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R&D investment and performance Nexus of African firms: Under the three stages Sigmoid Curve Model

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Abstract

This study examines the R&D investment and firm performance nexus under a three-stage sigmoid model on 923 firms in ten African countries. I applied a two-step system GMM, robust OLS, Fixed and Random Effect regression models to check the sensitivity of the assumption of the sigmoid model to different regression approaches, and the result proves it. This study demonstrates a three-stage sigmoid model. There exists a signficant negative relationship between underinvestment and firm performance (stage 1), a significant positive relationship between optimum investment and firm performance (stage 2), and a signficant negative relationship between overinvestment and firm performance (stage 3). It suggested that African firms should maintain optimum investment in their R&D projects to maintain positive profit.

Keywords: *Underinvestment, Overinvestment, R&D investment, Sigmoid model*

1. Introduction

Governments and universities often suggest increased R&D funding assuming that innovation produces national economic growth (Aghion & Howitt, 1990) and creates competitive advantages for firms (Caves & Caves, 1996). Similarly, firms often allocate substantial resources to R&D projects believing it enhances their competitiveness. Impressively, however, though researchers have quite scientifically evaluated the axiomatic assumption that R&D investment improves firm value, findings confirmed inconsistent results. Prior studies revealed that R&D investment improves firm performance (Sher & Yang, 2005), while other results confirmed that it hinders performance (Shin, Kraemer, & Dedrick, 2017). This contradiction in the R&D investment and firm performance cast doubt on the assumption that R&D investment indeed leads to big payoffs. Moreover, studies employing linear models to evaluate the R&D investment and performance nexus generally concluded that "the more, the better." Such a conclusion, however, might have contradicted firms' actual R&D activities; practically, few firms use substantial resources in R&D projects (Yang, Chiao, & Kuo, 2009). Considering the above arguments, I evaluated different levels of African firms' R&D investment and performance nexus under a three-stage sigmoid model.

2. Problem statement

R&D investment and firm performance have been the subject of numerous academic research, though the findings have significantly varied, indicating different forms in the R&D–performance nexus. For instance, Pantagakis, Terzakis, and Arvanitis (2012b) and Tebourbi, Ting, Le, and Kweh (2020) found a positive nexus whereas Usman, Shaique, Khan, Shaikh, and Baig (2017) and Shin et al. (2017) confirmed a negative linkage between R&D investent and firm performance. Besides, Artz, Norman, and Hatfield (2003) found a U-shape, while Hazarika (2021) confirmed an inverted U-shape linkage between R&D investment and firm performance.

These inconsistencies in empirical studies motivated me to do this research. I argued that these inconsistencies in empirical findings might be due to the following reasons. First, those studies found a negative relationship (Pantagakis, Terzakis, & Arvanitis, 2012a; Tebourbi et al., 2020) might reflect the R&D-performance association that resulted from the firm's under- or over-investment problems. Second, studies found a positive R&D-performance nexus (Shin et al., 2017; Usman et al., 2017) capture the effect of optimal investment in R&D projects on firm performance. Third, studies found either a U or an inverted U-shape relationship (Artz et al., 2003; Hazarika, 2021) still failed to simultaneously capture the influence of optimum level of R&D investment on firm performance.

I thus propose a three-stage horizontal sigmoid model to help reconcile the inconsistencies in the link between these crucial variables (R&D investment and Firm performance). The sigmoid model was developed by Richard Foster (1986) and can be applied to many business types of research. Hence, I propose this model assuming the R&D investment and performance nexus is curve-linear in that their linkage is negative at a lower level of R&D investment (stage 1), positive with optimum level R&D investment (stage 2), and, again, negative at a high level of R&D investment (stage 3).

Moreover, the above studies used a single data analysis method. That is, prior studies did not check the sentivity of the relust by using different methods. However, I argued that the R&D

investment and firm performance nexus udner each level of invetsment (stage 1 to 3) might be sensitive to different data analysis methods. hence, I employed two-step system GMM, robust OLS, Fixed and Random Effect regression models to check the sensitivity of the assumption of the sigmoid model to different regression methods.

This study, thus, contributed to the existed knowledge and management of firms by providing new insights into the R&D investment and performance nexus.

3. Literature review and Hypotheses development

3.1 Agency problem in Under investment

According to Brealey, Myers, and Allen (2008), underinvestment happens when firms bypass positive Net Present Value (NPV) projects, which, if taken, increase profits. These authors further pointed out that plummeting efforts and risk avoidance cause underinvestment. Managers might be reluctant to maintain valuable investment projects. Such managers are considered passive managers, leading to passive investment in the firm (Brealey et al., 2008).

As Myers (1977) argued, when leveraged is included in a firm's capital structure, conflict happens between bondholders and shareholders, assuming that managers act in the interest of the shareholders, or else between new and old shareholders, when managers protect the interest of old ones. Executives start ignoring investing in projects with positive Net Present Value (NPV) as creditors have the first right to be paid back from the return of the projects. Myers (1977) explained that from the shareholders' perspective, positive Net Present Value (NPV) projects could be considered negative NPV projects, and pass such projects leading to underinvestment. This is because the high debt in the firm stimulates managers to reject positive Net Present Value (NPV) projects, which hinders firm value.

Moreover, Myers (1977) pointed out that firm value comprises a firm's assets, growth opportunities, and its capacity to make future valuable investments. The value of growth opportunities depends on executives' decisions on investment. When executives try to maximize a firm's value, they should use all investment alternatives with positive Net Present Value (NPV). However, Myers (1977) revealed that when there is a risky debt, executives protecting shareholders' interest tend to reject projects that could offer positive Net Present Value (NPV). Risky debt considered a sort of profit tax produced from new investments, as value created would serve to recover bondholders' loans (Stein, 2003). Besides, Myers (1977) argued that managers decide to finance projects only when their NPV is positive and higher than the debt's nominal value. Managers choose investments whose NPV offers a residual payoff to shareholders after covering the debt.

3.2 Optimal investment

The primary purpose of the firm is to maximize shareholders' wealth it can be achieved at the optimal investment. However, a firm's investment practically deviates from the optimal level due to under or over-investment problems (Stein, 2003). Under and overinvestment are problematic for firms as they hinder the firm value.

Underinvestment hitches happen due to a substantial discrepancy between the cost of internal and external funds that switches the positive NPV investment to negative. Myers (1984) postulated that firms bypass a project that needs funds exceeding the internal finance as issuing debt or equity will make the project unprofitable. Myers (1984) further argued that firms primarily depend on internal finance to absorb investment opportunities and operate at a substantial investment level.

Overinvestment occurs due to a conflict of interest between the firm's managers and shareholders. Jensen (1986) postulated that managers might use internal finance to make investments that provide their personal benefits though it is unprofitable. This indicates that managers use internal finance for investments that benefit them as the capital market will not finance unprofitable investments. Thus, such firms will operate beyond the optimum, which hampers firm performance (Harford, Humphery-Jenner, & Powell, 2012).

However, Dogru and Sirakaya-Turk (2017) argued that the quality of investment and alignment of managers' and shareholders' interests determine the optimal investment. That is, the investment will rise firm value until the optimal investment is reached. At the optimal investment, the marginal cost of capital is equal to the marginal value of an investment, and hence firm value is maximized.

3.3 Agency problem in overinvestment

The issue of overinvestment is asserted by Jensen (1986). Overinvestment is associated with the managers behavior of investing in negative NPV projects. The overinvestment problem is that managers might abuse their power by accepting undesirable projects that could hinder the shareholders' and bondholders' value (Jensen & Meckling, 1976).

The overinvestment problem is based on the assumption that managers stress their interest contrary to the shareholders’, leading to decline the firm's total value (Jensen & Meckling, 1976). Managers consider the firm a source of economic profit, self-esteem, and increase their capital. For this reason, they make inefficient decisions that improve their personal/private profit but decrease the firm's values.

Overinvestment problems may take different forms. The first form of overinvestment is managerial empire building. For instance, Jensen (1986) and Brealey et al. (2008) link overinvestment to how executives use the firm's resources. When the firm lacks opportunities, managers use available resources for their opportunistic purpose instead of distributing them to shareholders as dividends. As Jensen (1986) argued, a firm's expansion beyond the optimum level and managerial control of resources would build a managerial empire by creating higher salaries and offering greater power and prestige.

Managerial overinvestment can have the form of managerial entrenchment that is a set of self-defense mechanisim created by executives to emphasize their comptencies instead of the firm’s interest. In this regard, managers prefer investing in projects with negative net present value (NPV) that can increase their personal capital/benefit. Overinvestment problems might also happen due to managerial overconfidence; when managers act in good faith in line with shareholder’s goal, they could overestimate competencies or be exaggeratedly optimistic about firm’s potential by investing in projects with no psoitive NPV (Stein, 2003). In this regard, managers perceive less risk than there really is and thus do not care in evaluating the uncertainties related to investment projects.

3.4 The three-stage Sigmoid model and Hypothesis

In addition to the above theoretical arguments, studies widely explored the link between R&D investment and firm performance showing their link have various forms. First, studies found a negative relationship between these key variables (Mank & Nystrom, 2001; Usman et al., 2017). Second, studies also found a positive linkage between them (Pantagakis et al., 2012b; Sher & Yang, 2005).

My argument on these fragmented linkages of R&D investment and performance is because while those studies found a negative relationship reflecting that such association is due to firm's under or over-investment problems, studies found a positive R&D-performance nexus might capture the optimal investment-performance nexus. Moreover, studies found either U or inverted U-shape association of these variables failed to capture the effect of different levels of R&D investment on firm performance.

I thus, propose a three-stage sigmoid model to reconcile the inconsistencies in R&D investment and firm performance nexus. The sigmoid model assumes the R&D investment and performance nexus is non-linear in that their linkage is negative at a lower level of R&D investment (underinvestment), positive with optimal investment, and negative again at a high level (overinvestment). These scenarios are demonstrated by *stages 1, 2,* and *3* of Figure 1.

This model implies that the marginal productivity of R&D investment during their intial staegs (stage 1) is too little that it leaves firms unable to maintain considerable innovative outputs. At this stage, the benefit obtained from innovation can't offset the R&D costs, leaving the firm unprofitable. Schumpeter (1961) argued that monopolistic firms eventually produce innovative outputs in the long run. This assertion implied that large firms are advantageous in technological advancements as they have more resources to undertake risky R&D projects that the external capital market would not likely finance. This situation reveals that the R&D efforts of larger firms could produce positive output than their small counterparts. Consequently, firms with initially low-level R&D investment would not make a positive, innovative output and thus achieve low profitability.

In contrast, when firms reached optimal R&D investment, they achieved the desired profitability. The quality of investment and alignment of interest of managers and shareholders determine the optimal investment, and increasing firm value (Dogru & Sirakaya-Turk, 2017). At the optimal investment level, the marginal cost of capital and the marginal value of an investment are in breakeven, and, hence, the firm is maximized. This situation is demonstrated by *stage 2* in Figure 1. However, when R&D investment increases beyond the optimum level, it hinders the firm's performance due to the possible agency problem. As Jensen and Meckling (1976) asserted, overinvestment is inherited with managerial behavior of investing in negative NPV projects, which ultimately hinders firm performance. The overinvestment problem happens when management invests in risky projects that could hamper the shareholders' and bondholders' value (Jensen & Meckling, 1976). Stage 1 of picture 1 demonstrated this scenario. Hence, I proposed the following hypotheses.

Hypothesis 1*: Underinvestment (stage 1) has a negative relationship with firm performance*

Hypothesis 2: *Optimal invetsment (stage 2) has a positve relationship with firm perofrmance*

Hypothesis 3: *Overinvestment (stage 3) has a negative relationship with firm perofrmance*

3.5 Objectives of the study

The main purpose of this study is to examine whether the R&D investment and performance nexus demonstrate the three-stage sigmoid model. More specifically, this study has the following specific objectives.

- To investigate the relationship between underinvestment and firm performance
- To examine the relationship between optimum investment and firm performance
- To examine the relationship between overinvestment and firm performance.

3.6 Synthesis of a three-stage sigmoid (S) model

Figure 1 presented a three-stage sigmoid model. A U-shape curve combines of a negative slope (stage 1) and a positive slope (stage 2). Likewise, an inverted U-shape curve combines a positive slope (stage 2) and a negative slope (stage 3). The theoretical grounds for R&D investment-performance nexus in each of the three stages, as discussed in the hypotheses development, are presented in Table 1 below.

Table 1. R&D investment-performance nexus in different levels of R&D investment

	Stage 1	Stage 2	Stage 3
R&D investment-performance nexus	-	+	-

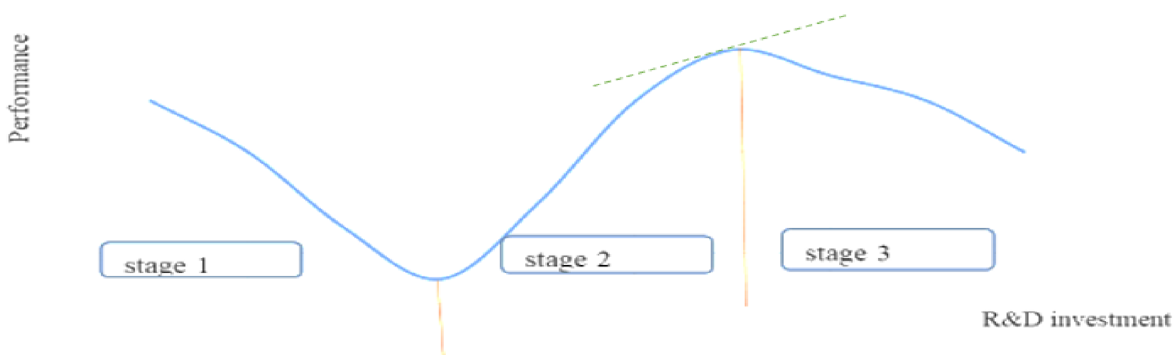

Figure 1. Three-stage sigmoid model (RN Foster, 1986)

4 Methodology

4.1 Data sources

This study was done on African firms and used firm-level and macro-level variables. I extracted the firm-level and country-level data from *Osiris* and *World Bank* databases, respectively.

4.2 Sample size and Sample distribution

I determined the final sample by excluding banks and insurance companies by considering their R&D investment might be unique. I also exclude firms with no data for the last ten years, from 2010 to 2020. I also banned firms with missed net income values, total sales, assets, current assets, current liabilities, equity, and R&D expenditures. The final sample thus comprises 923 firms in ten African countries.

I categorized the sample across countries and industries (see Table 2). Panels A sample firms across countries. Accordingly, 295 (32%), 222 (24 %), 127 (14 %), 84(9 %), 71(8 %), 52 (6 %), 30(3 %), 16 (2%), and 8(1%) are Egyptian, South African, Nigerian, Kenyan, Moroccan, Tunisian, Ghanaian, Zambian, Tanzanian, and Ugandan firms, respectively. Panel B of Table 2 reports a sample distribution across industries which are grouped based on the Global Industry Classification Standard (GICS). Accordingly, 151(16%), 136(15 %), 106(12%), 86(9%), 73(8 %), 58(6 %), 50(5 %), 44 (5 %), 35(4 %), and 19(2 %) of the sample firms are engaged in services, manufacturing, construction, food & beverage, trade& investment, energy, transport, agriculture, media & entertainment, hotel & tourism, IT & telecom, and health care industries, respectively.

Table 2. Sample distribution

Panel A: Sample distribution across countries			Panel B: Sample distribution across industries		
Country	Number of firms	%	Industry type	Number of firms	%
Egypt	295	32	Service	151	16
South Africa	222	24	Manufacturing	136	15
Nigeria	127	14	Construction	106	12
Kenya	84	9	Food & Beverage	86	9
Morocco	71	8	Trade &Investment	85	9
Tunisia	52	6	Energy	80	9
Ghana	30	3	Transport	73	8
Zambia	18	2	Agriculture	58	6
Tanzania	16	2	Media & Entertainment	50	5
Uganda	8	1	Hotel and Tourism	44	5
			IT and Telecom	35	4
			Healthcare	19	2
Total	923	100		923	100

4.3 Variables and measurement

Firm performance

The dependent variable in this study is firms' financial performanc proxied by the widely used metric, the return on assets (ROA), and computed ROA as follows in line with prior studies (Demis, Wang, Abdurahman, & Misraku, 2020; Demis, Wang, Misraku, & Yidersal, 2018a; H. Demis, 2016).

$$ROA = \frac{Net\ Income}{Total\ Assets}$$

R&D investment

I measure R&D investment by the ratio of R&D expenditure of the firm to its total sales. This approach captures inputs into the innovation process and determines the level of innovation opportunities within the firm.

$$R\&D\ investment = \frac{R\&D\ expenditure}{Sales}$$

The above R&D investment computation captures only under-investment in R&D (stage 1). However, this study proposes the horizontal S-curve that compressively captures the influence of under-investment (stage 1), optimal investment (stage 2), and over-investment (stage 3) in R&D on a firm's financial performance. Stages 2 and 3 are captured by incorporating the square and cubic of R&D investment, respectively. Therefore, I include R&D expenditure/sales square and

R&D expenditure/sales cubic as follows based on prior studies (Artz et al., 2003; Demis, Wang, Misraku, & Yidersal, 2018b; Ehie & Olibe, 2010).

$$Optimal\ R\&D\ invetsment = R\&D\ investment/sale^2$$

$$Over\ R\&D\ invetsment = R\&D\ investment/sale^3$$

Financial slack

Thoeries asserted that financial slack derives innovation, thereby maximizing profit (Barney, 1991; Cyert & March, 1963). Theories also cliamed that financial slack is a sources of management inefficiency and agency problems, thereby inhibiting firm performance (Jensen & Meckling, 1976). Such theoritical contradiction motivated me to control financial slack in this study. Available and potential slacks are used as a financial slacks indexs which are proxied as current ratio and debt to equity ratio, respectively.

$$Current\ ratio = \frac{Current\ Assets}{Current\ liabilities}$$

$$Potential\ slack = \frac{Debt}{Equity}$$

Financial development

World Bank and IMF (2005) define financial development as strengthening and diversifying the provision of vital services such as deposit and investment, loans and securities, liquidity and payment, risk diversification, monitoring of the fund users, and shaping the corporate governance of non-financial firms. This help meets economic agents' requirements effectively and efficiently, improving firm performance. Thus, I controlled financial development measured as follows in line with the World Banks measurement.

$$Bank\ deposit\ to\ GDP\ (\%) = \frac{Bank\ deposit}{GDP} * 100$$

$$Stock\ market\ cap\ to\ GDP\ (\%) = \frac{Stock\ market\ cap}{GDP} * 100$$

Selling and general administrative expenses (sgaes)

The ratio of selling and general administrative expense measures firm’s operating efficiency. An increase in this ratio implies a red light about future profitability (Anderson, Banker, Huang, & Janakiraman, 2007). More precisely, increment in this ratio indicates management inefficiency to control the costs. Such inefficiency might harm firm performance, and I controlled the selling and general administrative expense scaled by sales in this study consistent with prior studies (Lee & Wu, 2016; Stan, Peng, & Bruton, 2014).

$$\text{sgaes} = \frac{sgaes}{Sales}$$

Firm growth

I control firm growth because it is closely linked with firm’s survival and continuous growth will help survive in the market. It also help firm’s introduce innovation and knowledge of technological change. Both sales growth and employment growth are employed consistent with prior studies (Demis et al., 2018b; Vickers & Lyon, 2014).

$$\text{Sales growth} = \frac{Sales_t - Sales_{t-1}}{Sales_{t-1}}$$

$$\text{Employee growth} = \frac{Employee_t - Employee_{t-1}}{Employee_{t-1}}$$

Firm size

Studies widely emphasized the influence of firm size on performance, and their results confirm its negative and positive effects on firm performance (Aduralere Opeyemi, 2019; Olawale, 2017). Hence, I control firm size by employing the natural logarithm of firms' total assets.

Economic growth

Country's economic condition influenced firms' performance. This study used firms in ten African countries, and I believed that the heterogenous nature of those countries' economy might have influence on firm performance. Therefore, I control countries economic growth as it is proxied GDP growth rate based on constant 2010 U.S dollars (the World Bank computation of annual GDP growth rate).

Governance indicators

Effective government ensures the betterment of society and business. Primarily, the government is responsible to business regulations. World Bank's Worldwide Governance Indicators are six namely (1) voice and accountability, (2) political stability and absence of violence, (3) regulatory quality, (4) government effectiveness, (5) control of corruption, and (6) the rule of law. Their measurement ragnges from -2.5 (weak governance) and 2.5 (good governance). Hence, control of corruption, the rule of law, and regulatory quality are controlled. However, voice and accountability, political stability and absence of violence, and government effectiveness are excluded due to higher collinearity problems.

Table 3. Variables and measurements

Variables	Indicator	Measurement
Dependent variables	Return on Assets (roa)	Net income/Total assets
Independent variable	R&D investment (rds)	R&D expenditure/Sales
	R&D investment $(rds)^2$	R&D expenditure/$sales^2$
	R&D investment $(rds)^3$	R&D expenditure/$sales^3$
Control variables	Financial slack	current assets/current liabilities
		debt/equity
	Firm growth	$(sales_t\text{-}sales_{t-1})/sales_{t-1}$
		$(employee_t\text{-}emplyee_{t-1})/employee_{t-1}$
	Firm size	Natural logarithm of Total Assets
	Financial development	bank deposit/gdp*100
		stock market cap/gdp*100
	Economic growth (gdp)	Annual GDP growth rate (%)
	Governance indicators	Control of corruption (cc), Rule of Law (rl), Regularity Quality (rq)— -2.5 (weak) to 2.5 (strong)

4.4 Econometric model

$$ROA_{ij,t} = \alpha + \beta_1 ROA_{ij,t-1} + +\beta_2 rds_{ij,t} + \beta_3 rds^2_{ij,t} + \beta_4 rds^3_{ij,t} + \beta_5 cr_{ij,t} + \beta_6 de_{ij,t} + \beta_7 SGAES_{ij,t} + \beta_8 rds_{ij,t} + \beta_9 size_{ij,t} + \beta_{10} firm_{ij,t} + \beta_{11} employee_{ij,t} + \beta_{12} bdgdp_{j,t} + \beta_{13} stmktgdp_{j,t} + \beta_{14} gdp_{j,t} + \beta_{15} CC_{j,t} + \beta_{16} RQ_{j,t} + \beta_{17} RL_{j,t} + \mu + \delta + \theta + \varepsilon$$

$ROA_{ij,t}$ is firm performances of firm i, in a country j and at a time t, $cr_{ij,t}$ and $de_{ij,t}$ are available slack and potential slack of firm i, in a country j, at a time t, $SGAES_{ij,t}$ is selling general and administrative expense to sales ratio of firm i, in a country j, at a time t, $rds_{ij,t}$ is under R&D investment of firm i, in a country j, at a time t, $rds^2_{ij,t}$ is optimum investment in R&D, $rds^3_{ij,t}$ is over investment in R&D, $size_{ij,t}$ is the size of firm i, in a country j, at a time t, $firm_{ij,t}$ is firm's sales growth of firm i, in a country j, at a time t, $employee_{ij,t}$ is employment growth of firm i, in a country j, at a time t, $bdgdp_{j,t}$ is banking sector development of country j at a time t,

$stmktgdp_{j,t}$ is stock market development of country j at a time t, and $gdp_{j,t}$ is the annual GDP growth rate of country j at a time t, $CC_{j,t}$ is control of corruption of country j at a time t, $RQ_{j,t}$ is regularity quality of country j at a time t, $RL_{j,t}$ is the rule of law of country j at a time t, β_1 to β_{17} are coefficients and $\mu, \delta,$ and θ are country, industry, and year fixed effects, respectively and ε error term, and α is constant.

5 Result and Discussion

5.1 Descriptive statistics

African firms reported an average return on assets (roa) of 0.06 and R&D investment (rds) of 0.0085, respectively. They also reported an average current ratio (cacl) and debt-equity ratio (de) of 5.1244 and 1.4712, respectively. The average selling general and administrative expense (sgaes) is 0.2437, while the firm size (size) is 4.0259. African firms also reported sales (firm) and employee growth (employee) of 1.0376 and 0.2148, respectively. The sample African countries reported a bank deposit to gdp (bdpgdp) and stock market capitalization to gdp (stmktcgdp), and economic growth rate (gdp) of 46.8682, 29.1419, and 3.995 during the study period, respectively. Finally, those sample countries reported an average control of corruption (cc), regularity quality (rq), and the rule of law (rl) of -0.5185, -0.2448, and -0.3728, respectively. The negative sign of those governance indicators implied that governance is abysmal in Africa.

Table 4. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Roa	9,230	0.0627	0.5612	-27.1681	8.9537
rds	9,230	0.0085	0.0858	-1.3177	2.2705
cacl	9,230	5.1244	152.1310	-8.7205	8428.7000
De	9,230	1.4712	16.6241	-343.1730	696.3360
sgaes	9,230	0.2437	1.7321	-65.1000	60.4895
Size	9,230	4.0259	2.7149	0.0000	30.9341
firm	9,230	1.0376	30.4546	-521.8640	2236.5700
employee	9,230	0.2148	8.0023	-99.0065	715.6840
bdpgdp	9,230	46.8682	24.7032	0.0000	87.0700
stmktcgdp	9,230	29.1419	22.2181	0.0000	88.7300
gdp	9,230	3.9950	2.3997	-1.9172	14.0471
Cc	9,230	-0.5185	0.4199	-1.2747	0.2488
Rq	9,230	-0.2448	0.4289	-0.9232	0.4989
Rl	9,230	-0.3728	0.4143	-1.1815	0.1828

5.2 Correlation analysis

The absolute value of the correlation coefficient of 0.7 is a threshold for a strong association between two variables (Dormann et al., 2013). The highest correlation in this study is 0.529 between regulatory quality and control of corruption. The correlation coefficient between the rule of law (rl) and control of corruption (cc) and the rule of law (rl) and regulatory quality (rq) are 0.481 and 0.446, respectively. The correlation coefficient between the bank deposit to GDP (bdgdp) and stock market capitalization to GDP (stmktdg) is 0.472. These are relatively large coefficients but are below the threshold value of 0.7. However, the association between other variables is reasonably small (see Table 5). The correlation analysis further shows the absence of a multicollinearity problem in this study.

Table 5. Correlation analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Sgaes	1												
2. cr	-0.002	1											
3. de	0.001	-0.014	1										
4. rds	0.014	-0.020	-0.012	1									
5. size	0.001	-0.020*	0.072*	-0.160*	1								
6. firm	0.012*	0.013	0.019	-0.074	0.261*	1							
7. employee	0.211	0.007	-0.014	-0.006*	-0.239*	-0.068	1						
8. gdp	-0.006	-0.028	-0.002	-0.022	-0.193*	-0.025	-0.015	1					
9. bdgdp	0.034*	0.057	0.039	0.049*	0.061	0.017*	0.037	-0.306*	1				
10. stmktgdp	0.039*	0.003*	0.019	0.024*	-0.029	0.003	0.027	0.168*	0.472*	1			
11. cc	-0.024*	0.011	0.014	0.052*	0.116	0.011	0.026	-0.384*	0.453*	0.081*	1		
12. rq	-0.020*	0.008	0.006	0.051*	0.047	0.016*	0.032*	-0.280*	0.393*	0.235*	0.529*	1	
13. rl	-0.011	0.009	0.002	0.058	0.089	0.017	0.028	-0.288*	0.608*	0.332*	0.481*	0.446*	1

5.3 Regression result and Discussion

I used the two-step system GMM, robust Ordinary Least Square (OLS), fixed effect, and random effect regression models to check whether a three-stage sigmoid model's assumption is sensitive to different regression methods. I proved that the result is not susceptible to various regression models. The results are consistent across these regression models (see Table 6). I denote under-investment by *rds*, optimum investment by rds^2, and overinvestment by rds^3. The result of this study is impressive. There exists a signficant negative nexus between *rds* and *roa* and a signficant positive nexus between rds^2 and *roa*. However, the link between rds^3 and roa turns to negative and signficant. This result demonstrated a three-stage sigmoid (S) model in which there exists a negative linkage between underinvestment and performance (stage 1), a positive relationship between optimal investment and performance (stage2), and a negative relationship between overinvestment and performance (stage 3).

The signfciant negative nexus between underinvestment (*rds)* and firm performance (*roa)* suggests that African firms' intial investment in R&D projects should surpass a certain minimum level so that they may be better off spending on R&D projects. I caution African firms' managers to be conscious of the adverse impact of underinvestment and not to let go of R&D projects that might ultimately benefit firms. Similarly, during underinvestment, managers should exert efforts to alleviate the initial inefficiencies and enhance the benefit of R&D projects so they can rapidly get out of such sore situation. The negative nexus between overinvestment (rds^3) and firm performance (roa) implied that overinvestment hinders African firms' performance. This result further implied that the patience and resolution required in underinvestment could easily turn into unthinking rigidity in overinvestment. This result depicted the argument of Jensen and Meckling (1976) that managers might abuse their decision-making by adopting undesirable or risky projects that could hinder a firm's performance. Moreover, it implied that a firm's expansion beyond the optimum level and the rise of resources directly under managerial control would build a managerial empire but decrease firm value.

However, the positive linkage between optimal investment and performance (roa) is interesting. This linkage implied that optimum investment in R&D projects maintains a desirable financial performance. This result thus suggested that African firms should carefully monitor their R&D expenditure to prevent underinvestment and overinvestment problems. Proponents of low and high levels of R&D investment asserted that optimum investment in R& would provide new technological breakthroughs, thereby improving firms' financial performance (Sher & Yang, 2005; Zhao & Li, 1997). This is what my study discovered.

Table 6. Regression result

Roa	*GMM (1)*	*OLS (2)*	*Fixed Effect (3)*	*Random Effect (4)*
roa_1.	.0628* (.2322)			
Rds	-.8551* (.9605)	-.8367* (.4315)	-.1562*(.6127)	-.2460* (.6213)
rds^2	.8474* (.1298)*	.9957* (.4267)	.6924* (.2138)	.9874* (.2721)
rds^3	-.7935* (.9277)	-.1922* (.7454)	-.9766* (.2410)	-.9580* (.3199)
cacl	.0408* (.0751)	.0075* (.0030)	.0134** (.0017)	.0127* (0.0017)
de	-.0026* (.0407)	-.0164* (.0045)	-.0033* (.0020)	-.0023* (.0020)
sgaes	-.0910** (.4503)	-.2296*** (.0367)	-.1443* (.0236)	-.1560* (.0236)
size	-.5285* (.6387)	-.0141** (.0116)	-.0189** (.0118)	-.0207** (.0098)
firm	-.0084* (.0449)	-.0020** (.0017)	-.0029** (.0021)	-.0028** (0.0021)
employee	.1258** (.1820)	.4167** (.0368)	.1166* (.0096)	.1290** (.0098)
bdpgdp	.0011** (.0040)	.0026** (.0008)	.0006* (.0003)	.0005** (.0003)
stmktcgdp	.0017* (.0072)	.0038** (.0007)	.0008* (.0003)	.0009* (.0003)
Gdp	.0081** (.0350)	.0258* (.0054)	.0010** (.0018)	.0016** (.0018)
Cc	-.4628* (.7245)	-.7915* (.1084)	-.0795* (.0337)	-.0518* (.0342)
Rq	.2695* (.8451)	.3163* (.0778)	.0494* (.0274)	.0409* (.0279)
Rl	.3239* (.7001)	.1022* (.1134)	.2231* (.0284)	.2221* (.0290)
_cons	.8688* (.2567)	.2824* (.0938)	1.6479* (.0638)	4.7982* (0.0771)
AR(1)	0.121	R-square 0.91	R-sq between 0.7	R-sq between 0.91
AR(2)	0.481	obs 9,230	9,320	9,230
Sargan	0.712	Prob > F 0.0000	0.0000	0.0000
Hansen	0.781			

*To alleviate the potential outliers, I winsorized all variables (except governance indicators) at the 1st and 99th percentile of their distribution, * and ** denotes the significant level at 1% and 5%, respectively, standard errors are in parenthesis. (AR(1) and AR(2)) and the Sargan and Hansen tests of the validity of over-identification restriction, p-values are reported. The null hypothesis of the Arellano-Bond test for serial correlation is no autocorrelation. The null hypothesis of the Sargan test is over-identifying restrictions are valid. The null hypothesis of the Hansen test is that instruments as a group are exogenous. If the p-values of the Arellano-Bond, the Sargan, and the Hansen tests are above 0.05, the null hypotheses are accepted (Roodman, 2009). As can be seen from this Table, the p-values of the Arellano-Bond, Sargan, and the Hansen tests are not less than 0.05. We thus can conclude that there is no first-order and second-order serial correlation. The Sargan test of over-identification gives higher p-values for all models, suggesting that there is no problem of over-identification. Similarly, the Hansen test offers high p-values in all models, implying that instruments as a group are exogenous. R-square (robust OLS) and R-square between (fixed and randome) are aslo reporeted.*

5.4 Robustness check

The following further analysis checked whether the assumption of a three-stage sigmoid model is sensitive to alternative firm performance measurements in addition to different estimation techniques. In doing so, I used the alternative firm performance measure, return on equity (roe). However, the robustness analysis produces a consistent result with the main analysis implying the assumption of the sigmoid model is not sensitive to an alternative firm performance measure. For more, see Table 7.

Table 7. Robustness check

	GMM (1)	OLS (2)	Fixed Effect (3)	Random Effect (4)
roe_1	.2834* (.3280)			
Rds	-.3991* (.2189)	-.2298* (.5163)	-.2183* (.5883)	-.1904* (.5674)
rds^2	.8775* (.2061)	.8694* (.8001)	.9114* (.0860)	.8498* (.0200)
rds^3	-.2525* (.5155)	-.9925* (.8533)	-.0464* (.0724)	-.0117* (.9968)
cacl	.0529* (.0571)	.0004* (.0013)	.0005* (.0016)	.0003* (.0015)
De	-.0181* (.0318)	-0.0020** (.0016)	-.0007** (.0019)	-.0009* (.0018)
Sgaes	-.2901** (.4858)	-.0243** (.0170)	-.0091** (.0227)	-.0146* (.0202)
Size	-.2318* (.4402)	-.0018** (.0032)	-.0071** (.0113)	-.0004* (.0059)
Firm	-.01043**(.0335)	-.0007** (.0018)	-.0014* (.0020)	-.0013** (.0020)
employee	.0749** (.1499)	.0260** (.0095)	.0102** (.0092)	.0135** (.0089)
bdpgdp	.0021** (.0041)	.0011* (.0003)	.0011** (.0003)	.0010** (.0003)
stmktcgdp	.0017** (.0079)	.0011** (.0003)	.0010** (.0003)	.0010** (.0003)
Gdp	.0114* (.0245)	.0010** (.0021)	.0009** (.0017)	.0010** (.0017)
Cc	-.4193* (.4989)	-.1996* (.0387)	-.1630* (.0324)	-.1704* (.0315)
Rq	.1441* (.7915)	.0158* (.0292)	.0099* (.0263)	.0102* (.0261)
Rl	.2451* (.6576)	.0017* (.0343)	.0032* (.0273)	.0028* (.0272)
_cons	.5638* (.8826)	.3656* (.0321)	.3140* (.0613)	.3831* (.0377)
AR(1)	0.11	R-square 0.81	R-sq between 0.65	R-sq between 0.86
AR(2)	0.465	obs 9,230	9,320	9,230
Sargan	0.692	Prob > F 0.0000	0.0000	0.0000
Hansen	0.339			

*To alleviate the potential outliers, I winsorized all variables (except governance indicators) at the 1^{st} and 99^{th} percentile of their distribution, * and ** denotes the significant level at 1% and 5%, respectively, standard errors are in parenthesis. (AR(1) and AR(2)) and the Sargan and Hansen tests of the validity of over-identification restriction, p-values are reported. The null hypothesis of the Arellano-Bond test for serial correlation is no autocorrelation. The null hypothesis of the Sargan test is over-identifying restrictions are valid. The null hypothesis of the Hansen test is that instruments as a group are exogenous. If the p-values of the Arellano-Bond, the Sargan, and the Hansen tests are above 0.05, the null hypotheses are accepted (Roodman, 2009). As can be seen from this Table, the p-values of the Arellano-Bond, Sargan, and the Hansen tests are not less than 0.05. We thus can conclude that there is no first-order and second-order serial correlation. The Sargan test of over-identification gives higher p-values for all models, suggesting that there is no problem of over-identification. Similarly, the Hansen test offers high p-values in all models, implying that instruments as a group are exogenous. R-square (robust OLS) and R-square between (fixed and randome) are aslo reporeted.*

6 Conclusion and implication

6.1 Conclusion

This study examines the R&D investment and firm performance nexus under a three-stage sigmoid model. Based on data availability, I used a total of 923 firms in ten African countries. The Osiris and the World Bank databases are used to extract data for firm-level and country-level variables, respectively. I applied a two-step system GMM, robust OLS, Fixed effect, and random effect regression models to check the sensitivity of the sigmoid model to different regression approaches. However, the result is not sensitive to various regression models.

I proposed a three-stage sigmoid model based on its assumption that while underinvestment and overinvestment in R&D projects hinder firm performance, optimal investment favors firm performance. Accordingly, this study contributed by providing clear insight into the relationship between R&D investment and firm performance by considering different levels of investment in R&D projects (under-investment, optimum investment, and overinvestment). The result of this study thus demonstrates a three-stage sigmoid model. There exists a significant negative nexus between underinvestment and firm performance (stage 1), a singificant positive nexus between optimum investment and firm performance (stage 2), and a signficant negative nexus between overinvestment and firm performance (stage 3).

5.1Implication

The result of this study demonstrated a sigmoid model implying that while under and over-investment in R&D projects hinders firm performance, optimum investment favor firm performance. This meant that while managers let go of R&D projects with positive NPV at the underinvestment level, they might misuse their decision-making at the overinvestment level by investing in R&D projects with negative NPV that increases their benefit but hinders firms' value. This study suggested that African firms' managers should maintain the optimum investment in R&D projects and avoid the problems associated with under and overinvestment in R&D projects. To avoid underinvestment problems in R&D, companies should use debt financing. However, to eliminate the overinvestment problems, companies should have a good corporate governance that will possibly reduce agency problem in firms.

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