Leveraging Innovation to Increase Intra-Regional Trade: The Case of the Common Market for Eastern and Southern African Region

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Abstract

This paper analyses the role that technology innovation plays on the volume and value of COMESA export trade to COMESA member states and other 43 major importers by using a gravity model. The role of technology innovation in enhancing competiveness and trade performance is widely accepted in the literature. However, limited work has been done for the COMESA region. We estimate the role of technology innovation on export trade using a panel data set of 12 years (2007-2018) with the Poisson Pseudo-Maximum Likelihood (PPML) technique given its advantage in handling several estimation challenges. Results suggest 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. It is recommended that the region 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,

1.0 Background

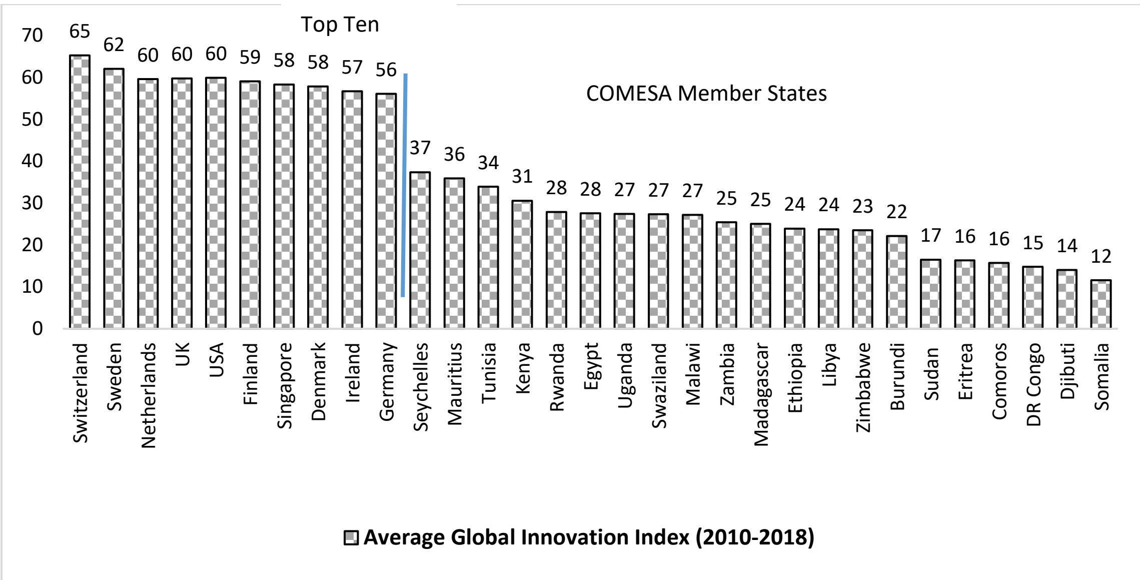
Innovation is an important factor of the non-price competitiveness of a nation's products (Buxton *et al.*, 1991). It enables and drives the expansion of varieties of products or quality improvements for a range of existing kinds of products that a country or a region can put on the market. Recent trends in international trade in especially 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, 2013) and by how much. There is a strand of literature that predicts that innovation has a positive impact on extensive margin of trade, by introducing new products and varieties that a country exports (Grossman and Helpman, 1989). On the other hand Grossman and Helpman, (1991) stress, the impact of innovation on intensive margin of trade by increasing product quality and Eaton and Kortum (2001, 2002) argue for productivity. International trade theory highlights the importance of technological innovation in explaining a country's international competitiveness (Fagerberg, 1997). Accordingly, technological innovation is defined as the countries' capacity to put new ideas into practice by developing new products and processes which play a key role in international trade. This helps to introduce a new quality of a good, or a new use of an already existing good, a new production method, opening up of a new market, and a change in economic organization (Márquez-Ramos and Martínez-Zarzoso, 2009).

1.1 Context

Innovation generates 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 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 with each other through investments and production (value chains), trade and knowledge mobility, and so on.

Although there are different efforts at regional level and therefore COMESA, these have not significantly improved Africa's Science, Technology and Innovation (STI) performance. African countries still perform poorly on three main indicators: tertiary education institutions, intellectual property and innovativeness and productivity and competitiveness (ECA, 2016). African countries perform poorly on intellectual property in general, 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 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. This suggests that the levels of technology innovation, are significantly lower among the COMESA member states compared to the rest of the world.

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



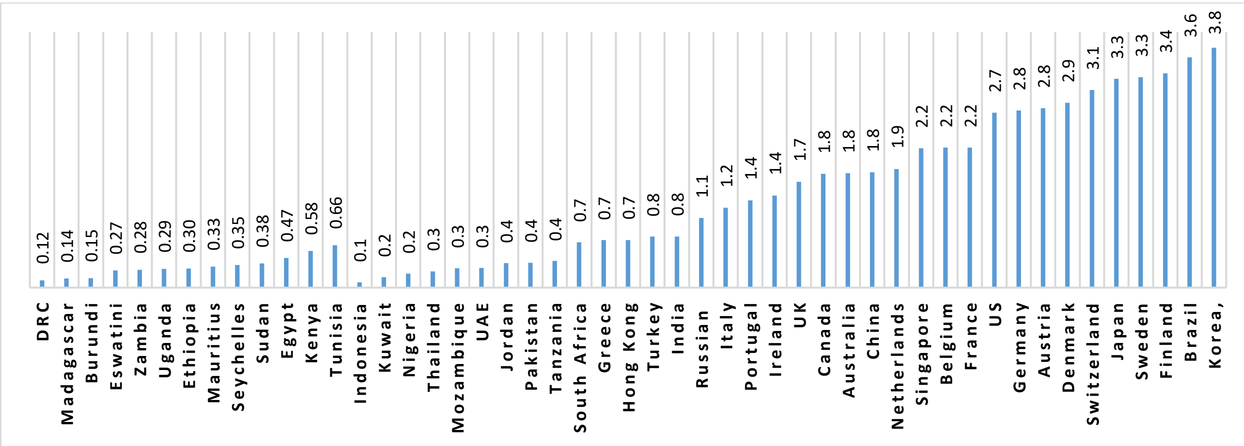
Data Source: www.globalinnovationindex.org

The limited levels of technology innovation is partly explained by the low funding for the same. 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, to further existing and new products, and to 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 the period 2008-2016 for only thirteen[2] out of the 21 COMESA member states and the other importing countries. The statistics suggest that whereas the COMESA countries for the analyzed period allocated less than one percent of GDP, 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. This suggest that any meaningful progress should be accompanied by significant increases in budgetary allocations.

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

[2] The rest of the countries did not have data and there are many gaps and 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 patents that countries get. Patents are an indicator for monitoring the innovation of technologies, the technology competitiveness of a country or the economic performance of a company or country. 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 opportunity. 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

It is evident that the majority of the COMESA member states have an average of less than 1 patent with the exception of a few like Tunisia, Mauritius, Seychelles, and Egypt which have average patents between 9 and 87. When contrasted with the other main importers of COMESA products, it is illustrated how huge the gap is with Japan having close to 0.3million average patents. This suggest that technology innovation has not been given adequate attention in the COMESA region.

1.2 COMESA current technology innovation status and initiatives

In the past, the National Systems of Innovation for Science and technology among COMESA Member States were narrowly defined to mean R&D. There was little emphasis on innovation aspects such as technology prospecting, procurement and diffusion. There was lack of explicit innovation policies in an environment of few and weak institutional linkages and collaboration, weak engineering and entrepreneurship capabilities and limited financial resources for technological innovation. This can be summed as a state of low levels of technological readiness and innovation capacities characterized by neglected and poor R&D infrastructure. This is however changing over the last decade. There is evidence that COMESA Member States recognize the importance of STI in socio-economic and cultural development and have agreed to cooperate in various fields as stated in the decision of the 2010 COMESA Summit on Science and Technology Development.

For that matter, in June 2012 the first COMESA Ministerial Committee met and underscored the critical importance of implementing the decisions on STI, at the national level by each Member State[3]. This was envisaged to be achieved through a number of activities that led to the making and adopting of the following decisions by the COMESA summit to: establish science and technology parks and artisanal and industrial clusters; establish a COMESA Innovation Fund; create a database of scientist and engineers that can be organized and networked to provide a critical mass of expertise to advance the STI program, harmonize ICT curriculum in the region; provide master plans and blue prints for harnessing knowledge from around the world; provide programs for commercialization of R&D; coordinate and harmonize national frameworks on STI; promote nanotechnology, biotechnology and new materials such as polymers; and allocate at least 1 percent of GDP to R&D. This called for the establishment of: a COMESA Committee on STI which has been done; and the office of advisor on STI at national level and at the COMESA secretariat. In addition there was a proposal to establish a university for regional integration with a component of an academy of science technology and engineering and establishment of an innovation award which started in 2013.

[3] COMESA (2012) First Ministerial Meeting on Science and Technology

1.3 Problem Statement

Chen (2013) observes that different theories have been advanced to understand the link between innovation and trade but they differ in their predictions about how innovation increases exports. For instance in the first strand while Grossman and Helpman (1989) predicts that innovation has a positive impact on extensive margin of trade, by introducing new products and varieties that a country exports, the second strand stresses, instead, the impact of innovation on intensive margin of trade by increasing product quality (Grossman and Helpman, 1991) or productivity (Eaton and Kortum, 2001). 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 at regional level and therefore, COMESA, these have not significantly improved Africa's STI performance as observed. COMESA like the rest of Africa does not perform well on many measurements of innovation and competitiveness. Furthermore, as a result, there is a tendency for the COMESA member states to trade more with the rest of the world than among themselves. This is partly explained by the technology deficits 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?

1.4 The purpose of the study

This paper seeks to contribute to policy and to the empirical literature by providing a quantitative measurement of the influence of innovation on the extra and intra-COMESA trade. Specifically the study seeks to:

1. Compare the structure of the COMESA intra-export trade and the exports to the rest of the world in relation to imports into the region; and
2. Estimate the impact of innovation on extra and intra-COMESA exports

The rest of the paper is organized as follows: Chapter 2 is the review of selected literature and chapter three is the analytical framework and the methods used in the study. Chapter 4 is presentation of the results and finally chapter five is the conclusion and policy implications. In addition, there is the appendix that contains extra information deemed necessary and not in the main body of the paper.

2.0 Literature review

2.1 Theoretical 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 on the production base, hence resulting into gains from trade. According to Schumpeter (1942), the main force that brings about this structural change is the "perennial gale of creative destruction". Creative destruction is a process whereby waves of innovative activity hit the economic system in different points of time, resulting in the destruction of the old economic structure and the creation of a new one. There are various types of innovations: the introduction of new products, new methods of production and new forms of business organization as well as 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 key role in international trade and economic development (Márquez, & Martínez, 2009). Innovation is also an important factor of the non-price competitiveness of a nation's products. This is because it takes the form of an expansion of 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 small 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 to (Fagerberg 1997) international trade theory highlights the importance of technological innovation in explaining the international competitiveness of a country. 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 centred on resource endowments as the main factor explaining international trade patterns, the theory remerged. 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's (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 Lachenmaier and Woessmann (2004) there are two broad strands of theoretical literature predicting 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 become mature, so that finally developing countries will export these goods to the developed countries. This implies to keep ahead, developed countries must continually innovate and as they do that their export basket becomes even larger. The other models are endogenous growth models that recognize open-economy effects and endogenize the rate of innovation and predict dynamic effects of international trade on innovative activity. These include among other; Grossman and Helpman (1989; 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, to assimilate it, and to 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. It is Zahra and George (2002) who come up with four dimensions of absorptive capacity: acquisition, assimilation, transformation and exploitation capabilities that even shade more light on how technology innovation leads to increase in 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 for economic actors to leverage the knowledge generated through research and development (R&D) and through routine learning and practice of economic activities. Innovation is a key element for increasing trade as it is positively linked to improved quality of goods and services. Regional integration brings with it competition in the domestic market and as argued by Porter (1998), it can create pressure for improvements through innovations in ways that upgrade the competitive advantages of nations.

2.2 Empirical review

Empirical literature on innovations are largely concentrated on the link between innovations and trade. For instance Santacreu (2015) constructs a dynamic general equilibrium model in which imports and growth are connected by technological innovations and their international diffusion 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 and 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 as a function of its position on the transition path. Therefore, countries at early stages of development, with 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 by adopting an approach from the technology gap tradition and relating relative export flows to relative technology investments (R&D, patents, and *Science Policy Research Unit*[4] (SPRU) innovation rates in the United Kingdom. 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, & Martínez (2009) examines the effect of technological achievement on exports. Using the gravity model and technological achievement index (TAI) and confirmed 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 the period 1980 -2000, Lebesmuehlbacher (2015) examines the degree to which international trade and factor movements facilitate technology diffusion within developed and developing countries, particularly 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 demonstrates that long-term associations exist between technology progress and economic development with the impact of technology progress on economic development accounting for 13.2% while 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 observes that all countries must adopt innovations to benefit from the opportunities of the network age. This results from the three main arguments on innovation identified as; higher-technology goods present important opportunities to developing countries; many high-technology sectors are among the most dynamic in the global economy; and upgrading the technology content of the manufacturing sector diversifies the economy and creates opportunities in new markets. This 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) analyses the role that quality standards and innovation play on trade volume, using a gravity model. They argue that the net effect of quality standards on trade depends on the

[4] *SPRU* is a research centre based at University of Sussex

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

2.3 Overview of literature

The COMESA region highly values innovations as a means to promoting trade. This is demonstrated by the 16th 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. This has been driven by the need to put mechanisms in place to harness and mobilise existing knowledge in a structured manner that benefits all member states (Nakazzi, 2012). The Council is composed of representatives from academia, private sector and government and advices the member states in relation to existing and new knowledge and innovations, and the best ways of applying the knowledge and innovations.

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 is likely to lead to more integration among themselves 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 major gains in input combinations associated with innovation ECA (2016). This could be due to the fact that many of the world's innovations are generated in a few developed countries and then adopted globally. Therefore, technology diffusion across borders plays an important role in driving economic growth Lebesmuehlbacher (2015).

Although a number of studies have been done to investigate 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 to the empirical literature specifically by estimating the impact of innovation on trade and specifically intra-COMESA exports.

3.0 Methodology

3.1 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 the 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 X_{ij}, is proportional to the product of the two countries' GDPs, denoted by Y_i and Y_j, and inversely proportional to their distance, D_{ij}, broadly construed to include all factors that might create trade resistance as specified in *equation 1*.

$$X_{ij} = \alpha_0 Y_i^{\alpha 1} Y_j^{\alpha 2} D_{ij}^{\alpha 3}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where α_0, α_1, α_2, and α_3 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*

$$ln\,(X_{ij}) = ln(\alpha_0) + \alpha_1\, ln\,(Y_i) + \alpha_2\, ln\,(Y_j) + \alpha_3\, ln\,(D_{ij}) + et_{ij} \quad \ldots\ldots\ldots\ldots\ldots 2$$

Where et_{ij} is the error term.

According to Alemayehu and Idris, (2015) the gravity model has widely been used to identify determinants of bilateral trade, though they are often criticized for lacking a strong 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, 2001). However this challenge has since been resolved after the works of other scholars demonstrated that there is strong 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 Psedo Poisson Maximum Likelihood (PPML) method to address the problems associated with OLS (Silva and Tenreyro, 2006). The Pseudo Poisson Maximum Likelihood (PPML) approach has been used widely (see for example Liu, 2009; Westerlund and Wilhelmsson, 2011; Martinez-Zarzoso, 2013; Alemayehu and Edris, 2015) among others. The parameters of the econometric model are computed by finding the estimates that maximize the likelihood function in theses formulations. Although other estimation techniques such as fixed-effect and random-effect model have been widely used (Herrera, 2011), they are prone to heteroscedasticity and therefore their estimates are not robust. For that matter we did not venture to estimate using these techniques.

The use of the PPML estimator was chosen and justified on a number of grounds. Firstly, the PPML estimator accounts for heteroscedasticity which characterizes international trade data (Santos 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 is able to take advantage of the information contained in the zero values trade flows. A notable drawback of the OLS approach is that it does not take into account the information contained in the zero values of bilateral trade flows. Thirdly, due to the additive 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 among themselves and 43 major export destinations outside the region (see Appendix A1). We then add our variables of interest in addition to the augmented specification to estimate the following augmented regression as shown in *equation 3*:

$$X_{ijt}=\beta_0+\beta_{1.}lnY_{it}+\beta_{2.}lnY_{jt}+\beta_{3.}InDist_{ij}+\beta_{4.}Cont_{ij}+\beta_{5.}Lang_{ij}+\beta_{6.}\mathrm{llock}_i+\beta_{7.}\mathrm{llock}_j+\beta_{8.}\mathrm{comcol}_{ij}$$

$$+\beta_{9.}InTariff_j+\beta_{10.}InTraCost_i+\beta_{11.}InTraCost_j+\beta_{12.}InTec_i+\beta_{13.}InTec_j+\varepsilon_{ijt}\ldots\ldots\ldots\ldots\ldots\ldots\ldots.3$$

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 1are land locked 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 main 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 main variable of interest.

3.2 The Global Innovation index[5]

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. The number of patents a country registers was the best option, however, it had significant data limitations especially for the COMESA Member States which made it impossible to use this variable. Although the proportion of the national budget that is 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 these two was the Global Innovation Index (GII)[6] whose construction is scientific and data are were available for all the countries and the years of analysis. The GlI is an annual ranking of countries by their capacity for, and success in, innovation. It aims at capturing the multi-dimensional facets of innovation and provides 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.

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. Details are in the appendix Table A4.

3.3 Data sources:

We use export trade data from the COMTRADE and World Integrated Trade Solutions (WITS) database which covers 43 countries that each of the EAC Partner Sates exports. We extract distance data from the distance calculator website[7] which is defined as direct distance between the capital cities of a pair of trading partners without taking into consideration the actual routes by either forms 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 land locked or not, is an island or not, borders a trading partner or not and has the same official language or not were extracted from the Centre

[55] www.globalinnovationindex.org.

[6] 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

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

d'EtudesProspectivesetd'InformationsInternationales (CEPII)[8] gravity dataset. The Global Innovation Index data was extracted from the annual reports. The analysis is done for the period 2007 to 2018. Details of the sources and the data are in Appendix A2.

3.4 Estimation procedure

In the panel estimation process we had to make a choice between a number of estimation techniques to obtain the best and most robust results. The OLS was immediately discarded for reasons discussed above regarding the choice a model. The other options were the Random Effects - RE and Fixed Effects –FE models. Whereas the RE estimation is appropriate for estimating trade flows between randomly drawn samples of trading partners from a large population, the FE is most appropriate for estimating trade flows between *ex ante* predetermined selection of countries. These equally had their limitations.

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. Ideally we should have conducted the famous Hausman test to make a choice between the RE and FE techniques. The RE even when selected is likely to suffer from problem associated with heteroscedasticity – less precise coefficient estimates. We choose the PPML for its strength the and ability to overcome the limitation associated with the OLS, FE and RE prior presented.

The continuous data are 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 is to enable us establish the proportion of technology innovation that generates a given level or proportion of both extra and intra–COMESA exports. In this way policy makers can be guided to invest into technology innovation for increasing exports of the COMESA member States.

3.5 Diagnostic tests

We conducted the Levin *et al.,* (2000) test of panel unit roots that assume that the autoregressive parameters are common across countries. Levin, Lin and Chu (LLC) 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 multi-collinearity 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 fine, we concluded that there is no serious problem.

[8] CEPII make available a "square" gravity dataset for all world pairs of countries, for the period 1948 to 2006. This dataset was generated by Keith Head, Thierry Mayer and John Ries (2010)

4.0 Results

4.1 Introduction

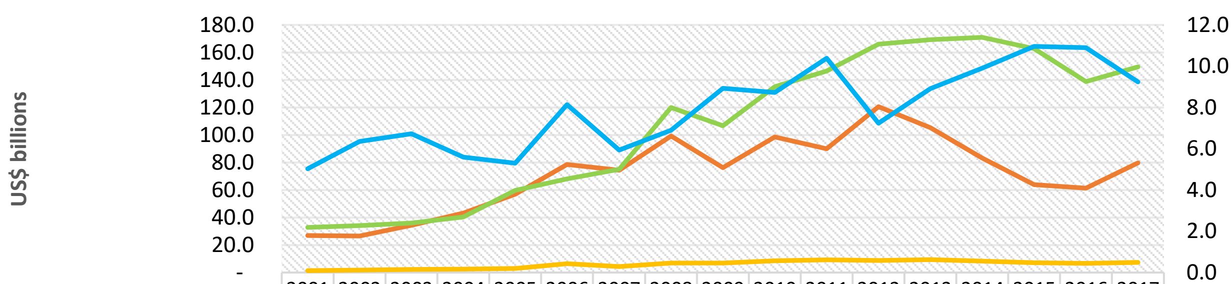
The chapter presents the results of the study. First, we present and discuss the trends in intra COMESA exports in comparison to the rest of the world between. This is intended to gauge the intensity of technology that the products embody. This is followed by a presentation and discussion of the structure of products that COMESA member states trade among themselves and the rest of the world. We then present the descriptive analysis of the variables used in the model. Finally, we present and discuss the results of the estimated model.

4.2 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). This significantly reduced to US$ 7.4 billion by 2017. Exports to the world (COMESA inclusive) increased overtime, 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.

From 2007, an increase in exports has been corresponding 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 actually fluctuated between 6 to 10 percent over years. The statistics suggest that although the regional integration has contributed to increasing intra-COMESA trade, there is a long way to fully achieve this objective.

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

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

Table 2 gives a summary of 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 for the period 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 US$ 90billion for the 11 year period, it was US$ 1.1 trillion for the exports to the RoW and US$ 1.7 trillion for the imports from the rest of the world. This suggests that there is more trade with the RoW than the bloc intra-trade. Specifically, the region has high propensity to import from the RoW compared to the regional/ bloc imports.

It is evident that the exports originating from the COMESA region are not as technology intensive products as those imported in the region from the RoW. The region exports commodities and light manufactured products and imports high technology manufactured products demonstrating the low levels of technology innovation in the region. This suggests that the COMESA bloc market for high technology products is available for member states if regional technology innovation is tapped into.

The intra-regional exports largely constitute ores, coffee, tea, mineral fuels, cement, sugar and sugar confectionary, 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 further strengthening the argument for exports of commodities and light manufactures. 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. On a comparative basis although some of the products produced and exported by COMESA member stated are similar to those imported, 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. From a positive perspective, any serious leaps in technology innovation in the COMESA region is likely to generate and guarantee a huge 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

4.4 Means of the estimated variables

Table 3 gives a summary of the means for the model estimation variables. The average COMESA export value for the 12 years of analysis to COMESA member states is US$22.3billions and the other main 43 importers is US$113billions suggesting the significant difference between intra-regional trade and trade with the RoW. On average the transport costs per container are higher (US$3,315) for importing COMESA member states compared to exporting member states (US$2,626). This implies that it is more expensive to import than to export within the COMESA region which is likely to impede intra-trade. Furthermore, the transport costs to import by the non COMESA countries is even lower plausibly and partly explaining the differences in the volumes and values between the two groups. The average GDP of the COMESA member states is only US$93billion compared to the other importing countries at US$1.99trillion). Whereas the average tariff in the COMESA region is 9.2, it is 4.2 for the importing countries suggesting that it is 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) for the COMESA region (24) is significantly lower compared to the importers outside the region (41). This suggests that there is still limited innovation within the region compared to the other countries with which the region trades with. This inevitably 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
Transports cost of exporters	2,626		
Transports 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

4.5 Estimation results

This section provides the main results of the empirical analysis conducted on the total sample of 15,876 observations. Results of equation (3) are reported in table 4 for the three categories adopted, namely; intra-COMESA exports, COMESA exports to 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 0.06 percent decrease in COMESA export trade to non COMESA partners, it leads to only 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 are in agreement with theory and empirical studies that argue that transport costs increase the cost of doing business and reduce the competitions of export firms.

Results suggest that the GDP of both the exporting and importing countries play a significant role in determining the level of COMESA member stated exports at 1 percent level of significance. GDP of the COMESA member states is a proxy for the production capacity and size of the economy. A 1 percent increase in the GDP leads to 0.20 percent increase in exports for COMESA member states. This results implies that member states should strive to grow their GDP as this significantly determines the level of exports. On the side of the GDP of the importers, increasing it by 1 percent leads to 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 not only positive and significant at 1 percent and therefore in agreement with *a priori* expectation, but revealing regarding 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 the level of 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 leads to reduction in COMESA exports by 0.04 percent. The results thus calls for continuing the liberalization process within the COMSA region to generate more intra-regional trade.

The distance between the trading countries has a strong bearing on the volumes of trade as these two exhibit an inverse relationship. The results for distance are significant at 1 percent and in agreement with *a prior* expectations. Increasing the distance by 1 percent leads to 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 the level of infrastructure development is still low although recent efforts are likely to yield good results.

Table 4: Estimation results

Variable	Ppml Estimates 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 movements of the exchange rate play a significant role in partly determining the volume of trade between partner states. Results show that the exchange rate in the other importing countries is significant at 1 percent level. Whereas a one percent appreciation in the exchange rate leads to 0.27 percent decline in imports among the other non COMESA states this is 0.18 percent for all the importers combined, for the COMESA importers, the exchange rate is 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 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 land locked 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 in this study 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, in the importing countries it is expected to increase consumption hence imports. 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.

This results suggests that intra-COMESA trade can and should be increased by targeting technology innovation in the region. Following from the literate, this can be achieved through two ways; endeavouring to innovate in the region and adopting technology from countries that have made significant advances in technology innovation. The results are in agreement with Wakelin (1998); Estrada *et al* (2006) and Márquez, & Martínez (2009) who found a strong relationship between innovation and growth of export trade. Perhaps what this study has not addressed, 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 examines the role of technology innovation in determining the intra-COMESA exports and exports to 43 major importing countries. The main aim is to estimate the impact of technology innovation on exports. The results suggest that indeed technology is a key element in increasing trade given that it is positively linked to improving the quality of goods and services. When countries innovate they generate a body of knowledge that enables them produce new products, improve existing ones and consequently improve on their levels of competitiveness. From the results, it is concluded that increasing technology innovation by 10 percent leads to 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 to increase exports and these should not be neglected including trade facilitation to reduce costs of doing business and increase competitiveness among others. Regarding technology innovation, we recommend that COMESA Member States:

- Should establish a COMESA Innovation Fund and increase and target funding of R&D to generate innovative technologies to foster product improvement, development and diversification;
- Should explicitly formulate innovation policies to address the few and weak institutional linkages and collaboration, weak engineering and entrepreneurship capabilities and limited financial resources for technological innovation;
- Should endeavor to establish science and technology parks; artisanal and industrial clusters for purposes of incubation;
- Create a database of scientist 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 and 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

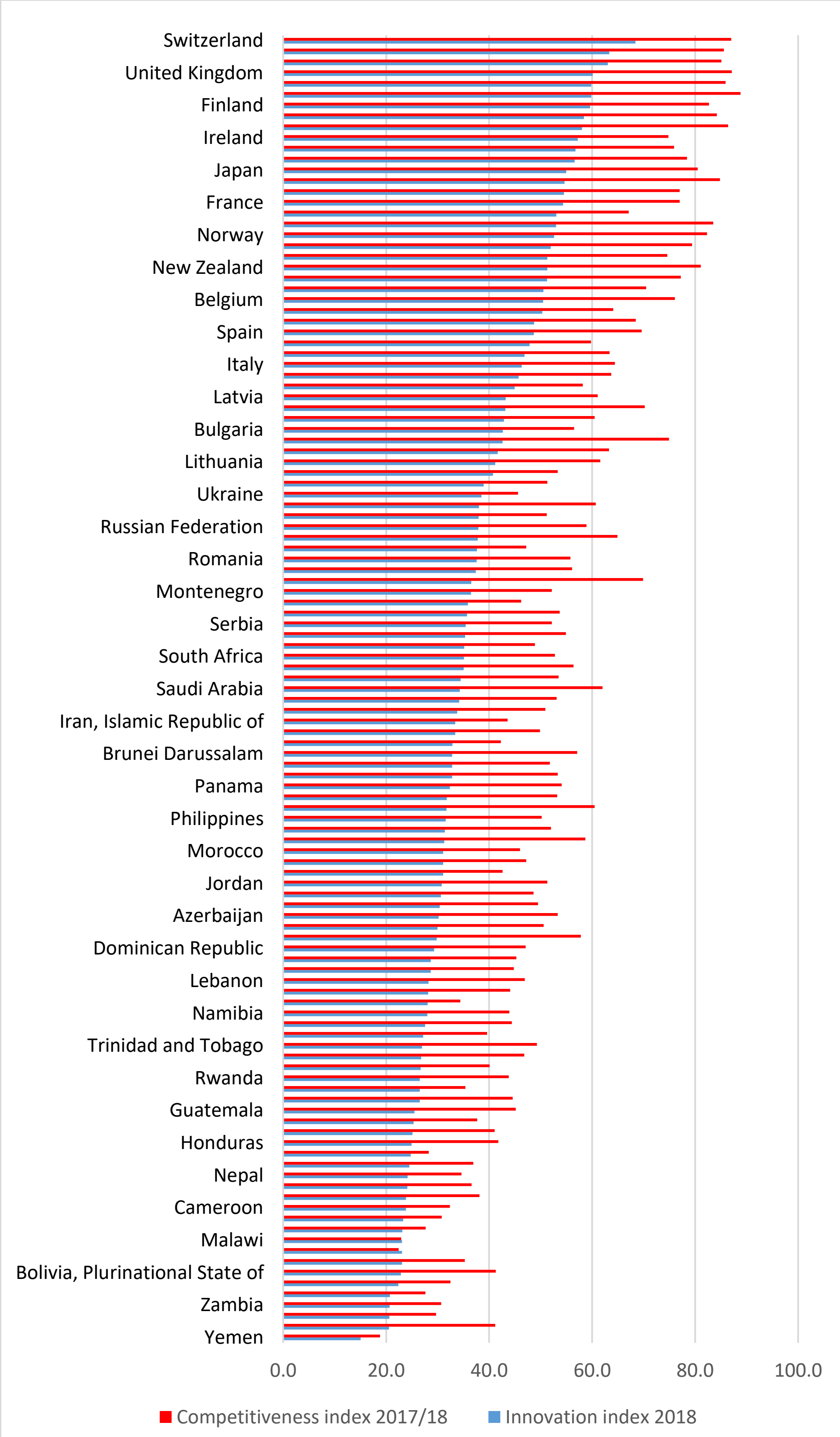

Table A1: The countries that constitute the trading partners in this research

	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 dollars	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

Index	
1	Institutions
1.1.	Political environment
1.1.1.	Political stability and absence of violence/terrorism
1.1.2.	Government effectiveness
1.1.3.	Press freedom
1.2.	Regulatory environment
1.2.1.	Regulatory quality
1.2.2.	Rule of law
1.2.3.	Cost of redundancy dismissal
1.3.	Business environment
1.3.1.	Ease of starting a business
1.3.2.	Ease of resolving insolvency
1.3.3.	Ease of paying taxes
2	Human capital and research
2.1.	Education
2.1.1.	Expenditure on education
2.1.2.	Public expenditure on education per pupil
2.1.3.	School life expectancy
2.1.4.	Assessment in reading, mathematics, and science
2.1.5.	Pupil-teacher ratio, secondary
2.2.	Tertiary education
2.2.1.	Tertiary enrolment
2.2.2.	Graduates in science and engineering
2.2.3.	Tertiary inbound mobility
2.2.4.	Gross tertiary outbound enrolment
2.3.	Research and development (R&D)
2.3.1.	Researchers
2.3.2.	Gross expenditure on R&D (GERD)

2.3.3.	QS university ranking average score of top 3 universities
3	Infrastructure
3.1.	Information and communication technologies (ICTs)
3.1.1.	ICT access
3.1.2.	ICT use
3.1.3.	Government's online service
3.1.4.	Online e-participation
3.2.	General infrastructure
3.2.1.	Electricity output
3.2.2.	Electricity consumption
3.2.3.	Logistics performance
3.2.4.	Gross capital formation
3.3.	Ecological sustainability
3.3.1.	GDP per unit of energy use
3.3.2.	Environmental performance
3.3.3.	ISO 14001 environmental certificates
4	Market sophistication
4.1.	Credit
4.1.1.	Ease of getting credit
4.1.2.	Domestic credit to private sector
4.1.3.	Microfinance institutions' gross loan portfolio
4.2.	Investment
4.2.1.	Ease of protecting investors
4.2.2.	Market capitalization
4.2.3.	Total value of stocks traded
4.2.4.	Venture capital deals
4.3.	Trade and competition
4.3.1.	Applied tariff rate, weighted mean
4.3.2.	Market access for non-agricultural exports
4.3.3.	Intensity of local competition
5	Business sophistication
5.1.	Knowledge workers
5.1.1.	Employment in knowledge-intensive services
5.1.2.	Firms offering formal training
5.1.3.	GERD performed by business enterprise (% of GDP)
5.1.4.	GERD financed by business enterprise (% of GERD)
5.1.5.	GMAT mean score
5.1.6.	GMAT test takers
5.2.	Innovation linkages
5.2.1.	University/industry research collaboration
5.2.2.	State of cluster development
5.2.3.	GERD financed by abroad
5.2.4.	Joint venture/strategic alliance deals
5.2.5.	Patent families filed in at least three offices
5.3.	Knowledge absorption
5.3.1.	Royalties and license fees payments (% of service imports)
5.3.2.	High-tech imports
5.3.3.	Communications, computer and information services imports, %
5.3.4.	Foreign direct investment net inflows
6	Knowledge and technology outputs
6.1.	Knowledge creation
6.1.1.	National office resident patent applications
6.1.2.	Patent Cooperation Treaty resident applications
6.1.3.	National office resident utility model applications
6.1.4.	Scientific and technical publications
6.1.5.	Citable documents H index
6.2.	Knowledge impact
6.2.1.	Growth rate of GDP per person engaged
6.2.2.	New business density
6.2.3.	Total computer software spending
6.2.4.	ISO 9001 quality certificates
6.2.5.	High-tech and medium-high-tech output
6.3.	Knowledge diffusion
6.3.1.	Royalties and license fees receipts (% service exports)
6.3.2.	High-tech exports
6.3.3.	Communications, computer and information services exports, %

6.3.4.	Foreign direct investment net outflows
7	Creative outputs
7.1.	Intangible assets
7.1.1.	National office resident trademark registrations
7.1.2.	Madrid system trademark registrations by country of origin
7.1.3.	ICTs and business model creation
7.1.4.	ICTs and organizational models creation
7.2.	Creative goods and services
7.2.1.	Audiovisual and related services exports
7.2.2.	National feature films produced
7.2.3.	Daily newspapers circulation
7.2.4.	Printing and publishing output
7.2.5.	Creative goods exports
7.3.	Online creativity
7.3.1.	Generic top-level domains (gTLDs)
7.3.2.	Country-code top-level domains (ccTLDs)
7.3.3.	Wikipedia monthly edits
7.3.4.	Video uploads on YouTube

www.globalinnovationindex.org.