Leveraging Innovation to Increase Intra-COMESA Trade

Isaac M.B. Shinyekwa,[†] Paul Corti Lakuma[⁑] and Martin Luther Munu[‡]

Abstract

This paper explores the role of technology innovation on the volume and value of COMESA exports to COMESA member states and other 43 significant importers by using a gravity model. The role of technology innovation on export trade was estimated using a panel data set of 12 years (2007-2018) with the Poisson Pseudo-Maximum Likelihood (PPML) technique given its advantage in handling several estimations challenges. The study found that technology innovation has a high potential in the COMESA region to enhance the overall quality of exports, increase competitive advantage and consequently increase the volume and value of exports. The study recommends that COMESA should increase investments in innovation, strengthen and build institutions that support technology innovation in addition to the ongoing trade facilitation efforts.

Keywords: Exports trade, technology innovation, gravity model, patent, R&D, PPML

JEL Classification Codes: F13, F15, O31, O32, O33, O34, O38,

[†] Senior Research Fellow Economic Policy Research Center, Plot 51, Pool Road, Makerere, ishinyekwa@eprcug.org

[⁑] Research Fellow Economic Policy Research Center, Plot 51, Pool Road, Makerere, plakuma@eprcug.org

[‡] Economic Policy Research Center, Plot 51, Pool Road, Makerere

1.0 Introduction

Innovation is an essential factor of the non-price competitiveness of a nation's products (Buxton *et al.*, 1991). It enables and drives the expansion of varieties of products or quality improvements for a range of existing kinds of products that a country or a region can put on the market. Recent trends in international trade, especially in developed countries, demonstrate a strong impact of innovation activity on export performance. Although there is agreement that innovation increases trade, there is no agreement on the predictions about how innovation increases exports (Chen, 2004) and by how much. A strand of literature predicts that innovation positively impacts the extensive margin of trade by introducing new products and varieties that a country exports (Grossman and Helpman, 1990).

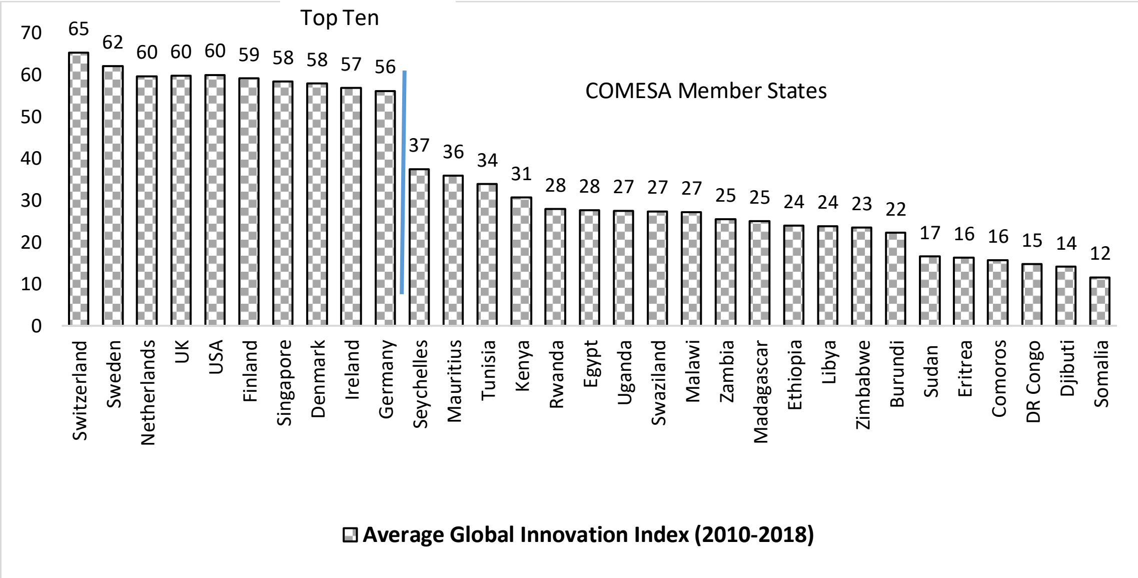
On the other hand, Grossman and Helpman (1990) and Eaton and Kortum (2001, 2002) also stress that innovation impacts the intensive margin of trade by increasing product quality and productivity. Furthermore, international trade theory highlights the importance of technological innovation in explaining a country's international competitiveness (Fagerberg, 1997). Accordingly, technological innovation is the countries' capacity to put new ideas into practice by developing products and processes that play a crucial role in international trade. Technological innovation helps introduce a new quality of a good, or new use of an already existing good, a new production method, opening a new market, and a change in the economic organization (Márquez-Ramos and Martínez-Zarzoso, 2009).

The context is that innovations generate greater competitiveness and trade, boosting integration, growth, and development. (ECA, 2016). Worldwide, countries at the top of the Global Innovation Index (GII) are also at the top of the Competitive Industrial Performance Index. African countries have very low rankings on both indices, as illustrated in Figure 1A in the Appendix. Regional integration is both a driver and beneficiary of the innovation. It enables favourable framework conditions for innovation. Moreover, when members of a bloc like Common Market for Eastern and Southern Africa (COMESA) grow in innovative capacities, they are likely to integrate even more through investments and production (value chains), trade, and knowledge mobility and so on.

Although there are different efforts at the regional level and specifically COMESA, these have not significantly improved Africa's Science, Technology and Innovation (STI) performance. African countries still perform poorly on three leading indicators: tertiary education institutions, intellectual property and innovativeness, and productivity and competitiveness (ECA, 2016). In general, African countries perform poorly on intellectual property, implying that formulated policies have not yet stimulated intellectual property and innovations based either on research and development or routine learning and practice. No African country ranks in the top 20 countries for patent applications, according to the World Intellectual Property Organization (WIPO). Figure 1 shows the average GII.[1] for the period 2009 – 2018 for the top 10 countries globally and COMESA countries. Whereas the GII for the top countries is 56-65, that for the COMESA member states ranges between 12 and 37, demonstrating the significant gap in innovation achievements. The GII also suggests that the levels of technology innovation are significantly lower among the COMESA member states than the rest of the world.

[1]The computation of the GII is given in Appendix Table A4, giving the details that constitute it

Figure 1: A comparison of the GII average scores for the top ten and COMESA countries

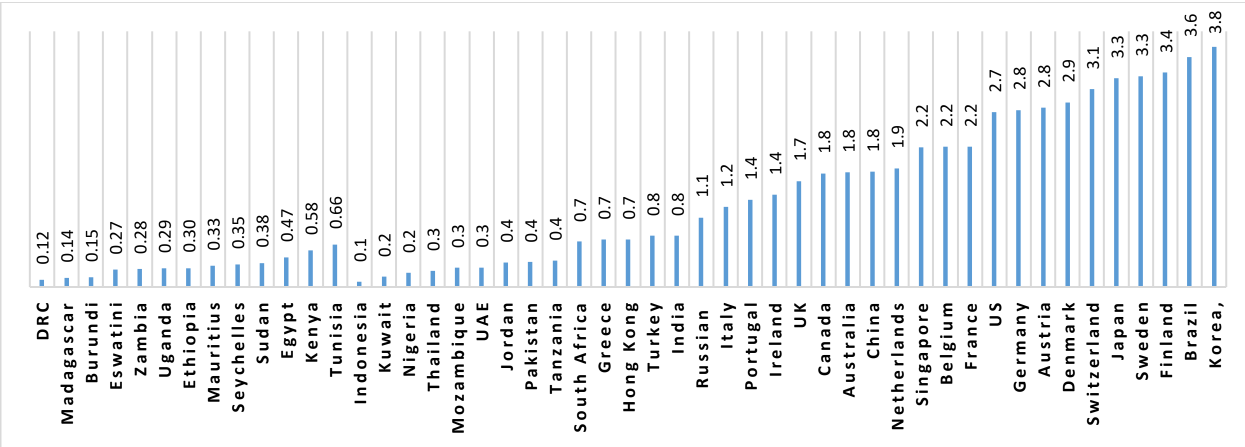


Data Source: www.globalinnovationindex.org

The low funding for the same partly explains the limited levels of technology innovation. Countries that have made significant investments accompanied with visible outcomes in innovation are more likely to have increased Research and Development (R&D) funding as a proportion of their GDP. The main objectives of R&D are to develop existing and new core competencies, further existing and new products, and develop existing and new business processes through invention and innovation. The R&D process is the engine that drives product and process differentiation. Figure 2 gives an average of R&D funding as a proportion of GDP for 2008-2016 for only [2] The statistics suggest that whereas the COMESA countries allocated less than one percent of GDP for the analyzed period, the other importing countries range between less than 1 and 3.8 percent. Note that the GDP of different countries significantly differ in absolute terms (refer to table 3), with COMESA member states likely to have lower GDP compared to the other importing countries. This further illustrates the limited funding of R&D in the COMESA region. The limited funding suggests that significant increases in budgetary allocations should accompany any meaningful progress.

[2] 13 countries out of the 21 COMESA member states and the other importing countries. The rest of the countries did not have data, and there were many gaps; therefore, we left them out.

Figure 2: Average Research and Development funding as a proportion GDP 2008-2016



Data source: WDI

The limited funding to technology innovation in the COMESA region is partly reflected in the number of countries' patents. Patents are an indicator for monitoring the innovation of technologies, the technology competitiveness of a country, or the country's economic performance. They play a prominent role in the entire technology life cycle, from initial R&D to the market introduction (demonstration to diffusion) stages, where competitive technologies can be protected with patents and licensed out to third parties to expand financial opportunities. Table 1 gives an average of patents obtained by countries between 2007 and 2017.

Table 1: Average patents between 2007 and 2017

COMESA		Other importers			
Burundi	0.5	Algeria	2.2	Morocco	131.9
Comoros	0.1	Australia	4,602.2	Mozambique	-
DRC	0.5	Austria	5,450.0	Netherlands	15,482.2
Djibouti	0.3	Belgium	4,730.5	Nigeria	2.1
Egypt	87.6	Brazil	893.6	Pakistan	9.7
Eritrea	0.1	Canada	10,555.5	Portugal	310.6
Ethiopia	1.1	China	152,823.8	S. Korea	105,807.4
Kenya	6.5	Hong Kong	943.0	Russian	24,098.7
Libya	0.7	France	36,130.3	Saudi Arabia	397.1
Madagascar	0.2	Germany	76,202.2	Singapore	1,932.2
Malawi	0.1	Greece	510.9	South Africa	1,128.7
Mauritius	29.5	India	2,677.0	Spain	4,820.6
Rwanda	-	Indonesia	20.3	Sweden	11,054.1
Seychelles	43.4	Iraq	1.2	Switzerland	16,864.5
Somalia	0.1	Ireland	1,657.4	Syrian	2.0
Sudan	-	Italy	11,871.5	Thailand	92.0
Swaziland	1.0	Japan	289,826.2	Turkey	544.5
Tunisia	9.0	Jordan	24.2	UAE	68.5
Uganda	0.5	Kuwait	45.8	UK	18,091.5
Zambia	0.7	Lebanon	14.8	Tanzania	0.2
Zimbabwe	2.1	Malaysia	591.6	USA	211,744.7
				Yemen	0.3

Data source: WIPO

The majority of the COMESA member states have an average of less than 1 patent except for a few like Tunisia, Mauritius, Seychelles, and Egypt which have average patents between 9 and 87 (Table 1). When contrasted with the other leading importers of COMESA products, it is illustrated how huge the gap is with Japan having close to 0.3million average patents. The limited number of patents suggests that technological innovation has not been given adequate attention in the COMESA region.

One way to generate competitiveness against imported products from without the COMESA region and promote intra-regional trade among members state is to increase the level of innovation partly to meet the required regional standards, increase variety and productivity. Although there are different efforts in COMESA, these have not significantly improved the region's STI performance as observed. COMESA, like the rest of Africa, does not perform well on many measurements of innovation and competitiveness. Furthermore, there is a tendency for the COMESA member states to trade more with the rest of the world than among themselves. The technology deficits partly explain this within the COMESA region to supply the quality and type of products imported from the rest of the world. The question is; how much innovation is likely to generate a given quality of intra-COMESA exports? What is the potential of technology innovation on intra-COMESA export trade?

This paper seeks to contribute to policy and empirical literature by providing a quantitative measurement of the influence of innovation on the extra and intra-COMESA trade. Specifically, the study seeks to: (i) Compare the structure of the COMESA intra-export trade and the exports to the rest of the world relative to imports into the region; and (ii) Estimate the impact of innovation on extra and intra-COMESA exports.

The rest of the paper is organized as follows: Section ii is the review of selected literature, and section iii is the analytical framework and the methods used in the study. Section iv is the results' and finally, section v is the conclusion and policy implications. In addition, the Appendix contains extra information deemed necessary and not in the main body of the paper.

2.0 Literature review

From a theoretical perspective, innovations and trade are part and parcel of the new trade theories of Heckscher and Ohlin, which focus on specialization as per endowment (Leontief, 1953). Countries endowed with capital are likely to innovate more and improve the production base, resulting in gains from trade. According to Schumpeter (1942), the main force of this structural change is the "perennial gale of creative destruction." Creative destruction is a process whereby waves of innovative activity hit the economic system at different points, resulting in the destruction of the old economic structure and the creation of a new one. There are various types of innovations: introducing new products, new production methods, new forms of business organization, and the penetration of new input and output markets (Schumpeter, 1919).

Technological innovation can be defined as the countries' capacity to put new ideas into practice by developing new products and processes which play a crucial role in international trade and economic development (Márquez-Ramos and Martínez-Zarzoso, 2009). Innovation is also an essential factor in the non-price competitiveness of a nation's products. Non-price competitiveness involves expanding the number of varieties of products or quality improvements for a range of existing kinds of products (Buxton *et al.*, 1991). Innovations are more than just minor changes put together but rather "new combinations" that disturb whatever equilibrium exists in the economic system (Schumpeter, 1940). Galbraith (1967) builds on this by formulating the so-called "Schumpeterian thesis," which proposes that large firms are more innovative than small firms.

Accordingly, international trade theory highlights the importance of technological innovation in explaining a country's international competitiveness (Fagerberg, 1997). Although the classical trade theory of international trade that stressed international differences in technology as a source of comparative advantage was diminished by the Heckscher–Ohlin (H–O) theory which centered on resource endowments as the main factor explaining international trade patterns, the theory re-emerged. Technological innovation bounced back to the forefront of research into trade with the development of the technology gap (Posner 1961) and the product cycle theories (Vernon 1966), among others. Whereas Posner (1961) argues that trade is generated by differences in the rate and nature of innovation, Vernon (1966) places less emphasis on the comparative cost doctrine and more on the timing of innovation.

According to Lachenmaier and Woessmann (2004), two broad strands of theoretical literature predict a relationship between innovation and exports. The first one presents international trade models that stress product-cycle features in the production of goods over time. These trade models tend to take innovation as exogenous and predict that innovation influences exports. These models include Vernon (1966), Krugman (1979), and Dollar (1986), among others. They predict that developed countries export innovative goods, which are later imitated by developing countries as these goods mature so that finally developing countries export these goods to the developed countries. This difference in technology implies that developed countries must continually innovate to keep ahead, and as they do that, their export basket becomes even more extensive. The other models are endogenous growth models that recognize that open-economy endogenizes the rate of innovation and predicts international trade's dynamic effects on innovative activity. These include, among others, Grossman and Helpman (1990), Segerstrom et al. (1990), and Young (1991).

To explain how technological innovation leads to increase in international trade, Cohen and Levinthal (1990) introduced the concept of absorptive capacity, which is the ability to recognize the value of new, external information, assimilate it, and apply it. They further look at two faces of technological innovation: creation and absorption. Therefore, they argue that some level of absorptive capacity is necessary to create, and the cost of adoption increases as absorptive capacity falls. However, Zahra and George (2002) came up with four dimensions of absorptive capacity: acquisition, assimilation, transformation, and exploitation capabilities that even shed more light on how technology innovation leads to increased exports.

Innovations can be facilitated by regional integration initiatives such as COMESA. As observed by Matambalya *et al.* (2015), regional integration enhances the framework conditions for innovation and economic actors to leverage the knowledge generated through research and development (R&D) and routine learning and practice of economic activities. Innovation is a crucial element for increasing trade as it is positively linked to the improved quality of goods and services. Moreover, regional integration brings competition in the domestic market. Porter (1998) argued that regional integration could create pressure for improvements through innovations in ways that upgrade the competitive advantages of nations.

The empirical literature on innovations is largely concentrated on the link between innovations and trade. For instance, Santacreu (2015) constructs a multi-country dynamic general equilibrium model in which technological innovations and international diffusion connect imports and growth through trade. The model has two sources of embodied productivity growth. First, in the spirit of the new growth theory, countries accumulate domestic technologies when their firms invest in R&D and innovate. Secondly, since technology is assumed to be embodied in intermediate goods, countries adopt foreign technologies embedded in the intermediate goods they import. The findings indicate that innovation and adoption through imports affect a country's productivity growth differently due to its position on the transition path. Therefore, countries at the early stages of development, with a low technological base, grow by adopting the new foreign technologies embedded in the intermediate goods they import. On the other hand, countries at later stages of development, with a high technological base, instead grow by developing new technologies through R&D.

Wakelin (1998) examines sectoral trade flows for 22 industries in nine Organization for Economic Cooperation and Development (OECD) countries. Wakelin (1998) adopted an approach from the technology gap tradition and related relative export flows to relative technology investments

(R&D, patents, and *Science Policy Research Unit (SPRU) innovation rates in the United Kingdom.*[3] The study establishes a positive relationship between relative innovation and bilateral trade performance at an aggregate level and for several manufacturing sectors. Furthermore, sectors are categorized as either net users or producers of innovations. Innovation appears to impact trade performance for the net producers of innovations than the net users of innovations. Although this result is sensitive to the use of different technology and innovation indicators, the results provide general support for a positive relationship between innovation and export flows,

Other works have also shown the existence of a non-linear relationship between technological innovation and international trade. For instance, Estrada *et al.* (2006) note that those companies with a high R&D intensity have a higher export probability than those with a medium R&D intensity. Márquez-Ramos and Martínez-Zarzoso (2009) examine the effect of technological achievement on exports using the gravity model and technological achievement index (TAI) and confirm the expected positive effect of technological innovation on export performance and the existence of non-linearities. Using a panel data set of 30 developed and 88 developing countries for 1980 -2000, Lebesmuehlbacher (2015) examines the degree to which international trade and factor movements facilitate technology diffusion within developed and developing countries, mainly focusing on the role of migration. Results show that trade and Foreign Direct Investment (FDI) do not significantly affect diffusion within either country group. In contrast, migration enhances technology diffusion, but only in developing countries.

Ali (2017) investigates the impact of technological progress on economic development by introducing a model in which the Human Development Index (HDI) is used as the dependent variable, and the TAI and Gross Capital Formation (GCF) are used as independent variables. The HDI, TAI, and GCF are used in this model as proxy variables for economic development, technological progress, and capital, respectively. The results demonstrate that long-term associations exist between technological progress and economic development with the impact of technological progress on economic development accounting for 13.2%. In comparison, the impact is 4.3% higher in eight selected East South Asian countries, at 13.5%, than in eight selected highly developed countries (9.2%).

Desai *et al.* (2002) observe that all countries must adopt innovations to benefit from the opportunities of the network age. The race to adopt technology results from the three main arguments on innovation. First, higher-technology goods present essential opportunities to developing countries. Second, many high-technology sectors are among the most dynamic in the global economy. Lastly, upgrading the technology content of the manufacturing sector diversifies the economy and creates opportunities in new markets. Diversification brings in the perspective of the services sector and how it can be linked to trade in both services and goods.

Cipollina *et al.* (2016) analyse the role of quality standards and innovation on trade volume using a gravity model. They argue that the net effect of quality standards on trade depends on the producers' ability to innovate and comply with market requirements. The analysis uses a sample of 60 exporting countries and 57 importing countries for a wide range of 26 manufacturing industries over the period 1995-2000. They demonstrate that the most innovative sectors are more likely to enhance the overall quality of exports and then gain a competitive advantage. Moreover,

[3] *SPRU* is a research center based at the University of Sussex

this effect depends on the level of technology intensity at the sector level and on the economic development of exporting country.

ECA (2016) examines how to harness the linkages between regional integration, innovation, and competitiveness within the framework of Africa's normative regional integration development model oriented to structural change. The results demonstrate that, in a virtuous circle, innovation is both a driver and beneficiary of competitiveness, endogenous growth, development, and transformation. Moreover, the growth of innovative capacities among members of a bloc will likely lead to more integration through investments and production (value chains), trade, and knowledge mobility. However, evidence from 15 African countries for 1995 to 2010 shows that growth in most of these countries was through factor accumulation and not through significant gains in input combinations associated with innovation ECA (2016). In some countries, the limited association between innovation and growth could be because many of the world's innovations are generated in a few developed countries and then adopted globally. Therefore, technology diffusion across borders plays a vital role in driving economic growth Lebesmuehlbacher (2015).

The COMESA region values innovations to promote trade. The importance of innovations is demonstrated by the 16^{th} Summit of the COMESA Authority of Heads of State and Government which established the Innovation Council, an Annual Innovation Award, and a Regional ICT Fund. These initiatives have been driven by the need to put mechanisms to harness and mobilise existing knowledge in a structured manner that benefits all member states (Nakazzi, 2012). The Council comprises representatives from academia, the private sector, and the government and advises the member states concerning existing and new knowledge and innovations and the best ways of applying the knowledge and innovations. The literature review demonstrates that innovation is critical to expanding exports, especially those of manufactured products. It improves the quality of products, reduces transport costs, enhances diffusion of technology, and leads to diversification of products for exports. Ultimately, innovation is central to growth and economic development. Although past studies have investigated the link between innovations and trade as illustrated, several gaps remain, especially on the influence of innovation and trade in the COMESA region. This paper seeks to partly address this gap by contributing to policy and the empirical literature, specifically by estimating innovation's impact on trade and intra-COMESA exports.

3.0 Methodology

The gravity model

We apply a gravity model to examine whether trade performance is partly attributed to the ability to innovate. In the literature, the model was developed by Tinbergen (1962) and Pöyhönen (1963). Gravity models are widely used in international trade literature, and they are an application of Newton's law of gravity. In its simplest form, the gravity equation for trade states that the trade flow from country *i* to country *j*, denoted by Xij , is proportional to the product of the two countries' GDPs, denoted by Yi and Yj , and inversely proportional to their distance, Dij , broadly construed to include all factors that might create trade resistance as specified in *equation 1*.

$$X_{ij} = \alpha 0 Y_i^{\,al} \; Y_j^{\alpha 2} \; D_{ij}^{\,a3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where α0, α1, α2, and α3 are parameters to be estimated. This relationship in *equation 1* is log-linearized, and parameters are estimated in its short form as in *equation 2*

$$In\left(X_{ij}\right) = In\left(\alpha 0\right) + \alpha 1\, In\left(Y_i\right) + \alpha 2\, In\left(Y_j\right) + \alpha 3\, In\left(D_{ij}\right) + et_{ij} \ldots\ldots(2)$$

Where *etij* is the error term.

According to Geda and Seid (2015), the gravity model has widely been used to identify determinants of bilateral trade, though they are often criticized for lacking a solid theoretical basis. In this vein, Cernat (2001) noted that despite its use in many early studies of international trade, the model was considered suspect in that it could not easily be shown to be consistent with the dominant Heckscher-Ohlin model explaining net trade flows in terms of differential factor endowments (ibid). However, this challenge has since been resolved after the works of other scholars demonstrated that there is a robust theoretical basis of the application of the model (see for example Anderson, 1979; Bergstrand, 1985; Deardorff, 1998; and Feenstra *et al*, 1998).

The censored nature of regional, bilateral trade implies that OLS estimates are biased. For that matter, we estimate the model using the Pseudo Poisson Maximum Likelihood (PPML) method to address the problems associated with OLS (Silva and Tenreyro, 2006). The PPML approach has been used widely (see, for example, Márquez-Ramos et. al., 2012; Geda and Seid, 2015). The parameters of the econometric model are computed by finding the estimates that maximize the likelihood function in these formulations. Although other estimation techniques such as fixed-effect and random-effect models have been widely used (Herrera, 2011), they are prone to heteroscedasticity, and therefore, their estimates are not robust. Thus, we did not venture to estimate using these techniques.

The use of the PPML estimator was chosen and justified on several grounds. Firstly, the estimator accounts for heteroscedasticity, which characterizes international trade data (Silva and Tenreyro, 2006). In the presence of heteroscedasticity, estimating gravity models with the OLS estimator results in biased and inconsistent estimates. Secondly, the PPML estimator can take advantage of the information contained in the zero values trade flows. A notable drawback of the OLS approach is that it does not consider the information contained in the zero values of bilateral trade flows. Thirdly, due to the addictive property of the PPML estimator, the gravity fixed effects are kept identical to their corresponding structural terms (Arvis and Shepherd, 2013; Fally, 2015). Finally, the PPML estimator can also be used to calculate the general equilibrium effects of trade-related policies (Anderson *et al.*, 2015). As a robustness check, in addition to the PMML estimation, alternative panel-based Tobit technique estimation was also made. Given that it produced similar results, we present only the PPML estimation results.

This model is estimated using bilateral export panel data of COMESA member states and 43 major export destinations outside the region (see Appendix A1). We then introduce the variables of interest in addition to the augmented specification to estimate the following augmented regression as shown in *equation 3*:

$$X_{ijt} = \beta_0 + \beta_1 InY_{it} + \beta_2 InY_{jt} + \beta_3 InDist_{ij} + \beta_4 Cont_{ij} + \beta_5 Lang_{ij} + \beta_6 Llock_i + \beta_7 Llock_j + \beta_8 comcol_{ij} + \beta_9 InTariff_j + \beta_{10} InTraCost_i + \beta_{11} InTraCost_j + \beta_{12} InTec_i + \beta_{13} InTec_j + e_{ijt} \quad (3)$$

Where *i* indexes exporter country, *j* importer country, and *t* time. The dependent variable X_{ijt} is the trade value between *i* and *j* at time *t*. Concerning explanatory variables, we include two groups of determinants of trade. The first includes standard gravity variables: Y_{it} and Y_{jt} to indicate, respectively, production of exporter and expenditure consumption of importer; $Dist_{ij}$ is the distance between country *i* and *j*; $Cont_{ij}$, $Lang_{ij}$, and $comcol_{ij}$ are dummy variables taking the value of 1 for pair of countries sharing, respectively, common border and common language, having a common colonizer and zero otherwise; $llock_i$ and $llock_j$, respectively whether the exporter and importer taking the value of 1 are landlocked and zero otherwise: and $Tariff_j$ is the bilateral applied tariffs in the importer country at time *t*. The second set of variables is included to test our primary hypothesis that a higher level of innovation yields a higher increase in export. Therefore, we firstly include *TraCost*, which controls for technology innovation in trade facilitation aspects both in the exporting and importing countries. Then, we include *Tec* for technology innovation which is the primary variable of interest.

The Global Innovation Index[4]

The variable of interest in this analysis is innovation and how it impacts international trade. There were two proxies (patents and the percentage of R&D of GDP) that could have served the purpose. However, these had limitations that led to being discarded. Patents had significant data limitations, especially for the COMESA Member States, making it impossible to use. Although the proportion of the national budget allocated to R&D is equally a good proxy for innovation, many countries included in the analysis did not have updated data. The best option aside from these two was the Global Innovation Index (GII)[5] whose construction is scientific. Data were available for all the countries and the years of analysis. The GII is an annual ranking of countries by their capacity for and success in innovation. It aims to capture the multi-dimensional facets of innovation and provide the tools that can assist in tailoring policies to promote long-term output growth, improved productivity, and job growth. The GII helps to create an environment in which innovation factors are continually evaluated. The core of the GII consists of a ranking of world economies' innovation capabilities and results. Details about the GII computation are in Appendix A4

Data sources:

We use export trade data from the COMTRADE and World Integrated Trade Solutions (WITS) database, covering 43 countries that each COMESA Member States exports. We extract distance data from the distance calculator website[6] Which is defined as the direct distance between the capital cities of a pair of trading partners without considering the actual routes by either form of transport. World Bank World Development Indicators (WDI) formed a valuable source of the per capita income, GDP, and manufactured exports data. The data on whether a country is a landlocked or not, is an island or not, borders a trading partner or not, and has the same official

[4] www.globalinnovationindex.org.

[5] The Global Innovation Index is co-published by Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO, a specialized agency of the United Nations

[6]http://www.timeanddate.com/worldclock/distanceresult.html?p1=115&p2=17

language or not were extracted from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII)[7] gravity dataset. The Global Innovation Index data was extracted from the GII annual reports. The analysis is done for the period 2007 to 2018. Details of the sources and the data are in Appendix A2.

Estimation procedure

We chose between several estimation techniques in the panel estimation process to obtain the best and most robust results. The OLS was immediately discarded for reasons discussed above regarding the choice of a model. The other options were the Random Effects - RE and Fixed Effects –FE models. When FE models estimation is used, and some variables do not change over time, the inherent transformation wipes out such variables. Therefore, FE models are best suited for estimating the impact of variables that vary over time.

Given that most of the variables in the model are non-varying, the FE is not best suited, and this one was discarded. The RE, even when selected, is likely to suffer from the problem associated with heteroscedasticity – less precise coefficient estimates. We choose the PPML for its strength and ability to overcome the OLS, FE, and RE limitations.

The continuous data were transformed into logarithms. The impact of the variables on manufactured exports is determined by the coefficients generated as elasticities after this transformation. The rationale for the transformation into elasticities was to establish the proportion of technology innovation that generates a given level or proportion of both extra and intra–COMESA exports. In this way, policymakers can invest in technology innovation for increasing exports of the COMESA Member States.

Diagnostic tests

We conducted the Levin *et al.* (2002) test of panel unit-roots that assume that the autoregressive parameters are common across countries. Levin et al., (2002) used a null hypothesis of a unit root that states that the panels contain unit roots and the alternative that the panels are stationary. The test results indicate that all the variables are stationary at less than 1 percent (the null unit root is rejected) in which case the co-integration test is not required to estimate the model. Furthermore, we use the simple correlation test to check multicollinearity in the model between the explanatory variables. Results show that the values of the correlation coefficients between explanatory variables are lower than 0.80, and as argued by Studenmund (2001) that below such a threshold, the model is acceptable, we concluded that there was no serious problem.

4.0 Estimation and Discussion of Results

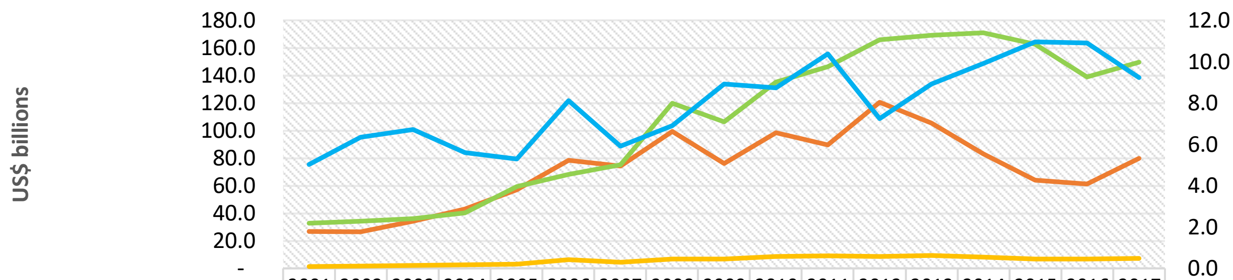
Intra-COMESA exports in comparison to the Rest of the World (RoW)

Figure 3 shows trade within the COMESA region and between the COMESA region and the RoW. Intra-COMESA exports are low (valued at US$ 1.7 billion in 2002, increasing to US$ 9.4 billion in 2013). Exports significantly reduced to US$ 7.4 billion by 2017. Exports to the world (COMESA inclusive) increased over time, from US$ 26.8 billion in 2001 to US$ 120 billion by 2012 and then declining to US$ 80 billion in 2017. On the other hand, imports from the world are much higher, suggesting a trade deficit over the years.

[7] CEPII make available a "square" gravity dataset for all world pairs of countries from 1948 to 2006. This dataset was generated by Head et. al. (2010)

From 2007, an increase in exports corresponds with increased imports, probably for capital goods and to facilitate production. This trend, however changed in 2014 when imports were registered at US$ 170 billion before declining. From this analysis, we assert that intra-COMESA trade (read on the right axis in percentage) is much lower compared to COMESA exports to the RoW, and yet the region heavily imports from the RoW. Specifically, the share of intra-COMESA exports, which was 5 percent in 2001 and peaked at 11 percent in 2015, fluctuated between 6 to 10 percent over the years. The analysis suggests that although the regional integration has contributed to increasing intra-COMESA trade, there is a long way to achieve this objective fully.

Figure 3: COMESA import and export trade with the region and the RoW



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Exports to COMESA	1.3	1.7	2.3	2.4	3.0	6.4	4.4	6.8	6.8	8.6	9.3	8.7	9.4	8.2	7.0	6.7	7.4
Exports to world	26.8	26.5	34.3	43.1	57.0	78.4	74.4	99.2	76.3	98.6	89.8	120.	105.	83.2	64.0	61.3	79.8
Imports from world	32.8	34.1	35.9	40.3	59.6	68.2	75.0	119.	106.	135.	146.	165.	169.	170.	162.	138.	149.
Intra-COMESA exports	5.0	6.3	6.7	5.6	5.3	8.1	5.9	6.9	8.9	8.7	10.4	7.2	8.9	9.9	11.0	10.9	9.2

Data source: International Trade Centre database

The structure of intra-trade exports, exports to and imports from the RoW

Table 2 summarises the intra- COMESA exports, exports to, and imports from the RoW. It gives the total value of the top 20 products for the categories outlined above from 2007 to 2017. The intention is to infer the technology innovation input in these different categories of products. Whereas the intra-COMESA exports amounted to a total of US$ 90 billion for 11 years, exports and imports to the Rest of the World (RoW) were US$ 1.1 trillion and US$ 1.7 trillion, respectively. The high trade value with RoW suggests a higher volume of trade with the RoW than the COMESA bloc. Specifically, the region has a higher propensity to import from the RoW than the COMESA imports.

The exports originating from the COMESA region are not as technology-intensive products as those imported in the region from the RoW. Instead, the region exports commodities and light manufactured products and imports high technology manufactured products, demonstrating the region's low levels of technological innovation. This result suggests that there is a scope for high technology products in the COMESA bloc.

The intra-regional exports essentially constitute ores, coffee, tea, mineral fuels, cement, sugar and sugar confectionery, inorganic chemicals, iron and steel, tobacco, plastics, cereals, copper, animal and vegetable oils, paper boards, soap, beverages, and spirits. This list is closely similar to COMESA exports to the RoW, strengthening the argument for commodities and light manufactures exports. On the other hand, the COMESA imports from the RoW constitute the following: Mineral fuels, machinery, electrical machinery, televisions, vehicles, cereals, iron and steel, plastics, pharmaceutical products, animal and vegetable oils, paper and paper products, optical, photographic and cinematographic products, fertilizers, organic chemicals, wood and wood articles, aircraft, spacecraft, and parts, and runner and rubber articles, sugars and confectionery. Although some of the products produced and exported by COMESA member states are similar to those imported, on a comparative basis, the majority differ with a tendency for imports to be more technology-intensive.

In summary, the technology innovation inadequacies and deficiencies in the COMESA bloc partly explain the limited intra-regional trade and huge imports from outside the region. However, from a positive perspective, any profound leaps in technology innovation in the COMESA region are likely to generate and guarantee a substantial intra-regional market.

Table 2: The structure of intra-COMESA exports, exports to and imports from the RoW in US$'000

Code	Intra COMESA Exports		Code	COMESA exports to the world		Code	COMESA imports from the world	
	Total 2007 to 2018	**90,347,222**		**Total 2007 to 2018**	**1,118,296,097**		**Total 2007 to 2018**	**1,740,257,780**
'26	Ores, slag and ash	10,393,388	'27	Mineral fuels, mineral	472,386,373	'27	Mineral fuels, mineral	253,150,233
'09	Coffee, tea, maté and spices	5,199,644	'74	Copper & articles thereof	98,202,757	'84	Machinery, mechanical applia,	180,471,119
'27	Mineral fuels, mineral	4,596,533	'71	Natural, precious stones, &metals,	48,468,240	'85	Electrical machinery & TV	131,224,600
'25	Salt; sulphur; earths & stone; & cement	4,300,925	'09	Coffee, tea, maté and spices	39,265,292	'87	Vehicles other than railway	127,935,137
'17	Sugars and sugar confectionery	4,136,684	'26	Ores, slag and ash	30,850,502	'10	Cereals	87,877,098
'28	Inorganic chemicals; precious metals,	3,905,646	'81	Other base metals; cermets;	13,702,375	'39	Iron and steel	77,562,950
'72	Iron and steel	3,228,563	'85	Electrical machinery &, TV	19,488,547	'72	Plastics and articles thereof	67,451,787
'24	Tobacco & manu. substitutes	3,201,180	'07	Edible vegetables & roots & tubers	20,288,224	'30	Articles of iron or steel	60,795,889
'39	Plastics and articles thereof	3,187,272	'62	Apparel and clothing	18,838,247	'73	Pharmaceutical products	50,923,533
'10	Cereals	2,852,233	'24	Tobacco & manu. substitutes	20,627,370	'15	Animal/vegetable fats & oils	39,615,810
'74	Copper and articles thereof	2,687,792	'39	Plastics & articles thereof	17,760,647	'48	Paper and paperboard;	28,149,069
'15	Animal or vegetable fats and oils	2,555,600	'72	Iron and steel	16,874,243	'17	Optical, photographic, cinematographic,	23,539,231
'85	Electrical machinery and, television	2,307,067	'08	Edible fruit & nuts; citrus or melons	14,017,410	'38	Fertilisers	22,550,090
'34	Soap, organic surface-active agents,	2,197,794	'28	Inorganic chemicals; precious metals,	11,334,743	'90	Miscellaneous chemical products	22,515,793
'84	Machinery, mechanical appliance,	2,084,287	'17	Sugars and sugar confectionery	15,347,692	'29	Rubber and articles thereof	22,436,492
'48	Paper and paperboard;	1,916,445	'33	Essential oils and perfumery, cosmetic	9,359,789	'26	Organic chemicals	22,026,084
'07	Edible vegetables & certain roots & tubers	1,854,058	'61	Apparel & clothing	15,439,183	'02	Wood and articles of wood;	21,423,849
'73	Articles of iron or steel	1,756,154	'31	Fertilisers	13,241,792	'40	Sugars & confectionery	20,521,278
'87	Vehicles other than railway	1,654,347	'06	Live trees and other plants;	11,037,889	'31	Aircraft,spacecraft, &parts thereof	19,664,951
'22	Beverages, spirits	1,560,034	'12	Oil seeds and oleaginous fruits;	10,636,384	'28	Meat & edible meat offal	18,982,470

Source: Authors computations from Trade map data

Means of the estimated variables

Table 3 is a summary of the means for the model estimation variables. The average intra-COMESA export value for the 12 years was US$22.3billions, and the other leading 43 importers was US$113billions suggesting the significant difference between intra-COMESA trade and trade with the RoW. On average, the transport costs per container are higher (US$3,315) for importing COMESA member states (from both members and non-members) compared to exporting member states (US$2,626) to all destinations. This cost differential implies that it is more expensive to import than export for the COMESA region. The high cost is likely to impede intra-COMESA trade.

Furthermore, the transport costs to import by the non-COMESA countries is even lower plausibly and partly explains the differences in the volumes and values between the two groups. The average GDP of the COMESA member states was only US$93billion compared to the other importing countries at US$1.99trillion). Whereas the average tariff in the COMESA region was 9.2, it was 4.2 for the importing countries suggesting that it was easier to export to them than the member states. Intuitively, the COMSA member states have short distances between them compared to the other importers. The average technology index (Global Innovation Index (GII)) for the COMESA region (24) was significantly lower compared to the importers outside the region (41). This low GII suggests that there is still limited innovation within the region compared to the other countries with which the region trades. This limited innovation negatively impacts the region when it comes to export trade.

Table 3: The mean values of the model estimation variable

Variable	COMESA	Other importers	All
COMESA Exports (billions)	22.3	113	84
Transport cost of exporters	2,626		
Transport cost of importers	3,315	1,453	2,044
GDP of importers (billions)	923	1,990	1,390
GDP of exporters (billions)	93		
Tariff by importers	9	4	56
Distance between cities	2,942	6,332	5,256
Technology innovation index for importers	24	41.2	36
Technology innovation index for exporters	24		25
Real effective exchange rate	119	106	110
Exporter is land locked	0.38		
Importer is land locked	0.43	0.43	0.43
Contiguity/bordering	0.12	0.02	0.05
Common language	0.56	0.29	0.38
Com colony	0.31	0.15	0.20

Estimation results

This section provides the main results of the empirical analysis conducted on the total sample of 15,876 observations. In addition, the results of equation (3) are reported in table 4 for the three categories adopted, namely, intra-COMESA exports, COMESA exports to the top 43 partners, and a combination of the two. Overall, the results show that the effects of the standard gravity variables are consistent with the theoretical gravity equation.

Import transport costs have a negative impact on COMESA export trade to non-COMESA import partners, and this is the same when COMESA member states are combined with other importers. Whereas a one percent increase in import transport costs leads to a 0.06 percent decrease in COMESA export trade to non-COMESA partners, it leads to only a 0.03 percent decrease for the combined set of importers. The results thus suggest that import transport costs are a significant impediment to COMESA export trade. The results agree with theory and empirical studies that argue that transport costs increase the cost of doing business and reduce the competitiveness of export firms (see, for example, Hummels (2007); Christ & Ferrantino (2009); & Behar & Venables (2010)).

Results show that the GDP of both the exporting and importing countries plays a significant role in determining COMESA member states exports at a 1 percent level of significance. GDP of the COMESA member states was a proxy for the production capacity and size of the economy. A 1 percent increase in the GDP leads to a 0.20 percent increase in exports for COMESA member states. These results imply that member states should strive to grow their GDP as this significantly determines exports within the bloc. On the side of the GDP of the importers, increasing it by 1 percent leads to a 0.13 percent increase of export trade for the member states, 0.05 percent for the other trading partners, and 0.07 percent for the combination of the two. The results are thus positive and significant at 1 percent and therefore in agreement with *a priori* expectation, but revealing the role of both exporter and importer size of the economy on trade.

The implication of tariff reduction in the COMESA region is pronounced in the results. Whereas tariffs are significant in reducing exports at 1 percent of significance for other importing countries, this is not the case for the COMESA member states' importers as there is no significance. This result suggests that the process of tariff reduction within the bloc has been to a large extent successful. Increasing tariffs by 1 percent among the other importers reduces COMESA exports by 0.04 percent. The results thus call for continuing the liberalization process within the COMSA region to generate more intra-regional trade.

The distance between the trading countries strongly bears trade volumes as this two exhibit an inverse relationship. The results for distance are significant at 1 percent and in agreement with *a priori* expectation. Increasing the distance by 1 percent leads to a 0.4 percent decrease in trade for COMESA importing partners and 0.03 percent for non-COMESA importing partners, and 0.11 percent for a combination of the two. In the COMESA region, connectivity remains a challenge as infrastructure development is still low, although recent efforts are likely to yield good results.

Table 4: Estimation results

	Ppml Estimates		
Variable	**COMESA**	**Other importers**	**All**
in_trans_exp	0.00913	-	-
	(0.0198)	-	-
in_trans_imp	-0.00220	-0.0610***	-0.0323***
	(0.0208)	(0.00971)	(0.00917)
in_gdp_exp	0.209***	-	-
	(0.00721)	-	-
in_gdp_imp	0.133***	0.0469***	0.0729***
	(0.00792)	(0.00254)	(0.00259)
in_tariff	-0.0152	-0.0419***	-0.00923
	(0.0164)	(0.00644)	(0.00588)
in_dist	-0.412***	-0.0272***	-0.118***
	(0.0194)	(0.00663)	(0.00666)
in_tai_imp	0.409***	0.317***	0.431***
	(0.0416)	(0.0193)	(0.0188)
in_tai_exp	0.504***	-	-
	(0.0446)	-	-
in_reer	-0.0387	-0.277***	-0.183***
	(0.0342)	(0.0250)	(0.0197)
land_i	-0.0738*	-	-
	(0.0326)	-	-
land_j	-0.00545	-0.0954***	-0.0544***
	(0.0273)	(0.0102)	(0.0105)
contig	0.216***	0.391***	0.242***
	(0.0396)	(0.0195)	(0.0207)
comlang_off	0.110***	0.0588***	0.0645***
	(0.0224)	(0.00825)	(0.00821)
_cons	-5.703***	-0.765***	-2.342***
	(0.413)	(0.185)	(0.170)
sigma_u			
_cons			
sigma_e			
_cons			
r2	0.376	0.353	0.374
r2_o			
r2_b			
r2_w			

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The exchange rate movements play a significant role in partly determining the volume of trade between member states. Results show that the exchange rate in the other importing countries is significant at the 1 percent level. Whereas a one percent appreciation in the exchange rate leads to a 0.27 percent decline in imports among the other non-COMESA states, this was 0.18 percent for all the importers combined. Note that for the COMESA importers, the exchange rate coefficient was not significant.

From a regional integration perspective and as expected, countries bordering each other exert a positive and significant impact on COMESA member states' exports at a 1 percent level of significance. Similarly, having a common language between exporters and importers increases the export trade of COMESA member states. Not only does the exporter being landlocked reduce exports among COMESA member states, but it also reduces imports among them and the importing countries.

The variable of interest in the analysis is the technology innovation, which was proxied by the Global Innovation Index (GII). The analysis accounted for the index in both the exporter and importer countries. While in the exporter country, it is expected to increase exports, it is expected to increase consumption hence imports in the importing countries. Both the coefficients of the GII for the exporters and importers are positive and significant at 1 percent. An increase in the GII index by 1 percent leads to an increase in COMESA member states imports by 0.40 percent, non-COMESA importers by 0.32 percent, and a combination of the two by 0.43 percent. On the other hand, increasing the GII by 1 percent leads to a 0.5 percent increase in the level and value of exports for the COMESA member states.

These results suggest that intra-COMESA trade can and should be increased by targeting technology innovation in the region. Following the literature, this can be achieved through two ways; endeavouring to innovate in the region and adopting technology from countries that have made significant technological innovations. The results agree with Wakelin (1998); Estrada *et al*. (2006), and Márquez-Ramos and Martínez-Zarzoso (2009), who found a strong relationship between innovation and growth of export trade. Perhaps this study identifies an area for further research, as proposed by Lebesmuehlbacher (2015) is technology diffusion and adaptation. The pathways should be established and more so contextualised to the COMESA region.

5.0 Conclusion and policy implications

The paper examined the role of technology innovation in determining the intra-COMESA exports and exports to 43 major importing countries. The main aim was to estimate the impact of technology innovation on exports. The results suggest that indeed technology is a critical element in increasing trade, given that it is positively linked to improving the quality of goods and services. Moreover, when countries innovate, they generate a body of knowledge that enables them to produce new products, improve existing ones and consequently improve their levels of competitiveness. The results conclude that increasing technology innovation by 10 percent leads to an increase in exports within the COMESA region by 5 percent.

We note that technology innovation is just one of the many other areas to consider in increasing exports. They should not be neglected, including trade facilitation to reduce business costs and increase competitiveness. Regarding technology innovation, we recommend that COMESA Member States:

- Establish a COMESA Innovation Fund and increase and target funding of R&D to generate innovative technologies to foster product improvement, development, and diversification;
- Formulate innovation policies to address institutional linkages and collaboration, weak engineering and entrepreneurship capabilities, and limited financial resources for technological innovation;
- Establish science and technology parks; artisanal and industrial clusters for purposes of incubation;
- Create a database of scientists and engineers that can be organized and networked to provide a critical mass of expertise to advance the STI program; and
- Provide legal and institutional frameworks to enhance technology diffusion, adaptation and harness knowledge from the rest of the world.

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Appendix:

Figure 1A: The strong relationship between the innovation and competitive indices

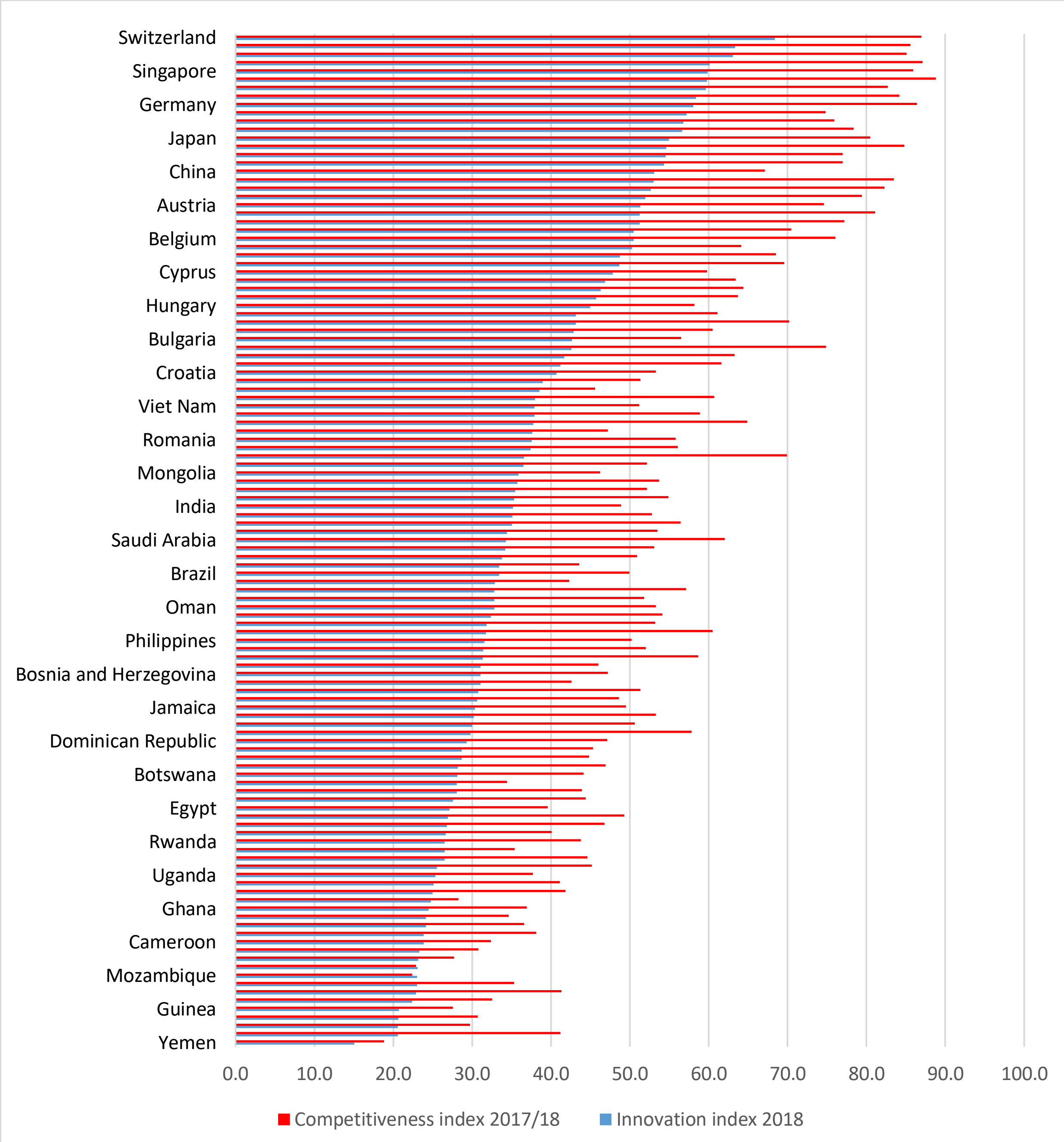

Table A1: The countries that constitute the trading partners in this research

	COMESA Member States		Other Main Importing Partners		
1	Burundi	1	Algeria	22	Malaysia
2	Comoros	2	Australia	23	Morocco
3	DR Congo	3	Austria	24	Mozambique
4	Djibouti	4	Belgium	25	Netherlands
5	Egypt	5	Brazil	26	Nigeria
6	Eritrea	6	Canada	27	Pakistan
7	Ethiopia	7	China	28	Portugal
8	Kenya	8	France	29	Russian
9	Libya	9	Germany	30	Saudi Arabia
10	Madagascar	10	Greece	31	Singapore
11	Malawi	11	Hong Kong	32	South Africa
12	Mauritius	12	India	33	Spain
13	Rwanda	13	Indonesia	34	Sweden
14	Seychelles	14	Iraq	35	Switzerland
15	Somalia	15	Ireland	36	Syria
16	Sudan	16	Italy	37	Tanzania
17	Sudan	17	Japan	38	Thailand
18	Swaziland	18	Jordan	39	Turkey
19	Tunisia	19	Korea	40	UAE
20	Uganda	20	Kuwait	41	UK
21	Zambia	21	Lebanon	42	USA
22	Zimbabwe			43	Yemen

Table A2: The variables used in this study their description and sources

Variable	Description	Source
in_exprts: Exports from i to j	Value of exports from the 21 COMESA countries to 21 COMESA and other 43 main importers, in thousands of US $	Trade map
in_trans_exp: Exporter's transport costs	Transport costs (US$ per container)	Doing Business
in_trans_imp: Importer's transport costs	Transport costs (US$ per container)	Doing Business
in_gdp_exp: Exporter's income	Exporter's GDP, PPP (current international $)	World Bank - Development Indicators
in_gdp_imp: Importer's income	Importer's GDP, PPP (current international $)	World Bank- Development Indicators
in_tariff: Tariffs	Tariffs levied in the importers country	WITS (World Bank)
in_dist: Distance	Great circle distances between the most important cities in trading partner	CEPII:http://www.cepii.fr/anglaisgraph/bdd/distances.htm
in_tai_imp: Innovation Index	Global Innovation Index	www.globalinnovationindex.org.
in_tai_exp	Global Innovation Index	www.globalinnovationindex.org.
in_reer: Exchange rate	Real effective exchange rate	World Bank - Development Indicators
land_i: Landlocked dummy	Dummy variable = 1 if the exporting country is landlocked, 0 otherwise.	CEPII:http://www.cepii.fr/anglaisgraph/bdd/distances.htm
land_j: Landlocked dummy	Dummy variable = 1 if the importing country is landlocked, 0 otherwise.	CEPII: http://www.cepii.fr/anglaisgraph/bdd/distances.htm
contig: share border	Dummy variable = 1 if the trading partners share a common border, 0 otherwise	CEPII:http: //www.cepii.fr/anglaisgraph/bdd/distances.htm
comlang_off: share a common language	Dummy variable = 1 if the trading partners share the same official language, 0 otherwise	CEPII :http://www.cepii.fr/anglaisgraph/bdd/distances.htm
Comcol: whether both had a common coloniser	Dummy variable = 1 if the trading partners have ever had a colonial link, 0 otherwise.	CEPII :http://www.cepii.fr/anglaisgraph/bdd/distances.htm

Table A3: Results of muli-collinearity for the independent variables

	tra_cost _exp	tra_cost _imp	gdp_ exp	gdp_ imp	tariff	dist	tai_ imp	tai_ exp	reer	land_i	land_j	contig	lang _off	comcol
tra_cost_exp	1.00													
tra_cost_imp	0.07	1.00												
gdp_exp	-0.20	-0.01	1.00											
gdp_imp	-0.02	-0.14	0.01	1.00										
tariff	0.05	0.39	-0.01	-0.14	1.00									
dist	-0.01	-0.35	-0.09	0.39	-0.38	1.00								
tai_imp	-0.04	-0.46	0.01	0.30	-0.69	0.58	1.00							
tai_exp	-0.13	-0.02	0.13	0.01	-0.02	0.06	0.05	1.00						
reer	-0.05	0.11	0.01	-0.03	0.36	-0.14	-0.30	-0.02	1.00					
land_i	-0.01	0.52	0.01	-0.17	0.06	-0.30	-0.14	-0.03	-0.05	1.00				
land_j	0.59	-0.01	-0.19	0.00	0.01	0.02	0.00	0.08	0.01	-0.02	1.00			
contig	0.10	0.22	0.00	-0.09	0.20	-0.30	-0.21	-0.07	0.05	0.10	0.08	1.00		
comlang_off	-0.05	0.10	-0.08	-0.08	0.12	-0.16	-0.11	0.08	0.03	0.11	0.00	0.11	1.00	
comcol	0.06	0.09	-0.11	-0.11	0.12	-0.21	-0.20	0.11	0.08	0.08	0.10	0.12	0.33	1.00

Table A4: The framework for different data used in constructing the Global Innovation index

The GII is computed by taking a simple average of the scores in two sub-indices, the Innovation Input Index (III) and Innovation Output Index (IOI), which are composed of five and two pillars, respectively. The III sub-index gauges elements of the national economy which embody innovative activities grouped in five pillars: i) institutions, ii) human capital and research, iii) infrastructure, iv) market sophistication, and v) business sophistication. The IOI sub-index captures actual evidence of innovation results, divided in two pillars: vi) knowledge and technology outputs and vii) creative outputs. Each pillar is divided into sub-pillars and each sub-pillar is composed of individual indicators. Sub-pillar scores are calculated as the weighted average of individual indicators; pillar scores are calculated as the weighted average of sub-pillar scores.