intensity and innovation performance. The curve in figure shows that at lower levels of R&D intensity innovation performance increase at an increasing rate until innovation performance reaches around 220 patent counts after which further increase in R&D intensity leads innovation performance increases at decreasing rate until it reaches a peak of around 230 patent counts. Any further increase in R&D intensity after innovation performance reaching its peak results in a fall in innovation to 110 patent count for an R&D intensity of 4 per cent. Innovation performance fell to 50 patent count when R&D intensity increased to 5 per cent. The relationship exhibited in figure can be interpreted as following the law of diminishing returns. As R&D intensity keeps increasing without a commensurate on other organization resources which aid in R&D (fixed factor), a further increase in R&D intensity leads to a less than a proportionate increase in patent count and eventually the patent count falls. The fall in patent count is because the fixed factors can no longer accommodate the increasing R&D intensity.

The study findings, though gives a new approach to understanding the relationship between R&D investments of firms and innovation performance some portions of the study findings are in sync with the prior literature. The general position of positive relation between R&D and innovation performance in the prior literature (Mairesse & Mohnen, 2005) has been confirmed even though the current study also showed that the positive relation is switched to negative at a point due to diminishing returns. It is also important to stress that findings of the study suggests that firms, in their quest to improve innovation performance tend to belief that R&D is the sole reason for improved innovation performance. The study findings show that increasing R&D activities of firms have not been commensurate with increased investment in other firm resources and activities that are not directly linked to but may be important for R&D activities. This is the source of diminishing returns to R&D investment. When firms focus on improving investment in R&D without a commensurate increase in other firm resources and activities, increasing R&D activities and investments at a point becomes inefficient. The evidence of diminishing returns to R&D intensity is a confirmation of Barbero, et al. (2021) who makes the point that generally the application of R&D in the bid to improve innovation performance has been inefficient due to decreasing returns to R&D intensity. The findings of the study also give credence to Palmberg (2006) and Metcalfe (1995) who have taken the position that everything within the organisation matters for innovation performance. This means that focusing on the intensity of R&D alone without paying attention to other areas of the organisation will generate less innovation outcome relative to increasing R&D intensity.

R&D intensity, as confirmed by the findings of this study, in accordance with the position of the literature. The study also confirms Mairesse and Mohnen (2005) assertion that estimating the relationship between R&D investment and innovation performance could be associated with endogeneity problems. This has been shown to bias the effect of R&D on innovation upwards, a postion our findings confirm. The litertaure position that OLS is inconsistent in estimating the relationship between R&D intensity and innovation performance (Carboni & Medda, 2021; Medda & Piga, 2014) has been confirmed by the findings of the current study. The findings of the study has shows that modeling the relationship based on OLS is difficient but instrumental variable analysis produces a more robust and accurate estimation of the effect of R&D on innovation performance.

5. Conclusions

The natural conclusion of the study based on the findings is that R&D intensity remains an important source of innovation performance. However, its effect on innovation performance as presented by the knowledge literature is over emphasized due to the inappropriate estimation of the relationship generally. The choice of OLS as an estimation technique for such as relationship biases the effect of R&D investment on innovation performance upwards. It is concluded that instrumental variable analysis implemented through the two stage least square rather than OLS is a much better estimation technique in modeling the relationship between R&D intensity and innovation performance. Other aspects of the organization are important in this discourse but have been overshadowed by the rather artificially embellished role R&D investment. The role of other aspects of the organization in the determination is relegated to the background. This is the source of the inefficiencies in transmitting R&D investments into innovation performance. It is concluded that the almost total neglect of other aspects of the organization has been an important source of the inefficiencies in transmitting R&D investment to innovation performance. The diminishing returns to R&D intensity is explained by the increased R&D intensity without a commensurate increase capacity of other organizational resources.

Acknowledgement

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