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Article

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The impacts of intellectual protection and R&D collaborations on firm-level innovations: the moderating role of internal funding

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ABSTRACT

Investments in research and development (R&D) and innovations are proven to be vital catalysts for the successful transition into knowledge-based economies. Despite the growing importance attached to innovations and R&D, they have yet to receive enough scholarly attention in developing countries. This research aims to examine whether intellectual protection and innovation collaborations influence R&D and technological innovations. The empirical results involving 549 firms revealed that trademarks positively and marginally influence technological innovations but not R&D. The findings also revealed that domestic and international innovation collaborations with other firms and universities have a positive marginal effect on both technological innovations and R&D. The results also show that firms' internal funds significantly moderate the relationship between intellectual protection, technological innovations, and R&D. The main implication from our finding is that Ghanaian firms should consider investing in intellectual protection and forging collaborations with domestic and foreign firms and universities to increase their innovation performance and competitiveness.

RESEARCH IMPACT

This research uses insights from the systemic perspective of innovation to examine how firms' open innovation (domestic and international) and intellectual property rights influence technological innovation and R&D in an emerging economy. We further assess the moderating effect of internal funds in the relationships. Our empirical model based on firm-level data from 549 Ghanaian firms revealed that firms' collaborations with domestic collaborations with other firms increase technological innovation and R&D, while collaboration with foreign firms increases just technological innovation. The results further proved that firms collaborations with Ghanaian universities increase technological innovation but not R&D. Contrary, firms' collaborations with foreign universities increase both technological innovation and R&D. Trademarks and copyright protections demonstrated to increase technological innovation and R&D. Utility models were found to increase R&D but not technological innovation. The result of the mechanism effects shows that firms' internally generated funds positively moderate the relationships between utility models and both technological innovations and R&D. A similar result was found for the positive moderating role of internal funding in the relationships between copyrights and technological innovations and R&D. Contrary, the result proved that internal funding has a negative moderating effect in the relationship between trademarks and technological innovations, as well as R&D. The research findings have several significant implications for theory and practice from the standpoint of enterprises operating in emerging markets. Theoretically, although developed economies have garnered sufficient scholarly attention on innovation collaboration and intellectual property protection, their impact on innovation remains underexplored in emerging markets. Therefore, researching how open innovation involving both domestic and foreign partners as well as intellectual property protection and how they interact with firms' internal funding resonates with emerging market perspectives. Our findings have provided empirical evidence that open innovation and intellectual property protection influence both technological and R&D activities. These findings contribute to the burgeoning systemic perspective of innovation literature. Second, this study adds some theoretical insights to our comprehension of

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the effect mechanisms through which these relationships work to impact technological innovation and R&D. These mechanism-effect relationships have not been fully examined by existing studies. The main practical implications from the finding that the low extent of open innovation is that policymakers could extend public funding support to firms and higher educational institutions that intend to collaborate with both domestic and foreign partners. Finally, the allocation of internal funds to assist R&D operations covered by trademarks, utility models, and copyrights should be a top priority for firm management in Ghana.

Introduction

Technological innovations and related activities, such as research and development, have recently been hailed as the primary drivers of long-term growth and development (Zhou et al., 2020). The endogenous growth theory underscores the importance of R&D, innovation, and human capital in countries' economic growth progression (Aghion et al., 1998). Engaging in research and development activities has been proven to have positive externalities, which can improve firms' productivity and competitiveness. In an era of intense market competition fueled by the rapid pace of globalisation, firms are encouraged to innovate to improve their competitive advantage over their competitors (Azeem et al., 2021). Several innovation models for achieving innovations have been proposed. The linear model was the first of these models that focused on providing support to engage in internal R&D. According to Godin (2006), the linear model initially focuses on basic research, is followed by applied research and development, and concludes with new knowledge production and dissemination. However, this model was criticised for focusing on innovating in isolation (Edquist & Hommen, 1999). Then came the widely accepted open innovation model (West & Bogers, 2014), which fosters innovations through a collaborative approach involving several actors in the innovation process. Firms can collaborate with actors such as knowledge institutions, clients and customers, consultants, and other firms. Then open innovation promotes resource and expertise sharing among partners, with each partner playing a complementary role. Innovation, on the other hand, extends beyond these collaborations to include vital resources such as infrastructure, human capital, and intellectual property rights tools. Several strands of research on innovations have shown that developed economies have embraced innovations (see Lascialfari et al., 2019). Developing countries are shown to be catching up with technologies and innovations, but at a slow pace (Das & Drine, 2020). However, due to heterogeneities in these countries, it is still not known which country-specific conditions drive individual countries' innovations. As a result, there is a call for research into how specific country conditions shape innovation.

Existing studies on firm-level innovations in Ghana and other developing countries exhibit numerous drawbacks that limit the scope to which firm-level innovations can be deeply analysed and understood. They have overly focused on small and medium-scale enterprises (see, for instance, Bamfo & Kraa, 2019), at the expense of large firms. We argue that for a detailed understanding of innovations, research should broadly not neglect any firm or sector in the analysis. We admit that there are numerous growing innovation studies, especially in Ghana, that have analysed innovations from the collaborating point of view (see, for instance, Odei et al., 2023). These studies have focused on innovation collaborations with just domestic partners, such as clients and customers, universities, and consultants, among others. While this study concluded that synergies involving domestic partners provide useful benefits to collaborating partners, we believe that ignoring innovation collaborations involving foreign partners limits our complete understanding of the benefits of firm collaborations. A thorough review of the extensive literature has also revealed that most of the research on innovations in Ghana and other developing countries has not considered key determinants such as intellectual property rights (IPR) protection. Although studies conducted elsewhere in the developed world have shown that they offer useful benefits to firms' innovations (see Deng et al., 2018; Odei & Hamplová, 2022). We argue that the neglect of studies on the impact of intellectual protection from an emerging market perspective limits our understanding of how they impact the innovation process in these countries. Finally, several strands of research (see Nylund et al., 2020; Odei et al., 2023) have proven that firms' internal innovation funding has a direct influence on innovations because these funds enable them to undertake and sustain the innovation process. But fewer studies, especially in emerging economies

like Ghana, have focused on the mechanisms by which firms' internal innovation funding moderates the relationships between intellectual property rights and innovation processes. Ignoring these critical determinants make our understanding of the innovation ecosystem in developing countries like Ghana incomplete, necessitating a different research approach or one that incorporates these neglected aspects of firms' innovation processes to provide a broader understanding of the innovation landscape. This research fills this gap by examining whether firms' domestic and international innovation collaborations as well as intellectual property rights influence their technological innovation and R&D. We further assess the mechanisms through which firms' internal funds moderate the relationships between innovation collaborations, intellectual property rights, and firms' technological innovations and R&D. To fulfil the objectives outlined above, this research seeks to answer the following research questions:

1. Do domestic and international innovation linkages influence technological innovation and R&D in emerging economies?
2. Does intellectual property right protection enhance technological innovation and R&D in emerging economies?
3. How do firms' internal funds moderate the relationships between innovation collaboration and intellectual property rights protection in emerging markets?

For the empirical estimation, we used a dataset from 549 firms in Ghana to examine whether intellectual property rights protection and innovation collaborations influence technological innovations and R&D. This study is novel as it analyses the influence of foreign innovation collaborations involving foreign firms and academic institutions and their abilities to influence Ghanaian firms' innovations. To the best of the researcher's knowledge, no existing research has examined these relationships in Ghana and other African countries. Another theoretical implication of the paper is its contribution to the growing literature on intellectual property rights and their ability to influence firms' innovation. Existing studies on IPRs' influence on firms' innovations have disproportionately focused on using patents as a measure while ignoring other forms of intellectual property rights protection such as utility models, copyrights, and trademarks. Our results have established that other IPR tools, such as utility models, trademarks, and copyrights, could positively influence firms' innovation performances. These results contribute to increasing the current knowledge of other less known intellectual property protection tools such as trademarks, copyrights and utility models as suitable substitutes for patents, which have been proven to influence innovation outcomes. These findings add to and expand on the growing literature on firm innovations from a systemic perspective and from the perspective of developing countries. One key practical implication from our results is that Ghanaian firms' collaborations with foreign partners could allow them to access advanced foreign knowledge, expertise, and technologies, which could have positive spillover effects on the entire Ghanaian economy. The main limitation of this research relates to the use of cross-sectional data for 2013. While we admit that this data could be considered outdated, it's the current and only innovation data released by the WBES for Ghana. The nature of the data also prevented panel data analysis due to data availability, especially for other countries. Despite these limitations, the results provide useful insights that could serve as the basis for understanding how intellectual protection and innovation collaborations influence firm-level innovations in Ghana during the years of the survey.

The rest of the article is organised in the following order: Section two reviews and deliberates on existing literature on the concepts of technological innovations, research, and development and the various factors boosting them. Section three is devoted to the methodology, measures, and source of data, while Section four is devoted to the detailed discussion of the empirical results in relation to the existing previous studies. Section five concludes the research with suggestions for further research, policy, and practical recommendations, as well as research limitations.

Theoretical background and hypotheses formulation

The main theoretical foundation of this research is the systemic perspective of innovation, which postulates that efficacious and sustainable innovation is contingent on firms' ability to coordinate and integrate a broad range of both internal and external antecedents of scientific and specialised knowledge (Midgley & Lindhult,

2021). For the past two decades, the national innovation systems of several countries have followed a linear model. This linear innovation model theorises that firms entirely depend on internally generated knowledge; this is characterised by an absurdly weak dependence on the integration of external knowledge. Innovation policies based on the linear model are primarily focused on providing public subsidies to businesses and providing the necessary R&D infrastructure needed to accelerate innovation. However, there has been a paradigm shift in policy focus in recent times, with the belief that innovation is an open process with an organised social tendency that is primarily fuelled by external knowledge (West & Bogers, 2014). The source of this external knowledge is cooperating with actors such as universities, various government ministries, other firms, suppliers, clients, and consultants (West & Bogers, 2014). The new knowledge obtained from these external partners becomes important for firms' innovation outcomes (Odei et al., 2023). It helps revive stagnated processes, leading to innovations. However, for new knowledge to be beneficial to firms' innovations, they must improve their absorptive capacities through human capital development.

Innovation refers to an organisation's aptitude to apply significantly improved knowledge, ideas, or behaviours that are expected to result in improved products, internal processes, marketing, and organisational management practices (Martínez-Ros, 2019). Innovation has become one of the most influential strategic resources firms can rely on to improve their competitiveness, performance, and productivity. The continued improvements in firms' innovation competencies are beneficial to improving and placing them competitively amidst the fast-paced, changing market environment. Industrial innovation capabilities rest on the capability to persistently convert new knowledge and ideas into significantly improved products, processes, marketing, and organisational methods to realise more profits. Innovations can therefore be new to the firm itself or to the firm's market (Odei & Hamplová, 2022). This implies that a given invention could be new to the firm itself and its competitors, and this novelty could grant them a temporary competitive advantage until their rivals follow in their footsteps. According to the source measures, innovations can be classified as technological or non-technological (Geldes et al., 2017). Technological innovations broadly encompass improved products and processes, while non-technological innovations entail marketing and organisational innovations (Geldes et al., 2017; Odei et al., 2023). Technological innovation is a broad set of activities undertaken by firms or in close collaboration with other actors that significantly lead to technological advancements that provide economic benefits to firms. Technological innovations essentially involve the expansion and utilisation of advanced technologies (Geldes et al., 2017). Research and development activities are known to be a significant source of new knowledge and a proven catalyst for the innovation process. Though R&D is an important source of new knowledge, certain schools of thought believe that it is not necessarily a requirement for innovations and that this could be acquired elsewhere through collaboration (Cappelen et al., 2012).

Research on the nexus between firms' innovation and intellectual property rights (IPRs) has increased in recent times (see, for example, Neves et al., 2021). Intellectual assets consist of the various forms of IPR protections that are indispensable for firms to transfigure their inventions and creativity into economic gains. IPRs enable inventors to protect their new knowledge and discoveries, as they grant them the exclusive right to benefit from these inventions. In the absence of these intellectual property protections, the free market will not afford inventors adequate inducements to undertake risky and costly investments to generate new knowledge and technologies. Vigorous IPR protection is necessary because knowledge has the special attribute of being a public good that is non-excludable. These distinct attributes make it problematic and difficult to prevent other people from using new knowledge without the consent of the inventor. IPR protection therefore serves as an incentive to finance innovation and boost innovation collaborations. The lack of these intellectual property protections is a disincentive to firms' innovations as they decrease the expected benefits; this could make inventors unwilling to undertake innovative activities (Acemoglu & Akcigit, 2012). Several IPR tools, such as trademarks, utility models, patents, copyrights, service marks, and industrial design rights, are used for protection. Patents are the most widely used and researched among all these tools. Intellectual property is considered an essential factor in determining whether individuals will be successful in launching new high-tech firms or expanding existing ones (Laplume et al., 2014). Research by Odei and Hamplová (2022) in small businesses found that European utility models influence both major and minor forms of innovation but not general innovations. Jafari-Sadeghi et al. (2021) found that trademarks positively influence technology expansion. Relatedly, Carree et al. (2015) also concluded that both trademarks and patents positively influence

innovative activities. Based on the findings of these studies, we summarise the understanding that IPR such as patents, copyrights, utility models and trademarks could be vital to the success of innovations because they provide legal protections and exclusive rights to innovative firms. These rights incentivize investments in R&D by ensuring that innovative firms can recoup their profits and investments from their innovation activities. We therefore hypothesise that

Hypothesis 1a: Trademarks are positively related to R&D and technological innovations.
Hypothesis 1b: Utility models has a positive influence on R&D and technological innovations.
Hypothesis 1c: Copyrights are expected to positively influence R&D and technological innovations.

Firms' innovation collaboration has also been proven to be an effective means through which firms can acquire new knowledge, technologies, and expertise if they do not have the competencies to generate them internally (Odei et al., 2020; West & Bogers, 2014). The open innovation model, which postulates that firms need not innovate in isolation but rather collaborate with other partners through resource pooling, suggests firms forge networks with external collaborators to supplement internal activities proposed to stimulate and sustain innovations. Firms require cooperative learning capabilities to be able to generate, broadcast, understand, and merge new external knowledge from network innovation development (West & Bogers, 2014). These collaborations also allow firms to collectively share the expected benefits and costs involved in the innovation process. Firms have lots of partners to collaborate with, namely higher education institutions, consultants, other firms, and customers, among others. In all these partnerships, the collaborations of academic institutions have been heralded as an effective means of acquiring new external knowledge due to their research focus (Fitjar & Gjelsvik, 2018). R&D activities performed by universities and other research institutes advance innovations in many ways. The common view assumes that academic research activities result in codified knowledge that manifests itself through journal publications. This knowledge is epitomised in the technological innovations and discoveries that firms can utilise to innovate. Firms' R&D collaboration with other firms can enable this codified knowledge to be transferred. A study by Odei et al. (2023) among Ghanaian firms concluded that firms' collaborations with other firms positively influenced process and marketing innovations, while collaborations with suppliers were positively correlated with organisational innovations. However, collaborations with Ghanaian universities negatively influenced all innovation outcomes. A related study by Azamela et al. (2022) in Ghana also found that firms' engagement with Ghanaian cooperative partners like universities enhances their innovation capacities. Based on the conclusions of these studies, we anticipate that firms' domestic partnerships with other firms and universities could enhance their ability to access new knowledge, resources, and expertise, which have been proven to significantly influence internal innovation efforts. Without these innovation collaborations, firms may not have access to these external knowledge and resources, so they may struggle to innovate. Based on the findings of these referenced studies, we hypothesise that

Hypothesis 2a: Firms' collaboration with other domestic firms is positively correlated with technological innovations and R&D.
Hypothesis 2b: Collaborations with domestic universities positively influence technological innovations and R&D.

Collaboration with foreign partners such as clients and universities, among others, provides access to advanced technologies, expertise, and knowledge that may not be readily available domestically (Audretsch & Belitski, 2024; Odei & Stejskal, 2020; Un & Rodríguez, 2018). This exposure to new knowledge and techniques can stimulate innovation within domestic firms, leading to the development of novel products or processes. Partnering with foreign firms, for instance, can facilitate access to new markets, distribution channels, and customer segments (Odei & Stejskal, 2020). By leveraging the networks and market insights of their foreign partners, domestic firms can identify and capitalise on emerging opportunities, driving innovation in response to changing market demands. International innovation collaborations have also been proposed to overcome weak domestic innovation potential (Moaniba et al., 2019). Due to the weak innovations in Ghana, firms could profit from internationalisation by forging collaborations with foreign partners such as universities, consultants, and other firms. These international linkages could be

avenues for firms to access advanced knowledge, technologies, and expertise, which are usually lacking in developing countries (Rodríguez et al., 2018). The continuous public support for innovations in advanced countries means that they abound in such advanced knowledge generated from R&D. This can have positive spillover effects in Ghana with minimal public innovation support. Odei and Stejskal (2020) research discovered that international collaborations with universities and businesses have additional effects on technological innovations and external R&D. We therefore summarise the understanding based on the above-mentioned existing studies that foreign knowledge, technologies, and expertise from other firms and universities could be beneficial to firms in countries with weak innovation prospects. These foreign collaborations could allow firms to access new knowledge that cannot be produced domestically due to the weak innovation ecosystem. This foreign knowledge can influence the technological knowledge and R&D potential of firms and have positive externalities on the entire economy. As a result, we hypothesise.

Hypothesis 3a: Firms' collaboration with foreign universities positively enhances technological innovations and R&D.

Hypothesis 3b: Firms' collaboration with foreign firms is positively related to improved technological innovations and R&D.

Funding is a fundamental factor affecting firms' research and development as well as innovation activities (Odei et al., 2023). The lack of funding may constrain firms' abilities to engage in R&D, which is known to improve innovation development. Innovation funding is a major concern for firm managers, industry practitioners, and policymakers because funding limitations due to imperfections in the capital markets lead to drastic reductions in innovation investments (Hottenrott & Peters, 2012). Sustainable innovation investments could impinge on financial constraints due to information asymmetries and high levels of uncertainty surrounding innovation activities. Innovation activities are cost-intensive, so the availability of funding could ensure that firms do not abandon on-going projects. Research on innovation funding by Shankar (2020) concluded that innovation funding impediments serve as a key factor that negatively influences African firms' innovation activities. Odei et al. (2023) study on Ghana found that internal funds positively influenced technological innovations in both the service and manufacturing sectors. Similar studies by Asiedu et al. (2021) found that internal funding enhances new product development among sub-Saharan African firms. However, Udimal et al. (2019) studies on Ghanaian small and medium-scale enterprises concluded that internal funding does not significantly influence new product innovations.

Despite the importance of funding in the innovation process, most firms in African countries face hurdles with financial access. They face considerable challenges, such as high interest rates and collateral demands (Appiah et al., 2019). These challenges mean that firms are normally cut off from the financial markets and other external funding sources (private and government). Firms may have to rely on internal funds generated from their accumulated profits. These internal funds will constitute most of the funding for firms, and this can influence their innovation activities, such as R&D, acquiring IPR tools, human capital development, and collaboration, among others. Firms with greater internal funding are better positioned to invest in collaborative innovation projects, both domestically and internationally (Fan et al., 2019). Adequate internal financial resources enable firms to cover the costs associated with collaboration, such as R&D expenses, personnel costs, and technology acquisition. Furthermore, internal funding levels impact the intensity as well as scope of firms' R&D activities, which in turn affects their ability to innovate (Cuervo-Cazurra et al., 2018). Firms with higher levels of internal funding could afford to allocate more resources to R&D efforts, including the development of new technologies, products, or processes. This increased R&D intensity can amplify the positive effects of intellectual property rights on innovation by enabling firms to pursue and sustain their innovation activities. We therefore posit that internal funding is more likely to moderate firms' collaboration and ability to secure IPR tools, which could influence overall innovation performances, which is in line with the systemic perspective of innovation theory that views access to funds as an internal asset (Midgley & Lindhult, 2021). We therefore hypothesise that

Hypothesis 4: Internal funding is expected to positively moderate the relationships between firms' collaborations and abilities to acquire intellectual property rights.

Methodology

Data for the empirical specification is based on a sample of 549 firms obtained from the World Bank Enterprise Survey (WBES) conducted between 2010 and 2013. As of the time of completing this research, the 2013 dataset is the latest released by the WBES for Ghana. The WBES is jointly conducted by three major financial institutions, specifically the European Bank for Reconstruction and Development (EBRD), the World Bank Group (WBG), and the European Investment Bank (EIB). The WBES is currently carried out in about 154 countries, encompassing more than 180,000 firms. The WBES solicits data using the stratified random sampling technique based on industries, firm size, and geographical locations (regions). The WBES has a broad array of data covering innovations, innovation collaborations, sources of innovation funding, intellectual property rights protection, firm characteristics, and human capital, among others. This comprehensive nature of the data makes the WBES one of the best datasets for empirical analyses of firm-level innovations. The popularity and usage of the WBES dataset have soared among innovation scholars, and it has been extensively used for several firm-level innovation analyses (see Odei et al., 2023). The final sample involved large and small firms from both the manufacturing and service sectors of Ghana, with a sectoral breakdown as follows: service sector (265, 48.27%) and manufacturing sector (284, 51.73%). The data was first cleaned before the empirical analysis; we omitted all 'don't know' spontaneous responses and replaced missing values with zeros.

All the key variables considered in this paper are binary and span around technological innovations, innovation collaborations, intellectual property rights protections, internal funding, and R&D. The binary attributes of these variables make it essential to utilise latent variables to empirically model their relationships. We acknowledge that there are evident unobserved variables or structural characteristics that could possibly influence both R&D and technological innovations, since R&D could be considered a catalyst for innovations. Our empirical strategy therefore first estimates bivariate probits without considering R&D as an endogenous dummy variable. This approach enabled us to determine whether a joint estimation is appropriate, but it did not allow us to calculate the influence of R&D on technological innovations. The presence of exogeneity is then tested by using maximum-likelihood simultaneous estimations of the two probit equations; this analytical approach is known as the recursive bivariate probit (Monfardini & Radice, 2008). Similarly, Filippini et al. (2018) describe this estimation strategy as a seemingly unrelated probit model with an endogenous binary variable. The seemingly unrelated bivariate probit model is generally used to calculate two simultaneous equations where one of the outcome variables is used as a covariate to predict the other. In sum, the bivariate probit model concurrently models two binary dependent variables whose unobserved characteristics are assumed to be correlated. This model simplifies the index function of an unobserved latent variable to another that may be considered orthogonal (Holm & Jæger, 2011). We presuppose that technological innovation is a latent variable designated by Z*1i, while Z*2i represents the other latent variable capturing R&D. As a result, we specify the two concurrent equations, with the unobserved latent as

$$Z_1^* = X_1\beta_1 + \varepsilon_1 \tag{1}$$

$$Z_2^* = X_2\beta_2 + \varepsilon_2 \tag{2}$$

where ε_1 and ε_2 are mutually normal with 0 means, same variances, and correlation ρ

$$\begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{Bmatrix} | X \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix} \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right) \tag{3}$$

We provide the bivariate probit model with observed outcomes as

$$Z_1 = \begin{cases} 1 & if\ Z_1^* > 0 \\ 0, & otherwise \end{cases} \tag{4}$$

$$Z_2 = \begin{cases} 1 & if\ Z_2^* > 0 \\ 0, & otherwise \end{cases} \tag{5}$$

Finally, we specify the bivariate probit model as

$$P\ (z_1 = i, z_2 = j) = \Phi_2\left(X_1'\beta_1, X_2'\beta_2, \rho\right)$$

We used the estimates of the marginal effects of the covariates in the conditional distribution (Greene, 1996). The marginal effects estimates allowed us to determine the directions and magnitudes of changes in the conditional probability of an outcome variable when there is a unit change in a covariate, holding all other remaining covariates constant (Onukwugha et al., 2015). The marginal effect for binary variables determines exactly how the conditional probability changes when the binary variable changes from 0 to 1. We specify the marginal effect for the bivariate probit model as

$$\frac{\partial \Pr(y-1)}{\partial x_k} \text{-} \emptyset(x\beta)\beta x \tag{6}$$

where $\emptyset(x\beta)$ represents the standard normal density computed at $x\beta$; βx is weighted by a factor f that depends on the values of regressors in x.

Finally, since our data is cross-sectional, we cannot completely rule out the issue of endogeneity as there is limited variability in the variables. We used the treatment effects technique to account for potential endogeneity in the variables (Hamilton & Nickerson, 2003). We utilised the inverse probability weights (IPW) method. This technique was employed to calculate the average treatment effects (ATE), which has been proven to yield consistent and robust outcomes due to the model's double robustness attribute. The IPW estimator involves two important steps (Seaman & White, 2013). It first works by fitting a propensity score model to calculate the probability of allocating conditional treatments to experimental baseline properties. Second, it estimates two models that assess the outcome based on the treatment and control groups. Each of the outcomes is weighted using the propensity scores from the first stage to produce weighted averages of the two outcome models (Seaman & White, 2013). The ATE results allowed us to determine the additionality effects of treatment on the outcomes of interests and thus, R&D and technological innovations. We modelled both outcome-dependent variables with R&D and technological innovations, while the treatment-dependent variables were the various dummy covariates that focused on treatments.

Measures

Dependent variables

We adopted two outcome variables to capture the levels of firm-level innovation. The first dependent variable is *technological innovation*, which is a dummy variable with a value of 1 if firms introduced significantly improved products or processes and 0 if they did not. Several studies have used similar measure for technological innovation (see for example, Odei et al., 2023). *Research and development* have been well-proven to be the greatest source of new knowledge production (Cuervo-Cazurra et al., 2018; Odei & Stejskal, 2020). The second outcome variable is R&D, a dichotomous variable with 1 indicating firms undertook R&D internally and 0 connoting they did not engage in any R&D activities.

Independent variables

In agreement with the literature (see, Deng et al., 2018; Odei & Hamplová, 2022), our first three covariates focus on measures widely used to capture intellectual property right protection. The first measure focuses on the *utility model,* taking the value of 1 if firms have acquired them and 0 otherwise. The second covariate is *trademark,* a binary variable with a value of 1 if firms confirm having trademarks and 0 otherwise. The third covariate is *copyright*, a measure with a value of 1 if firms have acquired copyrights in the last three years and 0 if otherwise. The next set of covariates focuses on firms' domestic and foreign innovation collaborations in agreement with the literature (Odei & Stejskal, 2020). The first is *firms' collaborations with domestic firms*, a binary variable with 1 meaning firms collaborated with other firms in the last three years and 0 meaning otherwise. The second is *collaboration with foreign firms*, also binary, with 1 denoting an establishment collaborated and 0 meaning they didn't. The next variable is *collaboration with domestic universities*, a measure of whether firms collaborated with Ghanaian academic institutions such as universities, with 1 signifying yes and 0 no. The *collaboration with foreign universities* variable focuses on whether firms reported to cooperating with foreign universities, where 1 means yes

and 0 means they didn't have these collaborations in the last three years. In accordance with the existing literature (see, Cuervo-Cazurra et al., 2018; Fan et al., 2019), firms' own internal funds have been acknowledged to play a significant role in their innovation activities. Internal funding provides firms with the needed financial resources to allocate towards innovation and R&D initiatives. Based on these literature, we included the variable *internal funding*, measuring whether firms reported to fund their innovation activities with their own internally generated funds, with 1 signifying yes and 0 meaning no.

Control variables

We controlled for sectoral characteristics that can help us better understand innovation dynamics across sectors. This is because innovation significantly varies across different sectors (Tether, 2003). We introduced the sector dummy, which contrasted the manufacturing and service sectors, a variable with 1 indicating the manufacturing sector and 0 indicating the service sector.

Results and discussions

Table 1 describes the results of the descriptive statistics, aimed at providing a general overview of the variables used in the study. The results show that about 27% of the sample reported having implemented technological innovations. Only about 16% of firms in our sample reported having invested in R&D. When it comes to intellectual property rights protection, just 3% of the sampled firms reported having utility models, copyrights, and trademarks. These results show that the levels of intellectual property rights protection in Ghanaian firms are very low. Our results on the low levels of intellectual property rights protection in Ghana have been confirmed by other studies (see Okyere & Denoncourt, 2021; Sey et al., 2010). Regarding firms' innovation collaborations, the results show that the extent of these collaborations is very low or almost non-existent. Although innovation collaborations are low, interfirm synergies were a bit higher in comparison to collaborations with domestic and foreign knowledge repositories. These low levels of firm and institutional collaborations have been confirmed by other related studies such as (Odei et al., 2023). Regarding funding sources, the results show that about 62% of the sampled firms reported using their own internal funding for their operations as well as innovations. Finally, most of the firms in the sample are from the manufacturing sector, representing about 52%. Table 1 also reports the results of the Pearson chi-squared (χ^2) test to establish the relationships between technological innovation, research and development, and intellectual property rights and innovation collaborations. The Pearson chi-squared (χ^2) test results revealed that all the selected variables have significant associations with technological innovations (except firms' collaborations with foreign universities). On the other hand, all variables of interest demonstrated statistically significant associations with research and development, with the only exception being collaborations with foreign firms.

We subsequently used the bivariate probit model to concurrently model the relationships between measures of intellectual property rights and innovation collaborations and both technological innovations and R&D. First, we used the bivariate probit model, and then we applied the seemingly unrelated

Table 1. Descriptive statistics and Pearson chi-square for both outcomes.

Variables	Means	Technological innovations χ^2	Research & development χ^2
Technological innovations	0.270	–	–
Research and development	0.163	–	–
Utility models	0.029	3.934*	8.999**
trademarks	0.026	13.394***	11.838***
Copyright	0.026	6.024**	11.838***
Domestic firms	0.004	10.827***	10.098***
Foreign firms	0.003	10.827***	3.320
Domestic universities	0.003	8.113**	5.562**
Foreign universities	0.001	2.699	5.109*
Internal funding	0.617	46.560***	36.375***
Manufacturing sector	0.517	0.486	8.240**

Source: Own estimations.
*Significant at 10%. **Significant at 5%. ***Significant at 1%.

bivariate probit model. Using these two well-known methods allowed us to decide on a suitable model that perfectly fit the data. Table 2 shows the results of the marginal effects after the bivariate probit model analysis of the outcomes of technological innovations and R&D. The results of the marginal effects of the bivariate probit regression model are shown in Table 2. As shown by the results of the Wald test of rho (from the first stage analysis), the coefficient is positive and statistically significantly different from zero at the 95% significance level. This result signifies that the unobserved heterogeneities of R&D as well as technological innovations are correlated. This further suggests that the concurrent estimation approach could be useful in enhancing the efficiency of the estimates if there are mutual determinants influencing both technological innovations and R&D outcomes. The two outcome variables of technological innovations and R&D could hence be said to be interrelated, and it is plausible that they can be related to each other.

The marginal effect results in Table 2 show that just trademarks demonstrated a positive influence on technological innovations ($\beta = 0.281$, $P < 0.05$). This therefore confirms our hypothesis 1a, which is partially supported by technological innovations. We found no statistically significant relationships between utility models and copyrights and their abilities to influence both R&D and technological innovations. These results mean that we reject hypotheses 1b and 1c. The results on innovation collaborations show that Ghanaian firms' collaborations with other domestic firms positively influence both technological innovations and R&D, hence fully supporting our hypothesis 2a. Our hypothesis 2b is also partially supported; we find that Ghanaian firms' collaboration with domestic universities positively influences technological innovations. When it comes to firms' foreign collaborations, the results revealed that foreign universities positively influence technological innovations and R&D. This means our hypothesis 3a is fully supported. Finally, we find evidence in our sample supporting the claim that firms' collaborations with foreign firms are likely to positively influence technological innovations but not R&D activities. As a result, hypothesis 3b is only partially supported. Other findings indicate that internal funding is a positive and statistically significant predictor of both R&D and technological innovations in the sampled firms. The results of the moderation analysis show that internal funds moderate relationships with intellectual property rights but not collaborations. These results mean that hypothesis 4 is partially supported. Finally, firms in the manufacturing sector are more likely to engage in R&D compared to those in the service sector.

As explained above, the summary statistic results of the bivariate probit model establish that the simultaneous estimation approach could change the efficiency of the results if there are shared factors affecting both technological innovations and R&D outcomes. Nonetheless, as indicated above, there happens to be a significant correlation between the two outcome variables' error terms. This situation does not automatically mean that they are interrelated. We therefore further used the recursive bivariate probit estimation method to assess whether the two variables are truly correlated. Table 3 above reports the results of the simultaneous estimations of research and development and technological innovations. While some may argue that R&D accelerates innovation, we argue in this paper that internal R&D is not always required for the introduction of new products (Bilbao-Osorio & Rodríguez-Pose, 2004; Cappelen et al., 2012). Firms without R&D capabilities could decide to partner with other firms or institutions, such as universities and other

Table 2. Results of marginal effects of bivariate probit regression.

Variables	Technological innovations Dy/dx (delta-method std. err.)	Research and development Dy/dx (delta-method std. err.)
Utility models	−0.047 (0.112)	0.071 (0.079)
trademarks	0.281* (0.146)	0.082 (0.109)
Copyright	0.060 (0.124)	0.130 (0.090)
Domestic firms	1.742*** (0.070)	0.208* (0.037)
Foreign firms	1.781*** (0.106)	0.068 (0.159)
Domestic universities	1.649*** (0.115)	0.095 (0.194)
Foreign universities	0.289** (0.112)	1.393*** (0.185)
Internal funding	0.259*** (0.036)	0.208*** (0.037)
Manufacturing sector	−0.053 (0.035)	0.069** (0.030)
Model fit summary		
Observations	549	
Wald test of rho = 0	8.902** (0.003)	

Source: Own estimations.
*Significant at 10%. **Significant at 5%. ***Significant at 1%.

Table 3. Results of marginal effects of seemingly unrelated bivariate probit.

Variables	Technological innovations Dy/dx (delta-method std. err.)	Research and development Dy/dx (delta-method std. err.)
Utility models	−0.066 (0.126)	0.069 (0.077)
trademarks	0.262 (0.168)	0.089 (0.098)
R&D	0.155 (0.564)	–
Copyright	0.027 (.1786)	0.127 (0.092)
Domestic firms	1.569 (130.236)	0.307* (0.152)
Foreign firms	1.673 (171.898)	0.068 (0.164)
Domestic universities	1.509 (143.757)	0.092 (0.171)
Foreign universities	0.120 (343.957)	1.340 (76.032)
Internal funding	0.228 (0.137)	0.209*** (0.037)
Manufacturing sector	−0.065 (0.050)	0.069* (0.030)
Model fit summary		
Observations	549	
Wald test of rho = 0	8.902** (0.003)	
LR test of rho = 0	0.001 (0.978)	
Prob > chi2	0.000***	

Source: Own estimations.
*Significant at 10%. **Significant at 5%. ***Significant at 1%.

Table 4. Moderation role of firms internal funding on both outcomes.

Variables	Technological innovations Coefficients (robust std. err.)	Research and development Coefficients (robust std. err.)
Utility models	−7.026*** (0.271)	−7.514*** (.253)
trademarks	7.026*** (0.271)	7.514*** (0.214)
Copyright	−4.619*** (0.117)	−4.030*** (0.167)
Internal funding	0.863*** (0.138)	1.016*** (0.185)
Utility models*funding	6.952*** (0.470)	8.002*** (0.405)
trademarks*funding	−6.295*** (0.580)	−7.550*** (0.530)
Copyright*funding	5.057*** (0.470)	4.939*** (0.480)
Constant	−1.242*** (0.117)	−1.820*** (0.167)
Model fit summary		
Observations	549	
Wald test of rho = 0	6.892** (0.009)	
athrho	0.244** (0.009)	
Prob > chi2	0.000***	

Source: Own estimations.
Note. The four collaboration variables have few values (observations) as seen from the mean results in Table 1. So, the interaction effects could not be estimated.
*Significant at 10%. **Significant at 5%. ***Significant at 1%.

higher educational institutions, in the open search for new knowledge. We therefore considered R&D endogenous, as previously explained above.

The results of the first stage model summary in Table 3 show that the p-value for the test of $\rho = 0$ is 0.978, and X^2 is 0.001 for the seemingly unrelated bivariate probit model. This result shows that the two explanatory variables are not jointly determined. This result means that technological innovation does not necessarily depend on research and development activities undertaken by firms. These innovations could be acquired from other partners and not through internal R&D. The results further indicate that there are heterogeneities in R&D and technological innovation outcomes. Because these two equations are not mutually determined, the estimations can be performed independently, so we consider the results of the bivariate probit to be consistent. Subsequently, we introduced the moderator variable of internal funding into the model. Engaging in innovation and R&D is known to be a cost-intensive venture that requires huge funding to be able to start and sustain. Our initial analysis of the WBES data shows that most of the Ghanaian firms' funding is generated internally with minimal public support (Odei et al., 2023). We therefore analysed whether these internal funds moderate the effect of firms' innovation collaborations and intellectual property rights protection. We estimated two separate models for each of the two outcomes. The results of the moderating role of internal funding on both outcomes are shown in Table 4 above.

When the moderator is included in the model, we see that the moderation effect for firm innovation collaboration could not be determined due to the smaller number of observations, as shown by the mean results in Table 1. However, when it comes to intellectual property rights, internal funds positively moderate the relationships between utility models and both outcome measures. The result also shows

Table 5. Results of average treatment effects for both outcomes.

Variables	Technological innovations Coefficients (robust std. err.)	Research and development Coefficients (robust std. err.)
Utility models	0.226 (0.126)	0.282* (0.125)
trademarks	0.445*** (0.122)	0.345** (0.135)
Copyright	0.299* (0.134)	0.345** (0.135)
Domestic firms	0.732*** (0.013)	0.590** (0.217)
Foreign firms	0.732*** (0.013)	0.339 (0.250)
Domestic universities	0.732*** (0.013)	0.505 (0.273)
Foreign universities	0.730*** (0.013)	0.838*** (0.016)
Internal funding	0.269*** (0.034)	0.196*** (0.027)
Observations	549	

Source: Own estimations.
*Significant at 10%. **Significant at 5%. ***Significant at 1%.
Note. ATE was calculated using the inverse probability weighting method, with technological innovations and research and development as explanatory variables.

that internal funds negatively moderate the relationships between trademarks and both outcomes of technological innovations and R&D. Finally, the results concerning the moderating role of internal funds on copyrights are as anticipated. The availability of internal funds plays a moderately positive role in the relationships between copyrights and both outcome measures.

Research and development (R&D) and innovation are hailed as the most important drivers of long-term productivity and competitiveness. At the macro level, investments in innovations and R&D have long been considered one of the best means to accomplish economic growth (Gardiner & Hajek, 2020). The results of the research have revealed that trademarks positively and marginally influence technological innovations. Firms that reported having trademarks are likely to improve their technological innovations marginally by about 28 percentage points. The results of the average treatment effects model, which is robust to endogeneity issues, provide a different result. It shows that firms with trademarks are more likely to improve their R&D by about 35 percentage points and their technological innovations by 45 percentage points when compared to firms without trademarks. Though utility models and copyrights were not statistically significant determinants of technological innovations and R&D, the ATE results in Table 5 provide different results. Firms that reported having utility models are more likely to enhance their R&D potential by about 28 percentage points when compared to firms without. However, when it comes to copyrights, the ATE results in Table 5 show that firms that reported having copyrights are more likely to enhance their technological innovations by about 30 percentage points and R&D by 35 percentage points. All these results are as expected because, with the weak intellectual property rights protection in Ghana, firms with these tools will be able to protect their new knowledge, inventions, and innovations from reaching their competitors. With these protections, they will be able to openly innovate without fear of, for instance, facing unhealthy competition from informal sector firms. Besides, when inventors become fully aware that their inventions could be protected, it can be a strong incentive for them to commit more resources to engaging in innovations. These results corroborate the findings of other related studies undertaken in Ghana and other African countries (see Marire, 2022; Udimal et al., 2019).

The results on the importance of innovation collaborations and their influence on both R&D and technological innovations are all as expected and in line with the literature (see, for instance, Odei et al., 2023). Although the means and results in Table 1 show that the extent of these innovation collaborations is low, they have proven to provide benefits for technological innovations and R&D activities. We found that collaborations with domestic firms are more likely to increase technological innovations and R&D marginally by 74 and 21 percentage points, respectively. Different results were observed for collaborations with foreign firms, which influenced technological innovations only marginally by 78 percentage points. The same results were provided by the average treatment effects, where firms that reported collaborating with domestic and foreign firms were more likely to stimulate their technological innovations marginally by 73 percentage points vis-à-vis non-cooperating firms. However, the influence of these collaborations was stronger for technological innovations than R&D, with just a 59-percentage point possibility of increase. Collaborations with foreign firms could help spur domestic innovations as they will allow Ghanaian firms to access new knowledge from abroad, which can have positive spillover effects on the entire Ghanaian economy (Odei & Stejskal, 2020; Un & Rodríguez, 2018). Also, given the low level of R&D in Ghana as shown

by the descriptive statistics, these foreign collaborations could help complement the R&D efforts of Ghanaian firms, leading to improved innovation performance. Our results on the importance of inter-firm collaborations and their influence on innovations in Ghana corroborate the findings of related research such as (Adomako & Nguyen, 2020; Adomako et al., 2021; Odei et al., 2023).

We found compelling evidence of benefits in the sampled firms' collaborations with both domestic and foreign academic institutions, as well as their ability to influence R&D and innovations. Firms' collaborations with Ghanaian universities increased the likelihood of technological innovations by 65 percentage points, but not R&D. The same trend of results was shown by the ATE, which showed that Ghanaian firms that collaborated with domestic universities were more likely to stimulate technological innovations by 73 percentage points when compared to firms that did not cooperate with such higher educational institutions. Foreign universities, on the other hand, demonstrated marginal effects on both R&D and technological innovation, with an expected marginal increase of approximately 29 and 39 percentage points, respectively. The ATE results, robust to confounding and endogeneity issues, show that firm collaborations with foreign universities have higher additionality effects on R&D (84%), compared to technological innovations (73%). On the other hand, firms' collaborations with domestic universities have a higher additionality effect on technological innovations (73%), but not on R&D. The results of the insignificant relationship between Ghanaian firms and domestic universities could be explained by the fact that they are not highly focused on science and technology education, which is why firms do not partner with them for R&D. There is also low public support for R&D; Ghana's gross domestic expenditure devoted to research and development (GERD) represents about 0.38 percent of GDP (Sam-Amoah & Frimpong, 2020). This situation means that collaboration with foreign academic institutions could be vital to fulfilling Ghana's R&D needs (Odei & Stejskal, 2020). For firms to tap the full benefits of these foreign and domestic collaborations, they must develop their absorptive capacities to be able to assimilate and absorb new knowledge from these partners (Volberda et al., 2010). Our results on the importance of firms' collaborations are consistent with the findings of existing studies (Abdulai et al., 2022; Odei et al., 2023).

Our results have pointed to the benefits of firms' own internal funds as a significant driver of both technological innovations and R&D. As shown by the marginal effect results, firms' own internal funds could likely increase technological innovations and R&D marginally by 26 and 21 percentage points, respectively. These results have been affirmed by the ATE results in Table 5, which also showed that firms that use their own funds are likely to enhance their technological innovations by 27 percentage points and their R&D by 20 percentage points when compared to firms that rely on other sources. This is as expected because Ghanaian firms face considerable funding challenges as there is minimal governmental support and commercial banks demand stringent collateral, which sometimes becomes a problem for small and medium enterprises (Domeher et al., 2017). So, the ability of firms to effectively manage their internal funds could ensure that they will be able to invest uninterruptedly in their innovation activities. It is also not surprising that firms' internal funds positively moderate the relationships between utility models and copyrights and their ability to influence technological innovations and R&D. Securing such IPR tools comes at a cost, so with reliable internal funds, firms will be able to acquire these protective tools to safeguard their new knowledge, innovations, and inventions. However, internal funds negatively moderate the relationship between trademarks and both outcome measures; this could probably be explained by the high cost involved in acquiring trademarks in comparison to, for instance, utility models, which are known to be low-cost (Prud'homme, 2017). This most likely results in insufficient internal funds, which could be the possible reason for the negative moderation effect. Our results on the importance of firms' internal funds and their ability to influence technological innovations and R&D are consistent with the conclusions of previous studies (Odei et al., 2023). Contrary to this, the Udimal et al. (2019) study on Ghana found no statistically significant relationship between internal funding and product innovations. However, our results differ from the findings of the Asiedu et al. (2021) study of African countries, which found that internal funding negatively influenced new product development.

Conclusion and implications

This research builds on the discussion on firm-level innovations from the perspective of an emerging economy by examining the significant determinants of technological innovations and R&D. Studies on

innovations have long been carried out in developed countries, but the momentum of such studies is gradually increasing in developing countries like Ghana. Despite the growing research on innovations in developing countries, the various factors influencing country-specific innovations remain unclear. This study is therefore intended to fill in the research gap by considering the factors capable of influencing technological innovations and R&D. We examined the possible heterogeneity in firms' innovations and the various related activities undertaken by firms to successfully innovate by using the seemingly unrelated probit model. The findings revealed that technological innovations and R&D activities are not jointly determined, even though they both have positive externalities towards each other. Using stratified data from 549 Ghanaian firms from both the service and manufacturing sectors and employing a blend of three estimation techniques, this research finds that just about 3% of sampled firms reported having utility models, trademarks, and copyrights. For these firms, these intellectual property rights protection tools positively influence technological innovations and R&D. The descriptive statistics results also showed that the extent of innovation collaborations among Ghanaian firms is very low or almost non-existent. However, for the few firms that collaborated, the results revealed that these collaborations were more likely to have a marginal or additional impact on their technological innovations and R&D. Internal funding was seen as the dominant source of funding for these firms, representing about 62% of all funding. These internal funds proved to significantly influence technological innovations and R&D outcomes and positively moderate the relationships between utility models, copyrights, and various outcome measures.

The findings of this study make a theoretical contribution because we built on existing literature from the perspective of an emerging economy. The first theoretical contribution of the research is the incorporation of international innovation linkages involving both foreign firms and academic institutions. These synergies have not yet been explored in the case of many developing countries that are characterised as having weak innovation potential. Our results have shown that Ghanaian firms' collaborations with foreign partners can enable them to access advanced foreign knowledge, expertise, and technologies, which could have positive spillover effects on the Ghanaian economy. Secondly, the importance of domestic collaboration was proven by our results. Both domestic firms and academic institutions were significant sources of R&D and technological innovations. These findings are consistent with the systemic view of innovation from the perspective of developing countries (Midgley & Lindhult, 2021). The findings on the role of intellectual property rights protection in influencing both technological innovations and R&D contribute to a systemic view of innovation from the standpoint of developing countries. Trademarks, utility models, and copyrights have been shown to have both marginal and additionality effects on technological innovation and R&D. These findings resonate with the conclusion of other studies (Marire, 2022; Odei & Hamplová, 2022; Udimal et al., 2019). These vital strategic resources could be acquired through firms' collaborations with issuing companies, which is in line with the systemic perspective of innovation. The finding that internal funding improves the relationship between utility models and technological innovation contributes to the systemic view of innovation by underscoring the importance of internal resources, such as funding, in shaping the effectiveness of intellectual property rights (IPR) mechanisms. It highlights the interplay between internal funding and IPR in facilitating innovation and R&D, demonstrating that the two factors are not independent but rather interact and reinforce each other within the innovation system. Firms should also consider diversifying their innovation strategies beyond reliance solely on trademarks as a means of protecting intellectual property. Firms should explore alternative strategies, such as patents, copyrights, or utility models, which may be more closely linked to R&D and technological innovation, which could benefit from internal funding support.

These results have major policy and practical implications. One key implication that arises from the results of the open innovation is that Ghanaian firms are yet to realise the full benefits of collaborating with, for instance, knowledge repositories (public research organisations and universities). According to Vega-Jurado et al. (2021), the low levels of firms' collaborations with higher education institutions are prevalent in countries with low absorptive capacities. This necessitates policymakers and firm managers working out collective strategies to make these synergies more beneficial, allowing firms to boost their innovative abilities to be able to access valuable knowledge from these knowledge institutions. The results have also shown the importance of both domestic and international synergies and their abilities

to influence technological innovations and R&D in Ghana. It is essential for firm managers and scholars to harness the full potential of synergies with both domestic and foreign innovation partners, especially higher educational institutions. Ghanaian firm managers need to take full advantage of the internationalisation process to exploit innovations from foreign countries with strong innovation potentials to complement the current weak innovation performance. These results first call for governmental support or funding. Public funding support could be extended to firms and academic institutions that intend to collaborate with both domestic and foreign partners. The focus of public support should be targeted at increasing research quality among Ghanaian researchers and higher educational institutions. The current research allowance regime, which does not consider research quality, needs to be reconsidered to have a clear quality focus, which, when done, could increase research quality rather than quantity. Second, to boost innovations in Ghana, the government needs to increase the existing gross domestic expenditure devoted to research and development (GERD), which is currently 0.38 percent of GDP. The increment could help improve research infrastructure and support, leading to an improvement in research quality. Improved research quality could be vital to enhancing collaborations for innovations. Lastly, the findings have shown that intellectual property rights protection influences both technological innovation outcomes and R&D. Another managerial implication of this result is that firm managers in Ghana need to focus on acquiring intellectual property rights protections for their innovations and inventions. The results have proven that internal funding moderates the relationship between firms' abilities to acquire intellectual property rights and tools such as utility models, copyrights, and innovations. Firm managers in Ghana should prioritise allocating internal funding to support R&D activities that are protected by utility models and copyrights. By investing in innovative activities that have the potential to generate a utility model and copyright protection, firms can enhance their competitiveness. Firms should consider the role of internal funding in shaping resource allocation decisions related to innovation and IPR management. Policymakers in Ghana should consider providing incentives and support for firms to invest in R&D and technological innovation, particularly in industries where trademarks may be less closely connected with innovation. This could include providing funding for R&D initiatives, tax incentives for innovation-related expenditures, or grants for collaborative research partnerships.

This research acknowledges a few limitations, which could potentially be improved by future research. First, the study is based on cross-sectional data for the year 2013, the current and only innovation data released by the WBES for Ghana. While we admit that the results might not reflect the status quo of innovations in Ghana, they provide useful insights that could help understand the determinants of innovations during the period. Furthermore, there is no data available on innovation collaboration and intellectual protection for other African countries. This prevented us from having panel data analysis involving other countries. When new data becomes available, further research could be conducted to compare our results and determine the trend of innovations in Ghana and other African countries. Furthermore, this study only considered technological innovations and R&D but not other measures such as non-technological innovations, patents for both product and process innovations, major and minor forms of innovation, etc. We recommend future studies consider these omitted outcome variables when data becomes available. Lastly, this research was limited to Ghana. Future research could possibly be carried out in other developing countries, especially Africa, to assess the generalisability of our findings. Finally, while we found statistically significant moderating effects of internal funding and how it impacts intellectual property protection, it would be interesting to assess the other mechanisms through which firms' collaborations and intellectual protection could effectively impact R&D and technological innovation. Future studies could, for example, examine the contingent effects of other factors that can impact the effectiveness of collaborations and IPR for innovation, such as the legal and regulatory environment in which firms operate (Huang et al., 2017; Telg et al., 2023) and market dynamics and competitive pressures (Nuruzzaman et al., 2019; Ogink et al., 2023).

Author' contributions

SOA: conception and design, analysis and interpretation of the data and the drafting of the paper; IS; Data curation, writing original draft, reviewing, and editing; EFH: writing original draft, reviewing, and

editing; GT: supervision, revision, and the final approval of this version. JH: data curation, writing original draft, reviewing and editing. All authors agree to be accountable for all aspects of the work.

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Data availability statement

Data could be provided on request.

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