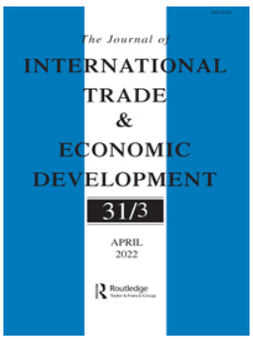

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The innovation and exports interplay across Africa: Does business environment matter?

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ABSTRACT

The paper investigates the relationship between innovation and export behaviour across manufacturing and services firms in Africa. The study is based on the general premise that innovation has a positive effect on firm's exports (self-selection hypothesis) and the complementary assumption that internationalisation drives firms to innovate (learning-by-exporting hypothesis). To test this complex, two-way link between innovation and exports, the study contributes to the existing literature by analysing the complementarity effects between product and process innovation in their relationship with exports. A combination of process and product innovation is expected to have a greater impact on the likelihood of firms entering the foreign market and on their export performance. Using data from 45 African countries, from 2006 to 2020, the multinomial probit and two-stage least squares models are estimated. There is support for the learning by exporting and the self-selection hypotheses for African firms. The findings also reveal the need to improve the business environment across African economies to foster greater exports and innovation.

KEYWORDS Exports; innovation; business environment; African countries

JEL CLASSIFICATIONS F14, M21, O55, O31

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1. Introduction

The literature, assessing the factors that stimulate firm exports, is rather extensive (Bernard, Jensen, and Lawrence 1995; Srinivasan and Archana 2011; Chen, Sousa, and Xinming 2016; Baltagi, Egger, and Erhardt 2017). The recent work focusses mainly on innovation as a survival means for enterprises in a highly competitive and dynamic trading environment (Azar and Ciabuschi 2017; Bagheri et al. 2019; Hameed et al. 2021). Innovation can generate direct and indirect effects. The former is linked to innovation, contributing to greater demand and higher exports by the provision of new and improved commodities (Ayllón and Radicic 2019), and indirectly by augmenting the firm's productivity and existing set of resources and capabilities (Love and Roper 2015; Bıçakcıoğlu-Peynirci et al. 2019). Firms may transform their intention to export into

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the capacity to export (the effect of conscious self-selection), by increasing their technology or by improving the quality of their products (López 2009; Sala Rios and Torres Solé 2021).

Despite theoretical consensus on the positive impact of innovation on firm exports (Caldera 2010; Damijan, Kostevc, and Polanec 2010; Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín 2012; Becker and Egger 2013; Freixanet and Churakova 2018), the empirical findings remain rather mixed, with inconsistent and fragmented results (Love and Roper 2015; Silva, Styles, and Lages 2017). While several studies have shown a significant positive link between innovation and export performance (Fernández-Mesa and Alegre 2015; Costa, Lages, and Hortinha 2015), others have reported a negative impact on exports (Boehe and Cruz 2010) or no impact (Silva, Styles, and Lages 2017). Furthermore, most studies focus mainly on developed countries and there is a dearth of literature disentangling the innovation-export association for developing economies and more so for Africa (Barasa et al. 2016). For instance, Barasa et al. (2016) observe a positive bi-directional relationship between product innovation and exports in four Sub-Saharan African countries. Furthermore, recent work on the association between innovation and export performance for African firms is Avenyo, Tregenna, and Ngwadleka (2021), which uses the Tobit simultaneous equation full maximum likelihood model for 28 African countries. There is evidence of a two-way positive link between innovation and export performance across African firms whereby innovation is crucial for export propensity and export intensity, and similarly exporting increases the likelihood of firms to innovate. The results are driven essentially by direct exports and are relevant for product and process innovation. Firms with a high share of foreign ownership and those with an internationally recognised quality certification strengthen this positive bi-directional link between innovation and export performance.

As a continent, Africa has been making constant progress in improving the key drivers of technological advancement and innovation. Internet access, speed and connectivity, mobile phone use and enrolment in science, technology, engineering and mathematics (STEM) education have increased in recent years. However, the region still lags in major innovation capacities. In effect, the innovation rates have been meager across African countries. The Global Innovation Index (GII) 2021 (World International Property Organisation, 2021) sets out the innovation landscape of 132 countries based on a set of 81 indicators covering different dimensions (like institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs and creative outputs), provides support for the low innovative capacity of African countries. The overall GII is the average innovation input sub-index that captures the enabling environment that facilitates innovative activities and the innovation output sub-index relates to innovation outputs from innovative activities in an economy. The index takes a value between 0 and 100, with 100 being the highest innovation level and zero otherwise. Most African economies have a low index value, with the lowest value of 15 for Angola. Mauritius, South Africa and Kenya are the top performers in the region, with an index of 35.2, 32.7 and 27.5, respectively.

African firms, in effect, perform relatively poorly in innovation (Kraemer-Mbula and Wamae 2010; Avenyo, Tregenna, and Ngwadleka 2021) and exports (Adeoti 2012; Rankin, Söderbom, and Teal 2006). Growth in innovation represents a major challenge for the region to solve its constraints in productivity, exports and competitiveness (Egbetokun et al. 2016). In many African economies, the innovation ecosystem is still nascent, with many challenges in terms of lack of investment and finance, no adequate governance

and regulatory structures, and difficult access to inputs, business support, mentorship, skills and infrastructure (Yawson 2021). Innovation and investment in new technologies can address many challenges of low structural transformation and inclusive development in Africa. African countries that are further from the development frontier have an opportunity to benefit from innovation (World Bank 2017). Technological innovations associated with new products and processes can promote investment, increase productivity growth and facilitate changes in the organisation of firms (Sandven, Smith, and Kaloudis 2005). Furthermore, technological innovation can trigger competitiveness, shift resources from low to high productive activities, enhance the acquisition of knowledge and skills, create better jobs, build inclusive societies and promote prospects for achieving the Sustainable Development Goals in Africa (UNCTAD 2017).

The paper seeks to contribute to the scant literature on the innovation-exports nexus in Africa using firm-level data across 45 African countries from 2006 to 2020 in four ways. We extend on Barasa et al. (2016) by focussing on product and process innovation. In this paper, innovation is measured in terms of process innovation and product innovation. This is in line with exant literature focussing on the two main types of technological innovation in terms of product and process innovation (Azar and Ciabuschi 2017; Azari, Madsen, and Moen 2017; Boso et al. 2019). The former has a direct impact on a firm's productivity and reduces unit costs of production, which leads to increased demand (Okumu, Bbaale, and Guloba 2019). Higher demand implies increased exports. In addition, product innovation is associated with product demand enhancement, thus the need for the firm to adjust output upwards, which increases capacity expansion and hence exports. The study first explains the relationship between product and process innovation and exports. Second, compared to the Avenyo, Tregenna, and Ngwadleka (2021) study, which assesses the impact of the two types of innovation separately on exports, this paper identifies the complementarity effects between product and process innovation in their relationship with exports. Combining process and product innovation may have stronger effects on exports. This follows from Evangelista and Vezzani (2012) and Okumu, Bbaale, and Guloba (2019) measures of innovation on employment growth. Third, our analysis probes into the two-way relationship between innovation and export performance to test the self-selection hypothesis (i.e. most innovative firms self-select to participate in the export market) and the learning by exporting hypothesis (i.e. firms that exports are likely to gain experience and access external market-related knowledge and innovate). In investigating the two-way link, we consider export propensity and export intensity. Finally, we attempt to understand whether the innovation-exports nexus is mediated by the prevailing business environment across African countries. The business environment has a significant impact on a firm's strategies and behaviour (Krasniqi and Desai 2016; Reçica et al. 2019). As such, the uncertain environment governed by many business obstacles may hinder the ability of firms to export and innovate. However, this view has not generated an in-depth analysis when probing into the innovation and export performance relationship (Wakelin 1998; Roper and Love 2002; Gashi, Hashi, and Pugh 2014). This is so because existing studies have focussed mainly on developed economies where the business environment is perceived as favourable (Reçica et al. 2019), whereas, for African countries, the business environment is key for promoting exports and innovation.

The paper is structured as follows: Section 2 reviews the existing literature on innovation. Section 3 explains the data and methodology adopted, and section 4 discusses the findings. We conclude in section 5 with relevant policy options.

2. Literature survey

Innovation is defined as a new or improved product or process or - combination there of that differs significantly from the previous products or processes (Oslo 2018). It is considered a key for entry into international markets (Cieslik, Michalek, and Michalek 2014; Filipescu et al. 2013). Product and process innovations are usually the main innovation measures used in the empirical literature to assess the innovation-exports nexus. Product innovation provides a competitive advantage for market penetration through differentiated products (Tavassoli 2018; Avenyo, Tregenna, and Ngwadleka 2021), whilst process innovation reduces the firm's production costs, promotes efficiency and strengthens the enterprise's market position.

Innovation can increase firm-level performance by improving the capacity to transform factors of production into more and better products achieving economies of scale, and more efficiently creating products of higher value. The increase in productivity will boost the marginal productivity of labour, and as a result, enhance the quality of jobs. In addition, more productive firms are expected to penetrate the international markets and improve their capacity to export. All these potentials depend on the quality of the innovation and the ability of firms to translate innovation into improved performance. In particular, international markets select the most productive and innovative firms. Similarly, exports make it more profitable for firms to invest in innovation (Bustos 2011). The export market is different from the domestic market, as foreign consumers have different preferences and demands. This encourages firms to upgrade their products (Baldwin and Gu 2004; Eckel and Neary 2010), adopt some of their product attributes or develop new products, relocate to developing countries to reduce costs, and sell their best products on export markets (Manova and Zhang 2012). Exporting also exposes firms to international best practices and spillovers from abroad (Baldwin and Gu 2004), raising the returns to investing in the absorption capacity of these technologies.

Theoretical models by Bernard et al. (2003) and Melitz (2003) advocate that firm heterogeneity is a crucial element for explaining the export activity. Among these firm's different characteristics, productivity level and innovative capacity play a crucial role in determining export status and potential. As per Schumpeter and Nichol (1934) (considered as the pioneer of innovation), the introduction of new technologies and the creation of new markets are important for economic growth. Innovation is seen as a critical element for gaining and maintaining a sustainable competitive advantage in foreign markets to use economies of scale and scope (Fernández-Mesa and Alegre 2015). International trade and growth theories have stressed the role of innovation and productivity growth in accelerating export performance and predicting a mutually causal relationship between innovation and exports. The two main theoretical arguments that underpin the causal link between innovation and the firm's export performance are the self-selection hypothesis and the learning by exporting hypothesis. The self-selection hypothesis postulates that the most productive and innovative firms self-select to participate in the export market (Melitz 2003; Bernard et al. 2003; Guarascio and Pianta 2017; Segarra-Blasco, Teruel, and Cattaruzzo 2020). In contrast, the learning-by-exporting hypothesis suggests that exporting positively influences firms' innovation performance. Hence, there is a reverse causality between innovation and exporting (Bigsten et al. 2004; Faustino and Matos 2015; Guarascio and Pianta 2017; Segarra-Blasco, Teruel, and Cattaruzzo 2020).

Trade models with neo-technology and the neo-endowment concepts suggest that causality runs from innovation to exporting (Wakelin 1998). Neo-technology models, based on product life cycle theory (Vernon 1992) and technology-gap theory of trade (Posner 1961), suggest that competitive advantage is determined by the quality of products or services produced by firms. The export demand curve shifts outwards as firms improve the quality of products and services (Grossman and Helpman 1994) through innovation. Hence, from the neo-technology perspective, better export performance can be achieved through investment in new technologies and the development of new products and services that, in turn, depend on linkages with other firms (Metcalfe 1995). Within the product-cycle features in the production of goods over time (Dollar 1986), innovation is seen as exogenous and influences exports. This is also explained by developed countries exporting innovative goods, which are later imitated by developing nations exporting these goods to the developed world. For the latter to keep up their exports, they must continually innovate, and the more they innovate, the larger their exports will be. Neo-endowment models, in turn, postulate that factor endowment, namely raw materials, skilled or unskilled labour, capital and technology determine competitive advantage (Davis 1995). In dynamic models with heterogeneous firms, investments in firm-specific assets are associated with innovation that leads to the self-selection of firms into the export market (Cieślik, Qu, and Qu 2018). This is explained by the fact that innovative and productive firms with low marginal costs can export because of their ability to cover entry costs and cope with international trade costs (Cieślik, Qu, and Qu 2018). Innovation can thus enhance an enterprise's export performance in terms of its entry into the international markets (export propensity) and export intensity (Avenyo, Tregenna, and Ngwadleka 2021). As per Caldera (2010), innovative firms are more likely to export than non-innovative ones because exporting is profitable as the returns from their sales may recover the amount invested in innovation inputs.

In contrast, endogenous growth models endogenise the rate of innovation and predict the dynamic effects of international trade on firms' innovative activities (Grossman and Helpman 1991; Segerstrom, Anant, and Dinopoulos 1990; Young 1991; Howitt and Aghion 1998). In their framework, the emphasis is on the effect of international knowledge spillovers (through flows of ideas and/or goods), and the effect of trade on the incentive to invest in Research and Development (R&D) hence on innovation (Grossman and Helpman 1991; Howitt and Aghion 1998). The causality thus runs from exporting to innovation, where exporting firms are more likely to innovate than non-exporters. Three mechanisms explain the exporting-innovation relationship. First, strong competition from world markets compels firms to invest in innovation to upgrade their products and processes to remain competitive internationally. This also necessitates investment in innovation to adapt to varied technological requirements in the foreign nation. The second mechanism operates by a rise in external demand, leading to higher capacity use and greater economies of scale for exporting firms. Economies of scale arise as exporting firms produce for a wider market and thus, increased sales can recover investment costs in innovation, providing an incentive for higher levels of innovation (Love and Roper 2015; Wakelin 1998). Lastly, exposure to superior knowledge and technology on the international market leads to the learning by exporting effect, promoting greater innovation. When exporting firms interact with foreign networks, they gain from the market-related knowledge and access to specific expertise such as new production techniques and processes as well as new product designs. The transmission of new

knowledge and new technologies through foreign market participation provides exporting firms with a competitive advantage compared to their non-exporting counterparts (Aw, Chung, and Roberts 2000; Faustino and Matos 2015). Within the product-cycle trade models and the global-economy growth models, a mutual causal link between innovation and exports is postulated.

The debate between the self-selection and learning by exporting hypothesis and the causal link between innovation and exports have generated many studies. Although there is a general agreement across empirical studies that the self-selection mechanism is more likely to hold, there is limited evidence on the learning by exporting channel (Ferrante and Freo 2019; Serrano and Myro 2019). Existing empirical studies have found evidence in favour of self-selection of more productive and innovative firms into exporting, supporting the theoretical prediction by Melitz (2003). For example. Alvarez and López (2005) show that Chilean firms invest more before entering the export market, so much that firms aim to raise their productivity to enter the export market. Furthermore, Van Beveren and Vandenbussche (2010) address the issue of anticipation by instrumenting measures of innovation with spending on research and development and observe that controlling for the anticipation effect, there is no link between innovation and exports among Belgian firms. They conclude that all positive links between innovation and exports must come from firms, innovating in anticipation of their entry into the export market. Lopez-Bazo and Motellon (2018) assess the effects of product and process innovation on Spanish firms' export performance and find that the impact differs across regions. The gap in the export propensity between innovative and non-innovative firms, conditional on other sources of firm heterogeneity, tends to be wide in regions with an extensive high margin of exports.

However, the evidence has been mixed on the learning by exporting hypothesis. There is an observed relationship between exporting firms and innovation as exporting triggers innovation and productivity. Exporters thus tend to innovate more than non-exporters (Wakelin 1998; Alvarez and Robertson 2004). For instance, Barrère, Jung, and Karsaclian (2021) analyse the innovation-export hypothesis for Uruguayan manufacturing firms, and their results indicate that when firms in a developing country export to another developing economy, innovation precedes exports in line with the self-selection hypothesis. However, when the export market is a developed country, firms cannot cope simultaneously with innovation and export strategies, and they innovate to access export markets or transform knowledge from exports into innovation (i.e. the learning by exporting hypothesis). De Fuentes, Niosi, and Peerally (2021), in turn, find support for the circular relationship between Canadian firms' exports and innovation, whereby they reinforce and drive each other. Their findings indicate that policy initiatives and firm-level strategies for innovation and exports support the innovation-exports nexus, but the results are not uniform across sectors and time.

The empirical studies have focussed mainly on developed economies and the manufacturing sector in particular (for instance, Lopez-Bazo and Motellon 2018; Sala Rios and Torres Solé 2021 for Spain; De Fuentes, Niosi, and Peerally 2021 for Canada; Segarra-Blasco, Teruel, and Cattaruzzo 2020 for European countries). Studies on developing economies and the services sector are rather scant except for a few recent ones on emerging countries such as Lafuente et al. (2019) for Colombia; De Fuentes, Niosi, and Peerally (2021) for Mexico and Turkey; Spuldaro et al. (2021) for Brazil, Russia, India, and China and Barrère, Jung, and Karsaclian (2021) for Uruguay, amongst others. The link between innovation and exports for Africa has been analysed through country-specific studies or

a sample of African economies (Barasa et al. 2016; Márquez-Ramos, Martínez-Zarzoso, and Parra 2018; Amadu and Danquah 2019; Donbesuur et al. 2020 Avenyo, Tregenna, and Ngwadleka 2021). However, the empirical evidence for the continent remains inconclusive (Avenyo, Tregenna, and Ngwadleka 2021). Amadu and Danquah (2019) show that the interactions between research and development and innovation, and education and innovation have positive effects on the likelihood of manufacturing and service firms in Ghana to export, but the statistical significance of this result holds robust only for a limited sample. Donbesuur et al. (2020) and Márquez-Ramos, Martínez-Zarzoso, and Parra (2018) argue both product and process innovation impact positively the export performance of Ghanaian and Egyptian firms, respectively.

In contrast, Barasa et al. (2016) postulate a positive and significant impact of product innovation on exports in four Sub-Saharan African economies but fail to observe a statistically significant positive effect of exports on innovation. Hence, although the self-selection hypothesis holds, the learning by exporting mechanism does not seem to occur in this case. The positive link between innovation and subsequent exporting is mediated by market creation, while that between exporting and subsequent innovation is mediated by customer feedback. Market creation significantly mediates around 32.5% of innovation on subsequent exporting, whereas customer feedback has a larger coefficient, mediating about 67.4% of the effect of exporting on subsequent innovation. Avenyo, Tregenna, and Ngwadleka (2021) find evidence of a bi-directional positive link between product and process innovation and export performance across African firms whereby innovation is crucial for export propensity and export intensity, and similarly exporting increases the likelihood of firms to innovate. Firms with a high share of foreign ownership and those with an internationally recognised quality certification, strengthen the positive bi-directional link between innovation and export performance.

In addition, there is strong support favouring a causal effect of innovation on exports, particularly in the case of product innovations. Studies focusing on different types of innovation have indeed postulated a strong link between product innovation and exports (Roper and Love 2002; Nguyen et al. 2008; Caldera 2010; Tavassoli 2018) but a weaker link between process innovations and exporting (Cassiman, Golovko, and Martínez-Ros 2010). Similarly, in the South African case, Vannoorenberghe (2015) shows a strong association between product innovation and exporting but a weaker link between exports and process innovation. In contrast, Van Beveren and Vandenbussche (2010) and Becker and Egger (2013) state that product innovation is more linked to exports than process innovation, but the combination of both seems to be even more important. Taking the latter perspective, Ayllón and Radicic (2019) observe a strong complementarity between product and process innovation and exports of Spanish manufacturing firms.

The causality in the innovation-export nexus is difficult to separate as both activities are jointly determined. The difficulty of disentangling the effects is well known (Costantini and Melitz 2009). Whilst the current empirical studies provide mixed evidence on the learning by exporting hypothesis, the empirical work on the self-selection hypothesis tends to be clearer, favouring the idea that more productive and innovative firms tend to export more. However, the latter mechanism also depends on the assessed sector or activity or the mediating factors considered in analysing the innovation-export linkage. The reviewed literature suggests no conclusive evidence on the innovation-export performance nexus for developing economies and more so for Africa. This, therefore,

necessitates empirical investigation by testing the complex innovation-export association for African economies where growth in innovation is widely seen as a primary source of economic growth, and in the same vein, exports represent an essential avenue for development.

3. Data and methods

3.1. Data

Data were collected from the World Bank Enterprise Survey for 45 African countries from 2006 to 2020. The survey includes 44,605 firms across the manufacturing and services sectors.[1] Registered companies with 5 or more employees are interviewed in the manufacturing and services sectors, where services firms include those in construction, retail, wholesale, hotels, restaurants, transport, storage, communications, and information technology. The Enterprise Survey does not cover 100% government/state ownership firms.

The surveys unit uses two instruments: the Manufacturing Questionnaire and the Services Questionnaire. Information on the firm characteristics, gender participation, access to finance, annual sales, costs of inputs/labour, workforce composition, bribery, licensing, infrastructure, trade, crime, competition, capacity utilisation, land and permits, taxation, informality, business-government relations, innovation and technology, and performance measures are available. Over 90% of the questions objectively ascertain characteristics of a country's business environment. The remaining questions evaluate the survey respondents' opinions on the obstacles to firm growth and performance. The mode of data collection is face-to-face interviews. The strength of the data is that they provide comparable micro-level data on African countries using innovation and exporting variables.

A stratified random sampling methodology is adopted where all population members have the same probability of being selected, and no weighting of the observations is required. The population units are grouped within homogeneous groups, and simple random samples are selected within each group. This enables the computation of estimates for each strata with a specified level of precision, while the population estimates can also be computed by weighting the individual observations. The sampling weights take care of the varying selection probabilities across different strata. The strata for Enterprise Surveys are firm size, business sector, and geographic region within a country.[2]

3.2. Econometric strategy

We extend on recent work testing the innovation-export nexus for Africa, namely Avenyo, Tregenna, and Ngwadleka (2021) and Barasa et al. (2016). The two-way relationship between innovation and export performance at the firm level (that is, the self-selection hypothesis and the learning by exporting hypothesis) is analysed by considering the complementarity effects between product and process innovation, as measured by Evangelista and Vezzani (2012) and Okumu, Bbaale, and Guloba (2019). The study considers two dimensions of the firm's export performance in terms of export intensity and export propensity. Export intensity is the share of exports in a firm's total sales (Calof 1994; Salomon and Shaver 2005), whilst export propensity is defined as to

whether or not a firm is engaged in exports to foreign markets. The former is a continuous variable, while the latter is a dichotomous variable taking the value of 1 if the firm exports and zero otherwise. Exporters are defined in the firm-level survey as enterprises involved in direct or indirect export activities. Indirect exports are sold to a trader or third party who then exports the product without modifications, while direct exports relate to the sales of goods where the immediate recipient is outside the country's borders (World Bank Enterprise Survey 2020). This definition is used to compute export propensity and intensity. Similar measures have been used by Bertarelli and Lodi (2018); Avenyo, Tregenna, and Ngwadleka (2021), amongst others.

The following equations are estimated jointly using the two-stage least squares method.

$$\begin{aligned} Exports_{i,j} = {} & \beta_0 + \beta_1 FirmAge_{i,j} + \beta_2 FirmAge^2_{i,j} + \beta_3 Size_{i,j} + \beta_4 Sales\ Per\ Worker_{i,j} \\ & + \beta_5 Cost\ of\ Labour\ Per\ Worker_{i,j} + \beta_6 Business\ City_{i,j} \\ & + \beta_7 Foreign\ Ownership_{i,j} + \beta_8 Innovation_{i,j} + \beta_9 Business\ Environment_{i,j} \\ & + \beta_{10} Sector_{i,j} + \beta_{11} Country_{i,j} + e_{i,j} \end{aligned} \tag{1}$$

$$\begin{aligned} Innovation_{i,j} = {} & \varphi_0 + \varphi_1 FirmAge_{i,j} + \varphi_2 FirmAge^2_{i,j} + \varphi_3 Size_{i,j} + \varphi_4 Sales\ Per\ Worker_{i,j} \\ & + \varphi_5 Cost\ of\ Labour\ Per\ Worker_{i,j} + \varphi_6 Business\ City_{i,j} \\ & + \varphi_7 Foreign\ Ownership_{i,j} + \varphi_8 Exports_{i,j} \\ & + \varphi_9 Business\ Environment_{i,j} + \varphi_{10} Sector_{i,j} + \varphi_{11} Country_{i,j} + u_{i,j} \end{aligned} \tag{2}$$

where the subscripts *i* and *j* show the variable by the firm and by the industry or the sector. *Innovation* is the main variable of interest. It is a latent variable indicating whether the firm has introduced product innovation or process innovation or both. Similar measures of product and process innovations have been used by existing empirical work (Silva, Styles, and Lages 2017; Azar and Ciabuschi 2017; Azar and Drogendijk 2016; Azari, Madsen, and Moen 2017). In this study, the variable *Product Innovation* means introducing new or improved products and services, which have, for instance, significant improvements in capabilities or other functions, technical specifications, improved components and materials, incorporated software and are also user-friendly amongst others. It includes products or services that differ significantly in their characteristics or uses compared to those previously produced or provided by the firm. The use of new technology or a combination of existing technology contributes to product innovation which takes the value of 1, if the firm has introduced a new product or service and zero otherwise. The variable *Process Innovation* takes a value of 1 if the enterprise undertakes process innovation which is defined as the introduction of new manufacturing methods or offering of services, logistics, delivery or distribution methods for inputs, products or services as well as supporting activities (World Bank Enterprise Survey, 2020). We extend on previous studies on the innovation-export nexus by measuring the possibility of complementarity between process and product innovations; hence, the latent variable *ProcessProductInnovation* takes a value of '0', if the firm undertakes neither process nor product innovation, '1' if the enterprise engages in either product or process innovation and '2' if it undertakes process and product innovations. This measure is in line with Okumu, Bbaale, and Guloba (2019). Imbriani, Morone, and Testa (2014) find a positive association between innovation and exporting on Italian manufacturing SMEs.

Similarly, Rehman (2017) shows that Eurasian and Central and Eastern European firms which engaged in product or process innovation are more likely to export.

The main issue in estimating the innovation-export nexus is that the innovation and export variables may be endogenous, which will cause the parameter estimates to be biased and inconsistent. The learning by exporting and the self-selection hypotheses, whereby exporting firms gain knowledge from their involvement on the world market so much that these knowledge spillovers lead to an upsurge in exporting and innovation activities (Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín 2012; Yang, Nguyen, and Le 2018) and similar firms, which direct their resources and invest in innovation, are more likely to export. To confirm the endogeneity of the above variables, the Smith-Blundell test of exogeneity (Smith and Blundell 1986) is performed. The test involves specifying that the exogeneity of one or more explanatory variables is under suspicion. The Smith-Blundell test of exogeneity involves a Chi-Square test of the explanatory power of the residuals from the first-stage equation when added to the second stage. The test fails to reject the null hypothesis of exogeneity and indicates the presence of endogeneity in the exports variables and the innovation measures at the 1% significance level.

We instrument the endogenous variables using other variables in the dataset. The identification of the instruments was based on first comparing the results from estimating the reduced-form model and searching for those variables that were uniquely significant in determining each dependent variable. In equation (1) where exports are the dependent variable and innovation measures are the endogenous variables, two instruments are used, namely the percentage of permanent full-time employees who have undergone training and whether or not the establishment has invested in Research and Development (R&D). Similar to Dachs and Peters (2014), Harrison et al. (2014), Van Beveren and Vandenbussche (2010) and Rehman (2017) and Okumu, Bbaale, and Guloba (2019), process and product innovations, and the complementary measure of product and process innovations are instrumented using R&D. R&D is a binary variable taking a value of 1 when the firm has invested in R&D and 0, otherwise. Likewise, in line with Filipescu et al. (2013), Suárez-Porto and González (2014) and Avenyo, Tregenna, and Ngwadleka (2021), training is used as another exclusion variable. The two key characteristics of these instruments are that they must be strongly related to innovation, while they must be uncorrelated to the error term of the exports equation. Thus, training and investment in R&D are reasonably exogenous to the error term and do not have a direct effect on exports but could have an indirect effect through innovation.

For equation (2) where innovation is the dependent variable and exports the endogenous variable, transport, as an obstacle, is included as the instrument. Transport cost is more likely to impact negatively on exports, and it is an important factor determining the level or the probability of exporting, while it may not have a direct effect on innovation. Low exports are linked to higher distance costs involved in selling products and services across national and international frontiers. These two equations are then estimated through the two stage least squares (2SLS) method. Similar approaches have been used in several empirical studies treating innovation and exports as inextricably interdependent (Hughes 1986; Zhao and Li 1997; Smith, Madsen, and Dilling-Hansen 2002; Cassiman and Martínez-Ros 2004; Lachenmaier and Wößmann 2006).

Lastly, we measure whether the innovation-exports nexus is mediated by the prevailing business environment across African countries in the study. Although the innovation-exports link has been extensively analysed , the underlying mechanisms that

explain this relationship are often unclear (Barasa et al. 2016). In line with Véganzonès-Varoudakis and Plane (2019) and Nam and Tram (2021), an improved business environment promotes innovation. Hence, six main dimensions of the business environment are considered, namely access to finance, electricity issues, political instability, practices of competitors in the informal sector, tax rates and corruption. These six elements are the primary constraints faced by most African enterprises surveyed. We argue that a conducive business environment, where the above obstacles are minimised, will lead to greater innovation and exports across firms in Africa. Hence the innovation-export link is mediated through a favourable business environment.

3.3. Variables and descriptive statistics

In addition to the two main variables, exports and innovations, other covariates are also controlled for, in the analysis. In explaining exports status or exports share of enterprises, many other factors become important. The control variables are the first *FirmAge* which is the firm's age since incorporation. It takes years before firms eventually export on international markets and diversify their exports progressively. Firms gain expertise in entering new foreign markets from experience which lowers the fixed costs of entry to any other new market over the following years (Sheard 2014). As the firm's age increases, exports are likely to increase so much that a positive link is expected between the two variables. Older firms have had time to establish and expand their distribution networks and position themselves to tap export markets. In addition, mature firms may have accumulated significant knowledge stocks (Baldwin 1988). However, core capabilities can become core rigidities or competence traps (Leonard-Barton 1992), and younger firms may be more proactive, flexible and aggressive. Younger firms may adopt the latest updated technology, while older firms may still be using obsolete physical capital. Thus, the firm age squared is included (FirmAge^2) to model potential changes in the firm's ability to export and innovate (Niringiye and Tuyiragize 2010).

Furthermore, *Size* denotes the firm size ranging from a small- to medium-sized and large firm size. Small enterprises have fewer than 50 employees (*Small*), medium-sized firms have between 50 and 250 workers (*Medium Sized*), while large firms have more than 250 employees (*Large Sized*). Small is the benchmark dummy. Larger firms tend to benefit from economies of scale, are more profitable, have greater market power and have more internal resources to enter the foreign markets (Majocchi, Bacchiocchi, and Mayrhofer 2005; Serrasqueiro and Nunes 2008; Mairesse and Mohnen 2010; Williams 2011; Avenyo, Tregenna, and Ngwadleka 2021). Hence, larger firms demonstrate greater prospects of exporting via their scope of internalisation and economies of scale (Niringiye and Tuyiragize 2010; D'Angelo and Buck 2019), while small firms prefer to stay in domestic markets due to limited resources to face foreign competition (Rehman 2017). Similarly, larger firms may be in a better position to invest in innovation because they have access to more resources and have an incentive to invest in new technologies to expand their activities. It has also been postulated that a non-linear relationship may exist between firm size and exports, indicating a threshold effect (Wakelin 1998; Bernard and Jensen 1999). Although large firms have an incentive to export more, this happens up to a level as they may prefer to enter the market by foreign direct investment rather than exports. This, therefore, predicts a positive first-order but a negative second-order effect on exports (Cassiman and Martinez-Ros 2007).

In line with the above equations, sales per worker (*Sales Per Worker*) is included as a control variable measuring the firm's total sales divided by the number of employees. This is used as a proxy for labour productivity. As per the existing literature, enterprises with a high labour productivity ratio are more likely to export and invest in innovation and new technologies (Avenyo, Tregenna, and Ngwadleka 2021). Likewise, lower unit labour costs will encourage firms to enter foreign markets as they are better positioned to face the high level of global competition. Hence, the cost of labour per worker *(Cost of Labour Per Worker)* is included and measured by the total costs of labour in the last fiscal year divided by the total number of workers in the enterprise. Bernard and Wagner (2001), and Impullitti and Licandro (2018) show that higher productivity firms are more inclined to export.

The location of the enterprise (*Business City*) is also underlined in terms of a dichotomous variable taking a value of 1 if the firm is located in the main business city and zero otherwise. This dummy variable captures factors that influence transport costs, infrastructure and business services (Graner and Isaksson 2002). Likewise, the firm's ownership structure (*Ownership Structure*) is important for the cost to access foreign markets. Foreign ownership reflects the advantages of proprietary information and special access to marketing networks (Berry 1992). Firms with foreign networking relationships tend to have better export and innovative performance (Babakus, Yavas, and Haahti 2006). Foreign ties help reduce costs of export and innovative activities, mainly through the creation and sharing of information and knowledge with foreign partners (Mais and Amal 2011; Grandinetti and Mason 2012). To model ownership structure, enterprises are split into domestic and foreign-owned. Foreign-owned firms have a given percentage of their business activities owned by foreign individuals, companies or organisations. Foreign Ownership *(Foreign Ownership)* takes a value of 1 if at least 10% of the enterprise is foreign-owned and 0 otherwise. Firms with a high share of foreign ownership tend to adopt the latest technologies, build their knowledge capacity and innovate faster than domestic firms (Cieslik and Michałek 2018b). Similarly, foreign ownership increases the competitiveness of enterprises that are more inclined to penetrate foreign markets (Ye, Zhang, and Zhang 2021); hence, firms with higher foreign ownership tend to be more export-oriented and engage more in innovation (Okubo, Wagner, and Yamada 2017).

Export behaviour is likely to vary across sectors. Sector dummies (*Sector*) are thus included to capture differences across two broad sectors, namely manufacturing and services covered in the survey. For sectoral comparison, a dummy variable is introduced, and it is codified one if the firm belongs to the manufacturing sector and zero otherwise. There could be unobserved sector-specific factors like the extent of domestic and foreign competition and product characteristics for export behaviour which make some products more difficult to transport than others, thus limiting export potential (Niringiye and Tuyiragize 2010). The country dummy (*Country*) is also incorporated to account for country-specific effects (Cieslik and Michałek 2018a) and differentiate across countries in different parts of Africa. We differentiate across Central Africa, Southern Africa, Western, Eastern and Northern Africa. Northern Africa is the benchmark dummy. This geographical breakdown allows for a better analysis of the innovation-export nexus across different regions on the continent.

One crucial element in exporting performance and innovative capacity is the ease of doing business and the current business environment in which enterprises are operating. An accommodating business environment will encourage firms to operate efficiently and

strengthen incentives for firms to innovate and increase productivity (Rossi et al. 2021). Rossi et al. (2021) observe that a friendly regulatory environment is conducive for European firms to start exporting. Likewise, Reçica et al. (2019) indicate that macroeconomic instability is a moderating factor of export performance in transition economies where firms shift to the foreign market as a risk-shifting mechanism. A poor business environment may increase the obstacles to conducting business activities and decreases a country's prospects for reaching its potential in terms of production, exports and investment. The main obstacles specified by enterprises in the survey are access to finance, corruption, electricity problems, political instability, and practices of competitors in the informal sector and tax rates. We postulate that the higher the obstacles, the lower the firm's innovation and exporting levels, thus assuming a negative link. Rehman (2017) argues that trade regulations, political instability and the lack of skilled labour force are more likely to reduce the export performance of Eurasian firms.

Table 1 reports a detailed description of the variables used in the estimation process, with their computation and expected sign as well as the descriptive statistics of the firm survey data used for the 45 African countries.

4. Findings

The findings are first explained by a baseline regression where equation (1) with export propensity is estimated by the probit technique given the dichotomous nature of the dependent variable, while export propensity is a continuous variable estimated by the simple Ordinary Least Squares (OLS) method. Equation (2) is next estimated using the multinomial probit technique as the dependent variable accounts for the possible complementarity between process and product innovations and consists of 3 categories where 0 implies no innovation, 1 is either product or process innovation and 2 indicates a situation where the firm engages in both process and product innovation (see Table 2). The next part of the estimation results account for the endogeneity of exports and innovation; hence, equations (1) and (2) are estimated by the two-stage least squares method (see Table 3). Lastly, we argue that the innovation and exports link are mediated by the business environment so much that obstacles to conducting business activities may have a negative impact on exports and innovation. Different business constraints are included as mediating factors (see Table 4)

4.1. The export propensity, export intensity and innovation link-baseline regression

Table 2 reveals a positive statistically significant association between innovation and export intensity and export propensity at a 1% significance level. This result advocates that innovation drives firms' exporting and supports the self-selection hypothesis. Innovative firms are more likely to integrate the foreign markets (export propensity) and export higher levels (export intensity) than non-innovative firms (see columns (2a) and (2b)). Similar results have been observed by Rehman (2017), Amadu and Danquah (2019), De Fuentes, Niosi, and Peerally (2021), Rossi et al. (2021) and Avenyo, Tregenna, and Ngwadleka (2021) . Product innovation, however, seems to have the lowest impact on exports relative to process innovation. It is even statistically insignificant for export intensity in column (2a). Likewise, Manez-Castillejo et al. (2009) found no statistical evidence between product innovation and export probability but noted that

Table 1. Variables and descriptive statistics.

Variable	Description of variables	Expected sign	Obs	Mean	Std. dev.	Min	Max
Export propensity	Dummy = 1 if the firm is involved in either direct or indirect exports, and 0 otherwise	Positive	43429	0.176	0.381	0	1
Export intensity	A continuous variable showing the percentage of sales from direct and/or indirect exports in the last fiscal year, constructed as the sum of direct and indirect export intensities as a share of total sales	Positive	43429	8.101	22.490	0	100
Firm age	It is calculated by the number of years the firm has been in operation since incorporation	Positive/negative	43603	24.173	14.803	0	220
Firm age squared	It is calculated by squaring the firm age variable to capture any non-linear effect	Positive	43603	803.463	1368.443	0	48400
Capital city	It depicts the location of the firm being equal to 1 if it is located in the capital city and 0 otherwise	Positive	29489	0.377	0.485	0	1
Foreign ownership	It takes a value of 1 if at least 10% of the enterprise is foreign-owned and 0 otherwise	Positive	43730	0.146	0.353	0	1
Small sized firms	Dummy = 1 for those firms having less than 50 employees and 0 otherwise	Negative	44096	0.788	0.408	0	1
Medium sized firms	Dummy = 1 for those firms having between 50 and 250 workers, and 0 otherwise	Positive	44096	0.165	0.371	0	1
Large firms	Dummy = 1 for those firms having more than 250 employees and 0 otherwise	Positive	44096	0.046	0.210	0	1
Sales per worker	Continuous variable: Log of sales divided by total employment three fiscal years ago	Positive	32579	611,000,000	76,900,000,000	0	1.28E+13
Labour costs per worker	Continuous variable: Log of cost of labour divided by total employment three fiscal years ago	Positive/negative	38766	1,564,758	27,800,000	0	4.34E+09
Product innovation	Dummy = 1 if during last 3 Yrs, the firms have introduced new products or services and 0, otherwise	Positive	29282	0.331	0.471	0	1
Process innovation	Dummy = 1 if during last 3 Yrs, the firms have introduced new/significantly improved the process and 0, otherwise	Positive	29052	0.336	0.472	0	1

Product or process innovation	Dummy = 1 if the firms have invested in either product or process innovation and 0 otherwise	Positive	29151	0.196	0.397	0	1
Product∗process innovation	Dummy = 1 if the firms have invested in both product and process innovation and 0 otherwise	Positive	29151	0.236	0.424	0	1
Access to finance obstacle	Dummy = 1 if firms have reported that access to finance is a major hurdle in the business environment and 0 otherwise	Negative	43147	0.187	0.390	0	1
Corruption obstacle	Dummy = 1 if firms have reported that corruption is a major hurdle in the business environment and 0 otherwise	Negative	43147	0.071	0.256	0	1
Political instability obstacle	Dummy = 1 if firms have reported that political instability is an obstacle and 0 otherwise	Negative	43147	0.120	0.325	0	1
Electricity constraints obstacle	Dummy = 1 if firms have reported that electricity constraint represents an obstacle and 0 otherwise	Negative	43147	0.198	0.399	0	1
Tax rates obstacle	Dummy = 1 if firms have reported that tax is a constraint and 0 otherwise	Negative	43147	0.087	0.282	0	1
Informal sector competition obstacle	Dummy = 1 if firms have reported that informal sector competition is an obstacle and 0 otherwise	Negative	43147	0.088	0.284	0	1

Source: Author's compilation from the World Bank Enterprise Survey Database, 2021.

Table 2. Baseline regressions for export propensity and intensity and innovation.

	Export intensity	Export intensity	Export propensity	Export propensity	Innovation	Innovation	Innovation	Innovation
	OLS		Probit		Multinomial Probit		Multinomial Probit	
	(2a)	(2b)	(2c)	(2d)	(2e) Product or process innovation	(2f) Product ∗process innovation	(2g) Product or process innovation	(2h) Product ∗process innovation
Firm age	0.035	0.038	0.002	0.002	0.009	0.021	0.008	0.02
	(1.34)	(1.48)	(0.001)∗∗∗	(0.001)∗∗∗	(3.14)∗∗∗	(7.00)∗∗∗	(3.00)∗∗∗	(6.75)∗∗∗
Firm age squared	0.0004	0.0004	0.00001	0.00001	0.0001	0.0002	0.0001	0.0002
	(1.55)	(1.69)∗	(0.00001)∗∗	(0.00001)∗∗	(2.72)∗∗∗	(5.94)∗∗∗	(2.72)∗∗∗	(5.83)∗∗∗
Capital city	−3.617	−3.684	−0.031	−0.032	0.118	0.159	0.119	0.158
	(10.31)∗∗∗	(10.51)∗∗∗	(0.006)∗∗∗	(0.006)∗∗∗	(3.60)∗∗∗	(4.80)∗∗∗	(3.62)∗∗∗	(4.76)∗∗∗
Foreign ownership	11.556	11.544	0.192	0.191	0.375	0.397	0.345	0.365
	(16.52)∗∗∗	(16.52)∗∗∗	(0.011)∗∗∗	(0.011)∗∗∗	(7.87)∗∗∗	(8.26)∗∗∗	(7.21)∗∗∗	(7.55)∗∗∗
Medium-sized firms	8.786	8.761	0.194	0.194	0.055	0.171	0.014	0.127
	(16.16)∗∗∗	(16.14)∗∗∗	(0.009)∗∗∗	(0.009)∗∗∗	(1.32)	(3.99)∗∗∗	(0.33)	(2.93)∗∗∗
Large firms	15.049	14.977	0.344	0.343	0.293	0.403	0.22	0.325
	(14.77)∗∗∗	(14.74)∗∗∗	(0.016)∗∗∗	(0.016)∗∗∗	(4.37)∗∗∗	(5.78)∗∗∗	(3.25)∗∗∗	(4.63)∗∗∗
Product innovation	0.300	–	0.033	–	–	–	–	–
	(0.61)	–	(0.008)∗∗∗	–	–	–	–	–
Process innovation	3.241	–	0.051	–	–	–	–	–
	(6.42)∗∗∗	–	(0.009)∗∗∗	–	–	–	–	–
Product or process innovation	–	2.170	–	0.074	–	–	–	–
	–	(4.40)∗∗∗	–	(0.009)∗∗∗	–	–	–	–
Product∗process innovation	–	2.757	–	0.083	–	–	–	–
	–	(5.37)∗∗∗	–	(0.009)∗∗∗	–	–	–	–
Export intensity	–	–	–	–	0.003	0.004	–	–
	–	–	–	–	(4.81)∗∗∗	(5.91)∗∗∗	–	–
Export propensity	–	–	–	–	–	–	0.357	0.411
	–	–	–	–	–	–	(8.85)∗∗∗	(9.98)∗∗∗
Sales per worker	0.081	0.077	0.004	0.004	0.014	0.008	0.013	0.007
	(0.76)	(0.72)	(0.002)∗∗	(0.002)∗∗	(1.84)∗	(0.97)	(1.70)∗	(0.85)
Labour costs per worker	−0.152	−0.169	0.002	0.002	0.034	0.044	0.033	0.043
	(1.23)	(1.37)	(0.002)	(0.002)	(3.61)∗∗∗	(4.69)∗∗∗	(3.48)∗∗∗	(4.52)∗∗∗

Access to finance	−3.303	−3.316	−0.054	−0.054	−0.013	0.033	−0.003	0.043
	(5.78)***	(5.81)***	(0.008)***	(0.008)***	(0.27)	(0.66)	(0.07)	(0.87)
Corruption	−3.581	−3.523	−0.036	−0.036	−0.056	−0.022	−0.053	−0.021
	(5.21)***	(5.13)***	(0.011)***	(0.011)***	(0.89)	(0.34)	(0.84)	(0.32)
Political instability	−2.808	−2.848	−0.037	−0.038	0.096	−0.101	0.102	−0.095
	(4.82)***	(4.89)***	(0.009)***	(0.009)***	(1.89)*	(1.79)*	(1.99)**	(1.69)*
Electricity constraints	−3.148	−3.039	−0.06	−0.059	0.131	0.085	−0.117	0.101
	(4.92)***	(4.75)***	(0.009)***	(0.009)***	(2.38)**	(1.65)*	(2.12)**	(1.91)*
Tax rates	−4.706	−4.697	−0.063	−0.063	−0.136	−0.168	−0.127	−0.159
	(7.79)***	(7.79)***	(0.009)***	(0.009)***	(2.29)**	(2.73)***	(2.13)**	(2.58)***
Informal sector competition	−3.932	−3.991	−0.051	−0.052	0.195	0.06	0.202	0.068
	(6.09)***	(6.19)***	(0.010)***	(0.010)***	(3.34)***	(0.98)	(3.46)***	(1.11)
Manufacturing sector	4.227	4.236	0.091	0.091	0.129	0.240	0.111	0.22
	(12.28)***	(12.29)***	(0.006)***	(0.006)***	(3.95)***	(7.15)***	(3.38)***	(6.53)***
Central Africa	−1.406	−1.451	0.014	0.013	0.611	0.985	0.604	0.98
	(1.79)*	(1.84)*	(0.018)	(0.018)	(7.38)***	(11.37)***	(7.28)***	(11.26)***
Eastern Africa	1.032	0.952	−0.003	−0.004	1.367	2.033	1.372	2.04
	(1.75)*	(1.65)*	(0.009)	(0.009)	(29.62)***	(42.88)***	(29.70)***	(42.95)***
Southern Africa	−4.036	−4.097	−0.048	−0.049	0.597	1.101	0.601	1.107
	(9.12)***	(9.27)***	(0.009)***	(0.009)***	(12.67)***	(22.47)***	(12.75)***	(22.56)***
Western Africa	1.677	1.758	0.035	0.035	1.275	1.976	1.269	1.971
	(2.98)***	(3.11)***	(0.010)***	(0.010)***	(26.74)***	(40.39)***	(26.58)***	(40.23)***
Constant	7.224	7.328	–	–	−2.456	−3.172	−2.447	−3.16
	(6.60)***	(6.68)***	–	–	(26.32)***	(33.05)***	(26.26)***	(32.91)***
R-square	0.11	0.11	0.14	0.14	–	–	–	–
Wald Chi-square	–	–	–	–	3738.23***	3738.23***	3815.91***	3815.91***
N	18,550	18,601	18,550	18,601	18,601	18,601	18,601	18,601

Source: Author's Computation, 2021.

Table 3. Two-way link between innovation and exports: Two stage least squares (2 SLS) method.

	Export propensity 3(a)	Export intensity 3(b)	Product and process innovation 3(c)	Product or process innovation 3(d)	Product and process innovation 3(e)	Product or process innovation 3(f)
Product or process innovation	2.485	58.341	–	–	–	–
	(12.68)***	(2.08)**	–	–	–	–
Product*process innovation	0.548	13.587	–	–	–	–
	(2.13)**	(4.43)***	–	–	–	–
Export propensity	–	–	2.573	2.074	–	–
	–	–	(60.40)***	(7.93)***	–	–
Export intensity	–	–	–	–	0.042	0.037
	–	–	–	–	(76.42)***	(10.38)***
Firm age	0.003	−0.006	−0.002	−0.003	0.001	−0.001
	(1.65)*	(0.17)	(1.05)	(2.15)**	(0.77)	(0.49)
Firm age squared	0.0001	0.00001	0.0001	0.00002	0.00001	0.0007
	(0.62)	(0.15)	(0.30)	(0.95)	(0.65)	(0.47)
Capital city	−0.095	−4.461	0.101	0.086	0.170	0.152
	(3.21)***	(8.48)***	(5.95)***	(4.36)***	(10.26)***	(7.86)***
Foreign ownership	0.172	7.995	0.442	0.286	0.448	0.335
	(1.66)*	(4.95)***	(12.31)***	(3.55)***	(14.49)***	(4.48)***
Medium-sized firms	0.308	8.211	0.448	0.39	0.343	0.322
	(3.11)***	(12.24)***	(15.63)***	(6.84)***	(14.22)***	(7.88)***
Large firms	0.407	12.295	0.792	0.603	0.587	0.484
	(2.50)**	(8.14)***	(15.66)***	(5.29)***	(14.45)***	(5.70)***
Sales per worker	0.002	−0.044	0.009	−0.002	−0.003	0.002
	(0.37)	(0.30)	(2.09)**	(0.34)	(0.74)	(0.40)
Labour costs per worker	−0.008	−0.468	0.001	0.002	0.012	0.011
	(1.47)	(2.55)**	(0.16)	(0.33)	(2.38)**	(1.89)*
Access to finance	−0.103	−3.055	−0.154	−0.108	−0.147	−0.115
	(2.24)**	(4.02)***	(6.11)***	(3.21)***	(6.06)***	(3.65)***
Corruption	−0.052	−2.974	−0.105	0.057	−0.147	−0.106
	(1.27)	(3.25)***	(3.19)***	(1.39)	(4.75)***	(2.71)***

Political instability	−0.119	−3.769	−0.070	−0.140	−0.094	−0.150
	(3.78)***	(3.77)***	(2.49)**	(4.62)***	(3.53)***	(5.20)***
Electricity constraints	−0.053	−1.348	0.191	−0.039	−0.149	−0.037
	(0.86)	(1.00)	(6.87)**	(0.82)	(5.58)**	(0.85)
Tax rates	−0.092	−3.577	−0.143	−0.094	−0.179	−0.139
	(1.72)*	(3.97)**	(4.62)***	(2.15)**	(5.89)***	(3.39)***
Informal sector competition	−0.191	−5.932	−0.132	−0.204	−0.162	−0.220
	(4.56)***	(4.31)***	(4.28)***	(5.87)***	(5.42)***	(6.76)***
Manufacturing sector	0.144	3.265	0.187	0.173	0.146	0.146
	(2.68)***	(6.56)***	(9.01)***	(5.22)***	(7.36)***	(5.69)***
Central Africa	−0.189	−6.709	0.144	0.154	0.189	0.196
	(3.64)***	(3.14)***	(2.43)**	(2.42)**	(3.39)***	(3.58)***
Eastern Africa	−0.474	−10.499	0.303	0.299	0.194	0.214
	(9.80)***	(2.97)***	(3.88)***	(3.87)***	(2.45)**	(2.50)**
Southern Africa	−0.298	−9.015	0.305	0.237	0.317	0.271
	(5.52)***	(5.74)***	(6.54)***	(6.92)***	(6.77)***	(8.56)***
Western Africa	−0.364	−8.868	0.219	0.213	0.16	0.168
	(9.44)***	(2.79)***	(2.78)***	(2.61)***	(2.02)**	(2.02)**
Constant	−0.889	6.438	−0.695	−1.006	−0.813	−1.07
	(3.66)***	(3.39)***	(5.00)***	(5.49)***	(5.93)***	(5.78)***
	18,446	18,491	18,491	18,491	18,491	18,491

Source: Author's Computation, 2021.

Table 4. Linking innovation and exports by business environment.

	Innovation	Innovation	Innovation	Exports
	Complementarity of process and product innovation			
	Multinomial probit		Probit	Probit
	(4a)	(4b)	(4c)	(4d)
Firm age	0.007	0.018	0.001	0.008
	(2.39)**	(5.84)***	(0.44)	(4.09)***
Firm age squared	0.0001	0.0001	0.0001	0.0002
	(2.50)**	(5.26)***	(0.90)	(2.41)**
Capital city	0.178	0.213	0.068	−0.121
	(5.17)***	(6.15)***	(2.81)***	(4.84)***
Foreign ownership	0.322	0.32	0.153	0.625
	(6.47)***	(6.36)***	(4.46)***	(19.25)***
Medium sized firms	0.037	0.12	−0.002	0.634
	(0.84)	(2.66)***	(0.07)	(22.75)***
Large firms	0.223	0.352	0.077	0.993
	(3.09)***	(4.73)***	(1.51)	(22.57)***
Sales per worker	0.014	0.004	0.01	0.01
	(1.79)*	(0.53)	(1.72)*	(1.68)*
Labour costs per worker	0.031	0.041	0.01	0.007
	(3.23)***	(4.31)***	(1.40)	(0.99)
Manufacturing sector	0.053	0.182	−0.018	0.346
	(1.55)	(5.20)***	(0.76)	(14.17)***
Central Africa	0.647	0.971	0.334	0.172
	(7.63)***	(10.77)***	(5.53)***	(2.73)***
Eastern Africa	1.379	2.061	0.537	0.03
	(28.18)***	(40.68)***	(15.85)***	(0.82)
Southern Africa	0.668	1.234	0.272	−0.183
	(13.66)***	(24.09)***	(7.82)***	(4.89)***
Western Africa	1.194	1.966	0.436	0.132
	(24.29)***	(38.74)***	(12.77)***	(3.55)***
Export propensity	0.293	0.373	0.091	–
	(5.19)***	(6.61)***	(2.35)**	–
Export propensity*FinanceNOOBS	0.256	0.281	0.136	–
	(2.57)**	(2.70)***	(1.96)*	–
Export propensity*PolInstabNOOBS	0.272	0.269	0.154	–
	(2.56)**	(2.54)**	(2.08)**	–
Export propensity*ElectricityNOOBS	0.056	0.019	0.113	–
	(0.58)	(0.18)	(1.65)*	–
Export propensity*InformalCompNOOBS	0.074	0.007	0.075	–
	(0.81)	(0.07)	(1.17)	–
Export propensity*TaxRatesNOOBS	0.011	0.105	0.01	–
	(0.10)	(0.95)	(0.14)	–
Export propensity*CorruptionNOOBS	0.124	0.135	0.064	–
	(1.11)	(1.20)	(0.81)	–
Product*process innovation	–	–	–	0.273
	–	–	–	(6.47)***
Product or process innovation	–	–	–	0.241
	–	–	–	(7.06)***
Product*process innovation*TaxRatesNOOBS	–	–	–	0.077
	–	–	–	(1.02)
Product*process innovation*CorruptionNOOBS	–	–	–	0.052
	–	–	–	(0.68)
Product*process innovation*InformalCompNOOBS	–	–	–	0.015
	–	–	–	(0.45)
Product*process innovation*ElectricityNOOBS	–	–	–	0.045
	–	–	–	(1.24)
Product*process innovation*FinanceNOOBS	–	–	–	0.024
	–	–	–	(0.35)

(*continued*).

Table 4. Continued.

	Innovation	Innovation	Innovation	Exports
	Complementarity of process and product innovation			
	Multinomial probit		Probit	Probit
	(4a)	(4b)	(4c)	(4d)
Product∗process innovation∗PoliticalNOOBS	–	–	–	0.115
	–	–	–	(1.65)∗
AccesstoFinanceNOOBS	0.079	0.144	0.038	−0.002
	(1.65)∗	(2.80)∗∗∗	(1.08)	(0.05)
PoliticalInstabilityNOOBS	0.089	0.053	0.039	−0.057
	(1.77)∗	(1.05)	(1.09)	(1.53)
TaxratesNOOBS	0.073	0.121	0.036	−0.014
	(1.41)	(2.25)∗∗	(0.97)	(0.39)
ElectricityNOOBS	0.178	0.235	0.102	−0.019
	(3.73)∗∗	(4.67)∗∗∗	(2.99)∗∗∗	(0.52)
InformalCompNOOBS	0.175	0.145	0.106	0.133
	(3.73)∗∗	(2.97)∗∗∗	(3.15)∗∗∗	(3.81)∗∗
CorruptionNOOBS	0.221	0.232	0.11	−0.042
	(4.15)∗∗	(4.31)∗∗∗	(2.90)∗∗	(1.13)
Constant	−2.184	−2.847	−1.366	−1.75
	(23.40)∗∗	(30.03)∗∗∗	(21.21)∗∗	(25.91)∗∗
N	17,061	17,061	17,061	17,061

Source: Author's Computation, 2021.

process innovation increased the firm's probability to export. Further product and process innovation are associated with complementarity effects in their relationship with exports (see columns (2c) and (2d)). The coefficient on the composite measure of product and process innovation is highest on export intensity and export propensity, showing that the introduction of new products is not sufficient to boost exports as it is important for enterprises to complement it with new products or logistics distribution methods as well as supporting services. The complementarity between process and product innovation reveals that both are crucial for innovative firms to gain a competitive edge in foreign markets and adapt to market changes faster.

With regard to the control variables in the exports equation, specific firm characteristics emerge as important determinants of export intensity and propensity. In particular, the firm age impacts its ability to export and the level of exports. Similar results have been reported by Barasa et al. (2016) and Reçica et al. (2019). The resource-based view of venture internationalisation predicts that older firms will be better able to build an international network because they generally have a larger stock of resources than younger firms. Age also means learning and knowledge (Williams 2011). In contrast to Estrada and Heijs (2004) and Reçica et al. (2019), an inverted U-shaped relationship cannot be postulated in our case, as the coefficients for firm age and its squared terms remain positive and statistically significant. This quadratic link would have shown that as age increases, the export share rises or the probability of exporting rises, but after a few years, firms may exit the international market or their share of exports to total sales fall. Next, firm size is seen as a vital determinant of propensity to export and export intensity, suggesting that medium and large firms within the African region are more likely to export than small firms. This is in line with expectations and with the extant literature. This can be explained by the fact that small firms may be more risk-averse (Verwaal and Donkers 2003) due to lack of information or higher likelihood of failing relative to larger

enterprises. There are also high fixed costs to exporting making it difficult for them to enter the export market (Bigsten et al. 1997). Large firms are more likely to export due to greater economies of scale (Imbriani, Morone, and Testa 2014) and better access to various sources of finance (Ratten 2006), amongst others.

Regarding the location effects, the coefficient as to whether the firm is located in the main capital city is negative and provides no support to the theory of economic geography and trade by Krugman (1992). Sector and region dummies are also included in the regressions, whereby it can be observed that the manufacturing sector is more likely to export than the services sector across African countries. Exports shares also tend to be higher for the manufacturing sector relative to services. The region dummies are incorporated to account for differences across geographical regions within the continent. There is evidence that firms across Southern and Central Africa have lower export shares to total sales than those enterprises in Northern African countries. The reverse is noted for Western and Eastern African firms, which tend to have higher export shares than North African enterprises. In addition, the likelihood to enter the foreign market is lower for Southern African firms but higher for those located in West Africa than those in North Africa. Southern African economies tend to lag in their entrance into the foreign market and their share of exports.

Furthermore, sales per worker are positive and statistically significant only for export propensity, implying that those firms with high labour productivity have a greater incentive to penetrate the export market than those with low labour productivity. The variable sales per worker in the export intensity equation turns out to be statistically insignificant. A similar picture is gauged for labour costs per worker across export intensity and propensity functions. Enterprises require prior high productivity to export. This result is in line with empirical findings of Cassiman, Golovko, and Martínez-Ros (2010); Sharma and Mishra (2015) and Rehman (2017). Earlier productive firms are more likely to export because past productivity firms can cover the sunk costs of entry into the foreign markets. In addition, the ownership structure is factored in by differentiating between domestic and foreign-owned enterprises. There is evidence that foreign-owned private firms are more likely to export and have higher export shares. This can be explained by their better technological and skills superiority, more and productive human capital and better contacts in the international markets. Foreign firms are also in a better position than their domestic counterparts to establish forward and backward linkages so much that they can overcome productivity and export constraints. Foreign ownership is crucial in the risk-taking choices of enterprises in exporting and innovating activities. It provides firms with more information about the outside market and how to obtain high returns on their investment so much that firms may tolerate a higher risk level (Toshihiro, Wagner, and Kazuo 2017). Our results are in line with previous studies (Correa, Dayoub, and Francisco 2007; Du and Girma 2007; Toshihiro, Wagner, and Kazuo 2017) where foreign-owned firms are more successful exporters than their domestic counterparts.

Among the many obstacles to doing business across African countries, the results reveal that all the constraints are negatively associated with export propensity and export intensity. Access to finance, corruption, electricity constraints, political instability, and competition with informal firms and tax rates all show a negative and statistically significant relationship with exporting. There is strong support that a poor business environment acts as a barrier to the export propensity as well as export intensity. This

outcome infers that removing business obstacles may accelerate trade across African countries. Our findings align with Reçica et al. (2019) for transition economies.

In terms of the innovation equation (2), the key variable is the export status of the enterprise. The results reveal that exporting firms and those with high export shares tend to innovate more (product and process innovation) than non-exporting enterprises (see columns 2(e) – 2 (h)). This positive link supports the learning by exporting hypothesis (Di Cintio et al. 2019; De Fuentes, Niosi, and Peerally 2021; Avenyo, Tregenna, and Ngwadleka 2021). The multinomial probit regression indicates that exporting firms invest in product and process innovation with a higher coefficient for the complementary measure of innovation. In essence, exposure to higher economies of scale, superior knowledge and technology on the foreign markets lead to the 'learning-by-exporting effect' which promotes greater innovation (Love and Roper 2015; Wakelin 1998). Among the control variables, foreign-owned firms and larger firms are more likely to invest in innovation than domestic-owned enterprises and small firms, respectively. This is in line with existing work, for instance, Toshihiro, Wagner, and Kazuo (2017) and David et al. (2006), where foreign-owned firms have greater access to funds, can tolerate higher risk levels and can thus invest in new technologies and innovation. Innovation involves high costs, and these can be covered mainly by large enterprises which can better access external finance. There are scale and scope economies in the production of innovations, and large diversified firms are in a superior position to exploit them (Symeonidis 1996). The variable firm age and its squared term generate positive and statistically significant coefficients. This underlines that as firms grow older and more experienced, they accumulate more knowledge and are more likely to invest in innovation (Krasniqi and Kutllovci 2008).

In contrast with the export equation, where a negative coefficient was noted for firms' location in the capital city, there is evidence of a positive association between those firms located in the city and their innovative capacity. Being in the capital city implies easier and greater access to inputs, new products and techniques of production, knowledge spillovers generated by multinationals and large domestic enterprises, as well as basic facilities and infrastructural development. We further observe that those firms with higher labour costs per worker tend to invest more in product and process innovation. This can be explained by innovative firms needing skilled and highly educated workers and having to pay higher wages to attract such workers. In terms of the business environment, we note that access to finance and corruption are not statistically significant and do not represent potential obstacles for innovative firms while political instability, tax rates and electricity constraints act as barriers to innovation. This result is in line with Muok and Kingiri (2015) and Abiodun et al. (2016), who argue that weak institutions, infrastructure deficits, weak government support, poor institutional quality, including the rule of law, and control of corruption hinder the innovative capacity of enterprises in Africa. Lastly, Southern, Western, Central and Eastern African firms are more likely to invest in product or process innovation or both than their counterparts in Northern Africa. Manufacturing firms also have a higher likelihood to invest in innovation than those enterprises in the services sector.

4.2. Endogeneity of export propensity and innovation measures

The endogeneity of exports and innovation are accounted for with the Smith-Blundell test, which indicates the presence of endogeneity in the export variable and measures of

product and process innovation. While other coefficients stay remarkably unchanged, the impact of innovation on exports increases. The quantitative effects imply by the two-stage least squares estimates are substantially greater than those of the probit and OLS estimates (see Table 3 – columns 3(a) and 3(b)). Similar results have been highlighted by Toshihiro, Wagner, and Kazuo (2017) for Japanese firms.

The findings support the causal relationship whereby highly innovative firms self-select into the export markets and export positively influences the innovative performance of enterprises. Thus, the reverse causality between innovation and exporting holds for firms in the African region. This two-way relationship between innovation and exports is in line with existing literature (Amadu and Danquah 2019; Barasa et al. 2016; Cieslik, Michalek, and Michalek 2014; De Fuentes, Niosi, and Peerally 2021)

4.3. The innovation and exporting nexus: business environment matters

To uncover the mechanisms underlying the two-way link between innovation and exports across Africa, we hypothesise that this relationship is moderated by the business environment. Previous studies on the innovation-exports nexus for Africa have explained the channel through marrket creation or customer feedback (Barasa et al., 2016) or by foreign ownership and certification (Avenyo, Tregenna, and Ngwadleka 2021). We argue that a conducive business environment will promote a higher level of exports and innovation and encourage firms to operate on foreign markets. Table 4 reports the estimation results where we interact the firm's investment in product or process innovation with each element of the business environment. A similar exercise is done for those firms having invested in product and process innovation. Using the six dimensions of the business environment adopted in equations (1) and (2), together with the interaction terms to product and/or process innovation in the export equation, we can note that African firms are more likely to export and innovate under a politically stable environment, with good access to electricity and where access to finance is not an obstacle. Political stability appears as a key factor conducive to exports and innovation in Africa. Hence the results indicate that a good business environment with appropriate government measures to facilitate investment and exports will increase the firms' innovative capacities and their likelihood to penetrate the export market and improve their performance.

For many African countries that have long been characterised by social and political unrest, the promotion of innovation and exports can only be feasible in a stable business environment. A sound business environment will encourage investment in technology and knowledge-based capital whereby firms can better experiment with the latest technologies, ideas, and business models to grow, achieve economies of scale and increase their market share. The financing of innovation in terms of improving access to finance and other trade, investment and regulatory policies can help young innovative African firms in the manufacturing and services sectors.

5. Conclusion and policy recommendations

The paper investigated the link between innovation and exports for 45 African countries from 2006 to 2020 using firm-level data. Our results support the self-selection and learning by exporting hypotheses for African firms. After accounting for endogeneity of export intensity, export propensity and product and process innovation, both hypotheses

still hold robust. This further confirms the causal link between exporting and innovation. There also seems to be a positive association between firm size and export, and the same holds for innovation as medium and large firms are more likely to innovate than small enterprises. Ownership structure also matters for exporting as foreign private firms tend to have better exporting behaviour in terms of the entrance on the international markets and export intensity relative to domestic enterprises.

Obstacles in the business environment are major constraints for exporting and innovative firms in Africa. The main challenges are access to finance, corruption, electricity constraints, political instability, and tax rates. Based on the above findings, there is an increasing need for nations in the region to improve their business climate. Improving access to finance and reducing the infrastructural bottlenecks and ensuring political and social stability are key elements to create a more business-friendly environment. A suitable business environment will encourage foreign investments, which can upgrade the region's technological base and act as a foundation for innovative local firms in Africa to leap frog into the export market. Furthermore, African firms do not take advantage of the innovation opportunities available, where adopting or adapting existing innovations can result in high returns at low cost. To increase innovation capacity, African governments must invest in varied innovation needs of firms and encourage collaborative projects with high innovative performing economies such as China, Japan or India. Within these collaborations, enterprises can be better positioned to learn and adapt to innovations. Our results also show that product and process innovations are complementary and crucial for exporting firms. Hence, innovation policies must foster product and process innovation.

However, one limitation of the analysis is that it is based on cross-sectional data across countries over different waves. Performance of firms cannot be modelled over time, as panel data are not available for Africa, and not the same firms are interviewed over the different years. Furthermore, other measures of innovation could have been used to ensure the robustness of the innovation-export nexus. Non-availability of data on other components of innovation is a limitation that restricts the study to investigate only two types of innovation, mainly process and product innovation. More evidence is certainly needed over time as to whether exporting triggers innovation or innovation triggers exporting. Future work on African exporting and innovative firms should consider using panel data and controlling for different measures of innovation and other variables such as institutions, governance and the rule of law that are pertinent to the African economic and political environment.

Notes

1. Firms classified with ISIC codes 15-37, 45, 50-52, 55, 60-64, and 72 (ISIC Rev.3.1).
2. More information on the Data Collection Process and Methodology used for the World Bank Enterprise Survey can be accessed at https://www.enterprisesurveys.org/methodology.

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