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“The effect of firm informality on sustainable and responsible innovation in developing countries:
Evidence from Nigeria”

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The effect of firm informality on sustainable and responsible innovation in developing countries: Evidence from Nigeria⁺

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Abstract

At the turn of the millennium, developing countries face a twofold societal challenge. First, these countries need to understand the deep principles underpinning informality, which is by now recognized as a structuring phenomenon of their economies. Second, for reasons related to both intra- and inter-generational justice, these countries need to follow the sustainable development pathway. This paper highlights a micro-economic aspect of the relationship between these two goals by investigating how a firm being formal versus informal affects its sustainable and responsible innovation (S&RI) activity, a milestone for sustainable development. Using a propensity score matching methodological approach to analyze an original database extracted from the Nigerian Business Innovation Surveys for 2005-2007, we find that registered Nigerian firms have a higher propensity to introduce S&RIs than unregistered firms. This result is robust to alternative and widely used matching methods. Hence, in the prospect of sustainable development of Nigeria and developing countries in general, there should not be a hiatus between acknowledging and further understanding the importance of informality in the economy and promoting policies that give firms incentives to formalize.

Keywords: Sustainable development, sustainable and responsible innovation, informality, developing countries, Nigeria.

JEL classification codes : O17, O35, O55, Q01, Q55.

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1. Introduction

There exists a large literature examining the drivers of "eco-innovation," i.e., the activity yielding innovations that combine technological progress and environmental protection to achieve sustainable development.¹ An implicit fact that this literature puts the finger on is that innovations could have negative effects on the environment and a policy implication is that public authorities should give firms incentives to engage in environmentally friendly innovations. Such types of innovations are viewed as allowing firms to achieve a two-fold objective, namely, competitiveness and environmental protection (Porter and van der Linde, 1995).

The growing interest in eco-innovation has resulted from the broad objective of investigating the determinants of innovations that address societal challenges. Alleviating global warming, a goal embedded in sustainability, is indeed a major societal challenge associated with eco-innovation. In this context, however, as underlined by Divella and Sterlacchini (2021), another important challenge, namely, health and safety improvement, has been somewhat neglected in the literature despite the need to ensure and improve health and safety at both firm and customer levels.

Indeed, on the one hand, workers' health and safety are not always protected although firms generally do their best to make occupational health and safety as priorities. Relatedly, Divella and Sterlacchini (2021) stress that the COVID-19 sanitary crisis has highlighted the need to develop innovative processes and techniques to ensure the health and safety of employees. On the other hand, customers' health and safety are often found to be negatively affected by certain activities and products.² Consequently, innovations should help improving health and safety through devices and production processes that significantly reduce the likelihood of harmful effects. These types of innovations have been referred to as "responsible" innovations.

¹ Although still subject to investigation by both theoretical and empirical researchers from multiple disciplines, it is by now well recognized that the concepts of eco-innovation and sustainable growth are closely related (Pansera, 2012). According to van Dieren (1995) and Dresner (2008), the terms themselves have been used in international conferences that took place back in the 1970s and 1980s respectively. As far as academic research is concerned, Rennings (2000) is a major methodological contribution that highlights the role of ecological economics. Representative empirical contributions include Brunnermeier and Cohen (2003), De Marchi (2012), Ghisetti et al. (2015), González-Moreno et al. (2019), Horbach et al. (2012), Kammerer (2009), Kesidou and Demirel (2012), Li-Ying et al. (2018), Marzucchi and Montresor (2017), Sanni (2018), and Wagner (2007 and 2008).

² For example, exposure to some electronic devices and the use of certain beauty products can cause cancer or other serious health hazards.

In fact, Divella and Sterlacchini (2021) have termed "Sustainable and Responsible" innovations, S&RIs hereafter, innovations that address these important and broad societal challenges. More specifically, S&RIs are those innovations that account for and minimize the damage they cause on the environment and the health and safety of citizens. These innovations thus go beyond the standard eco-innovations in terms of their role in society as they encompass innovations that hurt neither the quality of the environment citizens live in nor that of their lives.

Micro-econometric studies of the factors that foster the introduction of S&RI are limited. Indeed, the extant literature has rather focused on the eco-innovation part of S&RI and most of these studies are based on data concerning developed countries. To be sure, some empirical evidence on eco-innovation in developing countries exists (Fernández et al., 2021), but it is disappointingly slim.³ To a large extent, these countries have less expertise and experience as to how to act to reduce the harmful effects of production and consumption activities such as pollution and health hazards (Ferronato and Torretta, 2019; Hoornweg and Bhada-Tata, 2012). More importantly, the regulatory framework is often not efficient enough to combat the harmful effects of these activities (Seng et al., 2018). Hence, from this point of view, stimulating S&RIs in developing countries can be seen to be as topical as it is in developed countries.

To the best of our knowledge, De Marchi (2012), Divella and Sterlacchini (2021), Fernández et al. (2021), Horbach (2008), Horbach et al. (2013), and Sanni (2020) are among the rare articles that have quantitatively investigated the determinants of S&RI. However, these papers have not analyzed the impact of a firm's status (formal vs. informal) on S&RI in developing countries. Formal firms are registered with public authorities while informal firms are not and the coexistence of both types of firms is known to be one of the key characterizing features of developing countries. In fact, it is even well known that the informal sector plays a significant role in these countries' economies (Ulyssea, 2018).

The informal sector is usually thought to carry about half or even more of the economic activities (La Porta and Shleifer, 2008, 2014, and 2016). In Africa, the informal sector contributes to 50% to 80% of GDP (African Development Bank, 2018). In terms of labor, 85.8% of total employment (77% when agriculture is excluded) has been recently found to be informal jobs, a percentage considered as the highest in the world (African Development Bank, 2021). Given the scale of the informal sector in developing countries, it is tempting to think of

³ More importantly, as far as our work is concerned, the analysis of S&RI in African countries has markedly been neglected despite the need for these countries to catch up in terms of innovation.

it as a hidden engine for innovation (Kraemer-Mbula and Wunsch-Vincent, 2016), making particularly interesting the investigation of the explicit role it plays.

A firm's status should matter in explaining S&RI in developing countries for at least two reasons. First, unlike formal firms, the activities of informal ones are often aimed at fulfilling livelihood needs and as such little attention is generally paid to the environmental consequences of their production processes. Second, due to greater constraints regarding access to bank financing, informal firms generally have fewer financial resources and are endowed with less human capital (La Porta and Shleifer, 2008 and 2014). This diminishes the likelihood of informal firms to innovate, let alone to introduce innovations that improve health and safety and/or reduce environmental impact.

The pervasiveness of informality in developing countries can thus be expected to hinder S&RI suggesting that firms that operate formally should be more likely to introduce S&RIs than those operating informally. From a policy perspective, giving firms incentives to register is thus expected to yield benefits in terms of sustainability, health, and safety in addition to the tax money that could be used to finance development projects. Recently, Fu et al. (2018) found that formal firms have a higher propensity to innovate than informal ones in Ghana. Kouakou (2022) reached a somewhat similar conclusion using data on Ivorian firms.⁴ However, none of these studies considered S&RIs.

Our objective in this paper is to investigate the impact of formality on the introduction of S&RI by firms in Nigeria, one of Africa's leading economies.⁵ The database we analyze includes both firms that are registered with the Corporate Affairs Commission of Nigeria, "formal" firms hereafter, and firms that are not registered, "informal" firms.⁶ Accounting for this firm dualism, we are able to pull out from the database a representative sample of firms that are active in the Nigerian economy, in particular, in the manufacturing sector. Applying the propensity score matching method to this database, we find that the average treatment effect on the treated units is positive and significant, i.e., that formal firms have significantly higher propensity to engage

⁴ Using a CDM-modeling framework (Crépon et al., 1998) involving technological and non-technological innovations, Fu et al. (2018) find a positive effect of formality on technological innovation. Similarly, Kouakou (2022) finds that formality has a positive impact on both technological and non-technological innovations although these effects lose some statistical significance when firm size is controlled for.

⁵ According to the World Bank, in 2016 Nigeria was ranked 1st in Africa and 27th in the world in terms of GDP. This country's economic and demographic weight has earned it the nickname of "Africa's Giant."

⁶ The raw data from which we extract our dataset has also been used by Sanni (2018).

in S&RI. This result holds even when using alternative matching methods, which suggests that policies that encourage firm registration should favor S&RI.

The remainder of the paper is organized as follows. The next section gives some background on Nigeria that shed light on the challenge faced by this country with an important informal sector and a strong will to follow a sustainable development pathway. Section 3 reviews some related literature on the drivers of S&RI. Section 4 describes the data and discusses some of its properties based on descriptive statistics. Section 5 presents the main ingredients of the econometric methodology we use to analyze the data and Section 6 discusses the estimation results obtained. Section 7 concludes by summarizing the findings of the paper and discussing some policy implications. The appendix contains some tables that are discussed in the text.

2. Informality and sustainable development: A Nigerian challenge

Broadly speaking, the informal sector refers to the set of activities that take place outside the framework of government laws and regulations. As such, the informal economy can be viewed both from the lens of the nature of the businesses themselves and the nature of the relationships between these businesses and their employees. In Nigeria, millions of people work and derive their sources of living from the informal sector.

In 2000, the informal sector represented 57.9% of GNP with a value of USD 212.6 billion (Schneider, 2002) and in 2015 it accounted for 41.43% of GDP (NBS, 2016). However, this sector often employs the most vulnerable people. In the same light, with functional institutions, the informal sector is fast becoming a facilitator of sustainable just transition through informal recycling/resource recovery activities and waste management policies in Nigeria. As highlighted by Ezeudu et al. (2021), these activities are likely to serve as internal enablers to the implementation of the circular economy (CE) in the markets.

With respect to employment, the informal sector has the lion's share. The ILO gave an estimate of 93% of total employment as informal in 2018 with 95% women and 90% men (OECD/ILO, 2019). The state of Lagos alone has over 5.5 million people with informal jobs representing 75% of the state's total labor force (Olubiyi, 2022). Clearly then, given the importance of the informal economy in Nigeria and that it is excluded from the evaluation of the GDP, there is bound to be an underestimation of this aggregate.

There is however no consensus on what the role of the informal sector really is.⁷ On the one hand, the sector may be regarded as a breeding ground for illegal activities that, to say the least, result in a loss of tax revenues, are highly unregulated, create unfair competition, and observe little or no health and safety standards (Schneider and Enste, 2000; Ulyseas, 2018). On the other hand, the sector may be seen as having great potential for job creation and immense capacity to meet the needs of poor and vulnerable people by giving them access to cheaper goods and services (Bank of Industry, 2018). This view also supports the idea that the high flexibility of the informal sector may allow to smoothen the economic consequences of such major international events as the recent COVID-19 pandemic and the Ukrainian war.

Despite its importance to the national economy, the informal sector in Nigeria is, surprisingly, often overlooked and misunderstood by academics and industry observers, while some even expect it to be eventually absorbed by the formal economy. For instance, the informal sector plays a huge role in the reduction of the amount of waste taken to landfills, environmental pollution, while creating local added value through the recycling market (Aparcana, 2017; Scheinberg et al., 2011). In the same vein, resource recovery and waste recycling activities are still by far largely informal as evidenced by the role played by scavengers and direct garbage collectors who often sort out household wastes from their carts (Imam et al., 2008; Ogwueleka and Naveen, 2021).

This goes without saying that municipal solid waste management is touted to play a significant role in the achievement of the United Nations Sustainable Development Goals for 2030 associated with livelihoods, poverty, public health, and environmental protection in low- and middle-income countries. However, given the significantly high contribution of the informal sector to the Nigerian economy, it is imperative to emphasize that sustainable and inclusive economic development will be difficult to achieve until the potential opportunities and needs of the informal sector are adequately addressed (Ezeah et al., 2013; Oguntoyinbo, 2012; Ogwueleka and Naveen, 2021). Given the "invisible" nature inherent to the informal economy, this task seems rather daunting. However, it is undeniably necessary, and this paper is a modest contribution to it.

⁷ The role of the informal economy in development has been subject to rich and intensive debate in both academia and industry. The difficulties that this phenomenon raises relate to the motivations behind its emergence, its measurement, and the policy decisions to adopt in the face of it. The interested reader might check, among others, Zylfijaj et al. (2020), Nikolovski and Pechijareski (2017), ILO (2015a, 2015b), Stein et al. (2013), La Porta and Schleifer (2014), Brown et al. (2014), Günther and Launov (2012), Bacchetta et al. (2009), Dimova et al. (2005), Maloney (2004), Smallbone and Welter (2001), De Soto (2000), La Porta et al. (2000), Johnson et al. (1997), Rogerson (1996), Roberts (1994), Tokman (1989, 1978), Moser (1978), and Sethuraman (1976).

3. Drivers of sustainable and responsible innovations - Overview of some contributions

One of the viable options of examining the challenges of sustainable development is through S&RI (Khavul and Bruton, 2013; Owen et al., 2012; Stilgoe et al., 2013). Thus, responsible innovation (RI) has been defined as "a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability, and societal desirability of the innovation process and its marketable products" (Von Schomberg, 2011: 50). However, recent studies have begun to go beyond RI and examine innovations that address not only societal challenges that are confined to the environmental change and climate change (environmental innovation or eco-innovation), but also other issues such as the health and safety of workers. This stems from the fact that firms would find it difficult to engage in sustainable activities without making the health and safety of their workers a top priority.

As a consequence, beyond eco-innovation, firms now incorporate improvement in occupational health and safety as emphasized in the relatively new concept of S&RI discussed earlier (Divella and Sterlacchini, 2021; Pouliakas et al., 2013; Sanni, 2020; Stilgoe et al., 2013). Both the formal and informal sectors assume a pivotal role in implementing innovations in products, processes, or services that tackle sustainable development issues. While the majority of enterprises in the formal sector engage in partnership with public, civil society, or other private actors, those in the informal sector either engage in unilateral activities or work with their business associations.

Many technologies can be deployed to reduce work-related health problems such as injuries and fatal accidents. Big firms in the formal sector have improved significantly in the implementation and adoption of such technologies whereas firms in the informal sector that are usually with small employee size do not have easy access to such technologies (Divella and Sterlacchini, 2021; Wong et al., 2015). In other words, the protection of the environment and that of the employee's health and safety is not properly taken into consideration in the informal sector unlike within the formal sector. This may be due largely to the unregulated nature of the informal sector. However, in the Italian case, Divella and Sterlacchini (2021) show that firm size plays less significant role in driving the adoption of health and safety innovations. In contrast, the analysis of Spanish firms by De Marchi (2012) has shown that firm size has a positive effect on S&RI and that firms with more history of innovativeness with regard to new

products or processes have a higher propensity to implement S&RI than other categories of innovation.

In the meantime, typical of enterprises in the informal sector, small and medium enterprises (SMEs), often find it difficult to understand the complexity of eco-innovation as well as lack the financial resources to implement low-carbon innovations (Hemmelskamp, 1999). Furthermore, big firms often implement more of S&RI because of better access to adequate laboratories, loan facilities, and skilled labor (Kammerer, 2009; Kesidou and Demirel, 2012). They also feel the pressure from nongovernmental organizations (NGOs) with portfolio on environment, which may spur them to introduce S&RIs. However, firms with small number of employees are challenged in terms of access to technological capabilities, financial resources, easy access to international markets, etc.

Firms with years of experience in the implementation of innovation are likely to have an advantage over younger firms in the same sector. For instance, it appears that the age of the firm may have some effects on the adoption or implementation of S&RI most especially with regard to product, incremental, and radical eco-innovations as well as resources efficiency (Fernández et al., 2021). Also, eco-innovative firms that are affiliated with a group of companies or conglomerates have a higher propensity to implement S&RI because the easy access to resources motivates them to innovate.

In the same light, firms that invest in improving the quality of their staff members are likely to develop the capability to implement S&RI in-house. Some of the factors affecting the introduction or implementation of S&RI have also been attributed to whether firms are located within the business hub or outside of it (Sanni, 2020). This seems important because more often than not, enterprises located within the central business district have access to human capital, communication infrastructure, better roads, markets, etc. In that respect, firms located far away from the center of a business hub are at a disadvantage (Gatrell, 2001; SMEDAN, 2013). Other impediments to firms' S&RI in developing countries such as Nigeria include high innovation costs, low access to technology and markets, insufficient infrastructure, and poor institutional quality and regulatory expertise (Horbach et al., 2013; Sanni, 2020).

In all, according to the literature, S&RIs seem to be affected by knowledge and information sources with tendencies to be more associated with external knowledge when compared with other types of innovations. This could be due to the technical nature of S&RI. The size and age

of the firms also seem to matter for the introduction of S&RI. These findings have a lot of implications for the implementation and adoption of this type of innovation. Unfortunately, little is known about the drivers of S&RI, most especially in developing countries. Even less information is available about the implementation of S&RI in the informal sector and this is the knowledge gap that this study intends to fill.

4. Data

The data we used was extracted from the Nigerian Business Innovation Survey (NBIS) for 2005-2007 which is a cross-sectional data. This wave of NBIS is the only dataset that allows for the dichotomization into formal and informal sectors. The survey was conducted in 2008 by the National Centre for Technology Management (NACETEM), an agency of the Federal Ministry of Science, Technology and Innovation of Nigeria.

The procedure followed in implementing the survey for this study followed the "Guidelines for Collecting and Interpreting Innovation Data" jointly developed by the OECD and the Eurostat popularly referred to as Oslo Manual (OECD/Eurostat, 2005). The survey instrument for the study was a structured questionnaire patterned toward the popular community innovation surveys (CIS) in Europe (Clausen et al., 2012; Escribano et al., 2009; Frenz and Ietto-Gillies, 2009; Gault et al., 2014; Laursen and Salter, 2006) which has also been used to study eco-innovation on several occasions (De Marchi and Grandinetti, 2013; Ghisetti et al., 2015; Hemmelskamp, 1999; Horbach, 2008; Sanni, 2018, 2020).

The questionnaire was however adapted to suit the national context. The data collection instrument has 13 sections altogether. Both the business directory of National Bureau of Statistics (NBS) and that of the Nigerian Stock Exchange trade database were used as sampling frame. The multistage systematic random sampling technique was employed in the sampling design. Firms were stratified by the sector of activities and employee size. Using the aforementioned databases, a proportional probability sampling (PPS) technique with a threshold of a minimum of 10 employees was adopted to select firms.

Using the Industrial Classification of all Economic Activities (ISIC revision 3.1), the manufacturing sector falls between divisions 15-37. Stratification of the firms was based on sector and employee size. The original dataset contains a total of 519 manufacturing firms, formal and informal. Due to missing data on some variables, the number of observations

reduces to 219. More detailed information about the data can be found in Sanni (2018 and 2020). The operationalization and descriptive analysis of the variables are shown in Table A1 in the appendix.⁸

It emerges from Table A1 that 65% of the 219 manufacturing firms in our sample have introduced S&RIs over the study period. Out of these firms, 67% are formal and 59% are informal. Sustainability and responsibility seem thus to be goals that are embedded in the competitiveness strategy of most of the firms in our sample. Table A1 also shows that the average level of firm size as measured by the number of employees is about 292 while the minimum and the maximum are respectively 10 and 3466 employees. The age of the firms in the sample is between 1 and 103 years with the average being equal to 23.34 years (Adeyeye et al., 2019; Adeyeye et al., 2018).

Concerning the proxy used for workforce qualification, i.e., staff training, we see that 75% of the firms in our sample have engaged in such a program. This engagement seems to be a prevalent phenomenon in our sample of firms. We also see that only 27% of the firms in the sample own a membership to a group of firms. As to locality, 22% of the firms are located in Lagos and, as argued, these firms are expected to be more likely to operate formally. As to informality, 78% of the firms in our sample are formal and 22% are informal. Formal firms constitute thus the majority of the firms in our sample. This is representative of what can be observed in the manufacturing sector in most west African developing countries. In fact, in practice, formal firms generally constitute the majority of the firms in the manufacturing sector while informal firms are rather usually found to be a majority in the trade sector.

5. Econometric methodology

In the same line as Lee et al. (2017) and Heredia Pérez et al. (2018), we adopt the propensity score matching (PSM) approach to analyze our dataset on Nigerian firms. Subsection 5.1 discusses the endogeneity problem that PSM allows to handle, the basic idea behind it, and the structure of the model used to estimate the scores. Subsection 5.2 discusses the outcome and treatment variables and subsection 5.3 the various variables used to estimate the scores.

⁸ Table A2 gives the correlations between the variables providing prior information on the relationship between the variables when later specifying a Probit model later in the econometric analysis of the data. As to Table A3, it serves the purpose of making sure that multicollinearity of the data doesn't pose a problem. This is indeed the case as the values of the Variance Inflation Factors (VIFs) are all largely smaller than 10.

5.1 Propensity score matching

The variable that indicates firm status may be endogenous due to unobserved characteristics that may be correlated with both S&RI and firm status. Given this potential endogeneity concern, simply comparing the decisions of formal and informal firms would produce biased results regarding the impact of formality status on the probability to introduce S&RI. Ideally, one would like to compare the likelihood that a randomly drawn firm introduces S&RI when it operates formally and informally. However, such a randomized experiment cannot be carried out. Alternatively, one could run an instrumental variable regression, but data on appropriate instruments is not available.

To overcome this issue, following Lee et al. (2017) and Heredia Pérez et al. (2018), we use the PSM method.⁹ The basic idea behind PSM is to reconstruct the original observational data in a quasi-experimental setting and then investigate how a given outcome is affected by a given treatment (Lee et al., 2017; Heredia Pérez et al., 2018). The PSM method compares counterfactual outcomes. It imputes a missing potential outcome for each firm by using an average of the outcomes of similar firms having received the other treatment level. Similarity between firms is based on estimated treatment probabilities referred to as "propensity scores." Propensity scores are balancing scores, that is, scores that allow direct comparisons of treatment and control groups to be more meaningful (Rosenbaum and Rubin, 1983).

In this paper, the propensity score refers to the propensity toward exposure to formality (the treatment), that is, the probability to operate formally given a set of observed covariates. Thus, the treatment group consists of firms that operate formally while the control group contains those firms which operate informally. As in Lee et al. (2017) and Heredia Pérez et al. (2018), we employ a Probit model to obtain propensity scores based on various firm characteristics such as size, age, workforce qualification, membership to a group of firms, and location.¹⁰ These variables are described in more detail in Table 1 above.

After estimating propensity scores, we match firms that operate formally with firms that operate informally on the basis of these scores and then estimate the effect of a firm's formal versus

⁹ See Abadie and Imbens (2016), Dehejia and Wahba (2002), Imbens and Wooldridge (2009), and Rosenbaum and Rubin (1983).

¹⁰ See Dabla-Norris et al. (2008), Fu et al. (2018), La Porta and Shleifer (2014), Mendi and Mudida (2018), and Williams et al. (2016).

informal status on S&RI by calculating the average treatment effect on the treated (ATT).¹¹ The ATT reflects the difference in the probabilities to introduce S&RI between formal and informal firms. Finally, we implement some balancing tests to verify the quality of the matching between the treated and control groups.

5.2 Outcome and treatment variables

The outcome variable is firm S&RI captured by a binary variable equal to 1 if a given firm has introduced S&RI over the study period and 0 otherwise. The S&RI activity is identified based on the actual "effect of innovation" as opposed to the "motivation for innovation" (Divella and Sterlacchini, 2021). More precisely, a firm is considered as having introduced an S&RI if this innovation has reduced environmental impacts and/or improved health and safety in a sufficiently clear and discernible way, i.e., if the innovation had medium or high such effects. This approach was considered by Horbach et al. (2012) for the eco-innovation part of S&RI.

The treatment is formality. It is reflected in a binary variable that takes value 1 if the firm is formal and 0 if it is informal. Such an independent variable was considered recently by Fu et al. (2018). As indicated, in the context of Nigeria, formal firms are firms which are registered with the Corporate Affairs Commission and informal firms are those which are not.¹²

5.3 Propensity scores

The variables used to calculate propensity scores, i.e., firms' probabilities to operate formally, are chosen based on both the literature and data availability. We include firm size, firm age, workforce qualification, membership to a group of firms, and location. Firm size is proxied by the natural logarithm of the number of employees, which is expected to have a positive effect on the propensity to be formal (Dabla-Norris et al., 2008).¹³ Similarly, firm age is measured by the natural logarithm of the number of years since the firm's operations started.¹⁴ Older firms may be more likely to be formal due to greater experience that allows them to better perceive the advantages of being formal.

¹¹ See Abadie and Imbens (2016), Caliendo and Kopeinig (2008), Lee et al. (2017), Heredia Pérez et al. (2018), and Zhao et al. (2022).

¹² For a discussion of theories and conceptions of informality, see Dell'Anno (2021) and Maloney (2004).

¹³ One reason for this is that larger firms are very often more productive than smaller ones and highly productive firms are generally formal firms. See Dabla-Norris et al. (2008) and La Porta and Shleifer (2014).

¹⁴ This variable has been used by Williams et al. (2016).

This said, however, the impact of firm age on formality might go the other way around. Indeed, younger firms, in particular, firms that have just started their operations, can potentially be more fearful than their older counterparts from the consequences of being caught by public authorities.¹⁵ Among the reasons are the facts that such firms newly entering the market neither are necessarily aware of the potential (corruption) mechanisms that could help them to avoid being fined in case they are caught, nor have always the sufficient means to face the potential fines. Note, however, that beyond the firm's ability to know these mechanisms, the probability to be caught and fined when operating informally also depends on the efficacy of the legal system (Dabla-Norris et al., 2008).

Membership to a group of firms is indicated by a binary variable taking the value of 1 if the firm is part of a group of firms and 0 otherwise (Mendi and Mudida, 2018). Firms that belong to a group are generally more professional and potentially more likely to operate formally. To proxy workforce qualification, an important characteristic of a firm, we use a binary variable equal to 1 if the firm has engaged in staff training over the study period and 0 otherwise (Sanni, 2018). This variable is expected to influence positively the probability to operate formally. In fact, staff training improves the skills of the employees and skilled firms are generally more likely to operate formally (Dabla-Norris et al., 2008).

Location is a factor that has been found in the literature to be important in explaining firms' behaviors and activities (Fu et al., 2018; Robson et al., 2009). We capture location by means of a binary variable taking value 1 if the firm is located in Nigeria's capital Lagos and 0 otherwise and expect this variable to have a positive impact on the probability of firm to be formal. Indeed, being the largest city in Nigeria, Lagos is home to economic activities that are more likely to be subject to stricter control by public authorities than other localities and this suggests that Lagosian firms should tend to go more formal than other firms.

6. Results

Table 1 below gives the results of the estimation of the Probit model of formality status intended to obtain propensity scores.¹⁶ Firm size, firm age, membership to a group of firms, and location

¹⁵ Dabla-Norris et al. (2008) considers this issue in a theoretical model involving a fine that amounts to the firm's profit when it is caught operating informally.

¹⁶ The acronyms used for the variables are given in Table A1 of the appendix.

have significant relationships with the probability to operate formally. We see that firm size influences positively the probability to operate formally. The larger firms seem therefore to be more likely to operate formally than their smaller counterparts. As indicated, these firms usually have an advantage in terms of productivity and the latter has been found to be positively associated with the firm's probability to be formal (Dabla-Norris et al., 2008; La Porta and Shleifer, 2014). In the same light, big firms in Nigeria have also been found to have a higher capacity to implement new external relations with other key actors within the national innovation system (Adeyeye et al., 2019), an important characteristic of eco-innovative firms in Nigeria (Sanni, 2018).

Another plausible reason is that larger firms typically have more financial resources than smaller ones to meet the costs of complying with regulation in the formal sector, such as minimum wage and corporate tax.¹⁷ In addition to the above, studies have also shown that there is a positive relationship between big firms and introduction of S&RI. Big firms tend to attract the attention of civil society and this pushes them to be environmental conscious while encouraging them to implement safety measures in their operations (Kammerer, 2009; Kesidou & Demirel, 2012).

Table 1 also shows that firm age has a negative relationship with formality status, that is, younger firms are more likely to operate formally than older firms.¹⁸ This may not be unconnected with the fact that there seems to exist some high level of organizational rigidities in the form of organizational culture within some older firms in Nigeria (Adeyeye et al., 2018). This may not however be the case with younger firms. Membership to a group is in a positive relationship with formality status, i.e., firms that belong to a group of firms are more likely to operate formally. As indicated, this may be because firms that are members of a group are more often than not more professional than their counterparts which do not belong to a group. Location matters for a firm's propensity to be formal. Firms located in Lagos have indeed greater likelihood to operate formally. The level of control by public authorities in the capital is a plausible explanation for this Lagos effect on formality.

The estimation of the Probit model of formality status allows us to calculate propensity scores of operating formally. On the basis of the ATT, these scores are then used to construct a matched

¹⁷ In theory, it is possible to find some start-ups, which are typically small firms, having more financial capacities than larger firms. This, however, seems uncommon in African developing countries.

¹⁸ See subsection 5.3 for a discussion of why the sign of this relationship may not be unambiguous.

sample to compare the probability to introduce S&RIs of firms that operate formally and that of those firms that operate informally. Table 2 below presents the results of the application of the PSM method. Following Lee et al. (2017) and Heredia Pérez et al. (2018), we use the "teffects psmatch" command in Stata to carry out the estimations.

Table 1. Probit model used to obtain propensity scores⁺

Independent variables	Estimated coefficients
<i>SZ</i>	0.219** (0.092)
<i>AG</i>	-0.293* (0.157)
<i>WQ</i>	-0.441 (0.474)
<i>MG</i>	0.131* (0.078)
<i>LC</i>	0.305** (0.119)
Constant	0.872* (0.527)
Wald test	1389.01***
Pseudo R-squared	0.054
Obs.	219

⁺ Standard errors in parentheses. *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$.

Table 2. Probability to introduce S&RI (formal versus informal firms)⁺

Estimation method: Propensity Score			
Matching			
ATT	0.224***	(0.084)	[0.008]
Obs.	219		

⁺ ATT: Average treatment effect on the treated. Abadie-Imbens robust standard errors in parentheses. p-value in brackets. *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$.

The ATT reflects the difference in the probability to introduce S&RI between firms that operate formally (treatment group) and those firms that operate informally (control group). We see from Table 2 that the ATT is positive and significant at the 1% level. This says that being formal increases a firm's probability to introduce S&RIs. Among other reasons, this might be explained by the fact that formal firms face significantly fewer financial constraints than their informal counterparts as they have access to bank financing and to the financial market (La Porta and Shleifer, 2014). This helps them to support their innovation activities, thus increasing their likelihood to introduce S&RIs. Better human capital is also an advantage of formal firms as regards innovation. In particular, their managers are typically more educated than those of informal firms (La Porta and Shleifer, 2008 and 2014), which should be beneficial for their innovation activities.

Besides, as previously discussed, another potential explanation for the positive effect of being formal on S&RI is that, by their very nature, informal firms usually carry out their activities with the objective of fulfilling basic livelihood needs. In such a context, the reduction of environmental impacts and the improvement of health and safety generally do not matter when designing their production and innovation strategies. Moreover, compared to formal firms, firms that operate informally usually exhibit fewer absorptive capacity (Mendi and Mudida, 2018), which is not good news for their likelihood to innovate (Cohen and Levinthal, 1990), let alone to introduce innovations that reduce environmental impacts and/or improve health and safety.

Table 3 below gives the results of balancing tests that allow us to evaluate the quality of the matching. We have implemented three different tests, namely, the t-test on the mean of each independent variable after the matching (Lee et al., 2017; Heredia Pérez et al., 2018), the Rubin's B-test, and the Rubin's R-test (Rubin, 2001).¹⁹ For a sample to be considered as sufficiently balanced, the value of the B-statistic should be less than 25% and that of the R-statistic between 0.5 and 2 (Rubin, 2001). As to the t-test, the difference in the means should not be significant.

We see that after the matching, for each independent variable, there is no significant difference between the treated and control groups, that is, these groups are not systematically different and this should be the case indeed (Lee et al., 2017; Heredia Pérez et al., 2018; Rosenbaum and Rubin, 1983). The value of the Rubin B-statistic is less than 25% (equal to 21.3%) and that of the Rubin R-statistic is between 0.5 and 2 (equal to 1.07). Therefore, the sample is sufficiently balanced (Rubin, 2001).

To check the robustness of our results, we have estimated the ATT by considering six alternative matching approaches, namely, (pure) Nearest-neighbor matching, Caliper matching, Kernel matching, Local linear regression matching, One-to-one matching, and Radius matching. The results are presented in Table 4 below.²⁰ We see that the ATT is positive and

¹⁹ The Rubin's B-test is based on the absolute standardized difference of the means of the linear index of the propensity score in the treated and (matched) non-treated groups. The Rubin's R-test is based on the ratio of treated to (matched) non-treated variances of the propensity score index. See Rubin (2001).

²⁰ These methods of matching are commonly discussed in the literature. See Abadie and Imbens (2006 and 2011) for details on the Nearest-neighbor matching and Dehejia and Wahba (2002) and Caliendo and Kopeinig (2008) on the Caliper matching. For the One-to-one and Radius matching approaches, see Huber et al. (2015 and 2013). Caliendo and Kopeinig (2008) discuss the difference between Caliper and Radius matching. Zhao et al. (2022)

significant in all these six matching approaches, as in the case of the (pure) propensity score matching method used earlier. This confirms the robustness of our conclusion regarding the positive effect of the status of a firm being formal on its likelihood to engage in S&RI.

Table 3. Balancing tests

Variables	T-test on the mean of each independent variable after the matching			
	Treated	Control	t-statistic	p-value
<i>SZ</i>	4.69	4.59	0.68	0.494
<i>AG</i>	3.02	3.01	0.11	0.916
<i>WQ</i>	0.73	0.69	0.71	0.477
<i>MG</i>	0.28	0.23	0.86	0.391
<i>LC</i>	0.22	0.15	1.63	0.105
	Rubin's B and R statistics			
Rubin's B	21.3%			
Rubin's R	1.07			

Table 4. Robustness check⁺

	ATT	Standard error ^a	Test-statistic ^b
(pure) Nearest-neighbor matching	0.308***	0.109	2.83
Caliper matching	0.225***	0.078	2.90
Kernel matching	0.233**	0.111	2.10
Local linear regression matching	0.341**	0.147	2.32
One-to-one matching	0.226***	0.087	2.60
Radius matching	0.100***	0.039	2.59

⁺ ATT: Average treatment effect on the treated. Number of observations: 219. *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$.

^a Abadie-Imbens robust standard errors for Nearest-neighbor matching, Caliper matching, One-to-one matching, and Radius matching.

^b z-statistic for Nearest-neighbor matching and t-statistic for the five other matching methods.

7. Conclusion

This paper has aimed at analyzing the effect of firm informality on sustainable and responsible innovation (S&RI) in developing countries. Applying the propensity score matching method to survey data on Nigerian firms, we find that the status of firm being formal impacts positively and significantly the likelihood that it introduces S&RI. This result is robust to the matching approach used. It suggests that the transition of firms from the informal to the formal sectors should foster the introduction of S&RIs. Hence, policies that provide firms with incentives to become formal are expected to bring societal benefits that go beyond the standard tax benefits, namely, environmental and health and safety benefits.

have used the upper four methods of matching given in Table 5.

Recently, Jessen and Kluwe (2021) conducted a meta-analysis that allowed them to conclude that information interventions and tax incentives are policies that are particularly effective for encouraging firms' formalization. Our results suggest that, if implemented within the Nigerian context, this type of policies could be expected to foster firm formalization and by the same token S&RI. Coincidentally, the same should be true for the case of another west African country, namely Côte d'Ivoire, for which Kouakou (2020) has argued that these policies should have a positive effect on formalization.

Regarding the implementation of these policies, public authorities could conduct information campaigns say, that highlight the benefits of operating formally such as increase in innovativeness, productivity, and non-price competitiveness, on the one hand, and access to bank financing and to the financial market, on the other hand. Tax incentives could also be a strong instrument as informal firms are very often unable to cope with the level of corporate tax that is applied in the formal sector. Establishing a lower level of corporate tax at the early stage of formalization could be a sound policy to give informal firms incentives to formalize.

Needless to say that other policy instruments than formalization could be used to stimulate S&RI and thus contribute to sustainable development in Nigeria. For instance, the incessant power cuts and recent national grid collapse have significantly increased the cost of generating energy through diesel power plants by many firms in Nigeria (Ayanda and Laraba, 2011). Consequently, many firms are now committed to reducing their carbon footprint while protecting the health of their staff from pollution coming from the diesel power plants. It is important therefore that there should be flexible policy instruments that will promote more engagements in S&RIs by the firms. Such policies may include rewarding voluntary commitments and renewable energy subsidies for firms that use such alternative source of power.

In the same light, a law similar to Executive Order 7 of 2019 in Nigeria, under which formal firms are granted road infrastructure development and refurbishment investment tax credit, could be enacted to suit firms that engage in S&RIs as well. Firms participating in this tax credit scheme are allowed to utilize the road construction or refurbishment cost as credit against company's income tax payable. Such tax credit schemes could be used to attract firms into the formal sector to engage in S&RI, since being formal increases a firm's probability to introduce S&RIs. As a matter of fact, enacting similar law to the Executive Order 7 could portend lots of opportunities for big firms, those that belong to a group of companies, and those that are young

since they are more likely to operate formally. This could mean that government only needs little effort to encourage them to engage in S&RIs. Moreover, the fact that the majority of the businesses with greater likelihood to operate formally are located in Lagos, a central hub of industrial activities with control by public authorities, will also help.

S&RI, in particular, as it relates to sustainable development in African countries, certainly deserves further research in at least two directions. First, the drivers of S&RI could be further investigated taking into account the specific institutional and economic context of African countries, including institutional quality as reflected in the degree of corruption, political instability, and the rule of law, and the quality of the business environment as reflected in business and market sophistication and infrastructure. Indeed, these factors are often problematic in African countries as they could potentially negatively affect firms' economic activities, in particular, innovation.

Another promising avenue for future research would be to investigate the impact of S&RI itself on African firms' performance, as reflected in productivity and profitability. In fact, since informality is a pervasive phenomenon in African countries and given our empirical results suggesting that the level of S&RIs might be reduced by this phenomenon, it is worth analyzing the impact of S&RI on African firms' performance. A positive impact would, in particular, strengthen the stake of promoting policies that give firms incentives to formalize.

Appendix

Table A1. Definition of the variables and descriptive statistics⁺

Variable type	Variable name	Description	Mean	Std. Dev.	Min.	Max.
Dependent/ Outcome variable	Sustainable and responsible innovation (<i>S&RI</i>)	Binary variable equal to 1 if the firm introduced innovation with high or medium effects in terms of reduction of environmental impacts and/or improvement of health and safety and 0 otherwise	0.65	0.48	0	1
Independent/ Treatment variable	Firm status (<i>ST</i>)	Binary variable equal to 1 if the firm is formal (treatment) and 0 if it is informal (control)	0.78	0.42	0	1
Independent/ Control variables	Firm size (<i>SZ</i>)	Natural logarithm of the number of employees	4.71 [291.31] ⁺	1.33 [557.46] ⁺	2.30 [10] ⁺	8.15 [3466] ⁺
	Firm age (<i>AG</i>)	Natural logarithm of the number of years since the firm's operations started	2.96 [23.34] ⁺	0.71 [13.08] ⁺	0 [1] ⁺	4.63 [103] ⁺
	Workforce qualification (<i>WQ</i>)	Binary variable equal to 1 if the firm engaged in staff training over the study period and 0 otherwise	0.75	0.43	0	1
	Membership to a group (<i>MG</i>)	Binary variable equal to 1 if the firm is part of a group of firms and 0 otherwise	0.27	0.44	0	1
	Location (<i>LC</i>)	Binary variable equal to 1 if the firm is located in Lagos and 0 otherwise	0.22	0.41	0	1

⁺ Actual value of the descriptive statistic of the corresponding variable.

Table A2. Correlation coefficients

	<i>S&RI</i>	<i>ST</i>	<i>SZ</i>	<i>AG</i>	<i>WQ</i>	<i>MG</i>	<i>LC</i>
<i>S&RI</i>	1						
<i>ST</i>	0.07	1					
<i>SZ</i>	0.23	0.16	1				
<i>AG</i>	0.07	-0.06	0.17	1			
<i>WQ</i>	0.27	-0.05	0.24	-0.09	1		
<i>MG</i>	0.14	0.08	0.31	0.08	0.11	1	
<i>LC</i>	0.11	0.07	0.12	0.12	0.12	0.05	1

Table A3. Variance Inflation Factors (VIF)

Variable	<i>SZ</i>	<i>AG</i>	<i>WQ</i>	<i>MG</i>	<i>LC</i>
VIF	1.21	1.06	1.10	1.11	1.04

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