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The Quality and Price of Africa's Imports of Digital Goods

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Abstract

Imported digital goods are critical for productivity growth in low-income countries. Using detailed data on international trade flows and tariffs, this paper finds that African nations tend to import relatively low quality, low price digital goods. It also finds that digital goods in Africa are subject to relatively higher tariffs, along with other factors that contribute to their higher cost in the domestic market compared to other regions, especially in some low-income countries. The findings show that the African Continental Free Trade Area will do little to reduce this tariff burden, as most digital goods are sourced from higher income non-members. In contrast, unilateral tariff liberalization toward all countries would significantly increase the imports of digital goods in Africa.

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The Quality and Price of Africa's Imports of Digital Goods*

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1 Introduction

The quality of internationally traded goods is strongly associated with income per capita: within narrow product categories, richer countries tend to import and export higher quality goods, which tend to carry a higher price (Schott, 2004; Hummels and Klenow, 2005; Hallak, 2006; Hallak and Schott, 2011; Feenstra and Romalis, 2014). While this earlier literature does not establish a causal relationship between product quality and economic performance, more recent evidence based on firm-level data reveals that access to high quality inputs is an important driver of firm upgrading in developing countries (Verhoogen, 2023). For example, Bas and Strauss-Khan (2015) find that tariff reductions on inputs led non-processing firms in China to increase the prices they paid for inputs and to increase the prices and quality of their outputs.[1] Focusing on Colombia, Fieler, Eslava, and Xu (2018) uncover an amplification effect in firm upgrading: tariff reductions on inputs lead firms to upgrade the quality of outputs, which increases their demand for other high-quality inputs; this gives incentives for local suppliers to upgrade, which in turn gives final-good producers further incentives to upgrade.

Among the set of inputs that matter for productivity growth in developing countries, there is growing evidence that digital goods are critical. Early evidence by Commander, Harrison, and Menezes-Filho (2011) reveals positive effects of information and communication technologies (ICT) in the performance of Brazilian and Indian manufacturing firms, while more recent evidence by Hjort and Poulsen (2019) shows that the arrival of submarine internet cables in Africa raised skilled employment, and led to increased firm entry, productivity, and exporting, thereby lifting average incomes. Using firm-level data for 82 developing countries, Cusolito, Lederman, and Pena (2021) find large positive effects of digital technology adoption on firm productivity.[2]

Since digital goods are mainly produced in advanced or large emerging economies such as China, the quality and prices at which firms and consumers in developing countries can acquire them in international markets are especially important. However, there is little systematic evidence on the quality and prices of imported digital goods in low-income countries, or on the degree of tariff protection they face. A recent study using item-level prices from the International

[1] Fan, Li, and Yeaple (2015) also find that Chinese firms responded to reduced tariffs on imported inputs by raising export prices and quality, and that this effect is stronger in more differentiated sectors. Bas and Paunov (2021) find broadly similar results with representative data from Ecuador (linking customs data to a more traditional plant panel survey), and in addition that imported-input driven upgrading is stronger in more skill-intensive firms and is in turn associated with increases in skill intensity.

[2] As summarized in Dutz, Almeida, and Packard (2018), recent related research for Latin America concludes that digital technology adoption offers a pathway to higher productivity. Total factor productivity of technology-adopting firms increased in Argentina, Brazil, Chile, Colombia, and Mexico (Brambilla and Tortarolo, 2018; Iacovone and Pereira-Lopez, 2018; Almeida, Fernandes, and Viollaz, 2017; Dutz, Mation, O'Connell, and Willig, 2017).

Comparison Program (ICP) suggests that machinery and equipment tend to be relatively more expensive in African countries than the rest of the world (Cruz, Cirera, Hjort, Lang, Konte, and Edet, 2024). For digital products, including machinery, equipment, and software, prices in Africa are up to 34% more expensive than in the United States, in US dollar terms.[3]

In this paper, we use detailed data on international trade flows and tariffs to study Africa's imports of digital goods. We first provide evidence on the relative quality and quality-adjusted prices of Africa's digital goods imports, as well as on the degree of tariff protection that is currently imposed on them. We then estimate the likely impacts of the African Continental Free Trade Area (AfCFTA) on digital goods imports, which we compare with a benchmark scenario of full unilateral import tariff liberalization from AfCFTA members towards all countries.

We begin by outlining the key features of digital goods imports and tariff protection across African nations that are part of AfCFTA. In 2019, Africa imported $59.4 billion worth of digital goods, with 35 percent sourced from China and 27 percent from the European Union. Digital goods constitute a smaller share of African imports (about 13 percent) compared to the rest of the world (around 21 percent). A few countries – South Africa, the Arab Republic of Egypt, Nigeria, Morocco, and Tunisia – collectively accounted for 70 percent of Africa's digital goods imports, while intra-African trade in digital goods remains minimal.

Despite this heavy reliance on imports, Africa imposes relatively high tariffs on digital goods globally, with an average tariff of approximately 5 percent, compared to an average of 2 percent in other regions. These tariffs remained relatively constant in recent years. Moreover, the level of tariff protection on digital goods correlates negatively with income per capita across African countries, with upper-middle-income economies like South Africa imposing tariffs as low as 0.9 percent, while low-income countries such as the Central African Republic and Cameroon applies tariffs as high as 15 percent, with some large economies such as Ethiopia and Nigeria, imposing tariffs around 9 and 10 percent, respectively on average.

We proceed by estimating the quality and quality-adjusted prices of Africa's imports of digital goods. We apply the methodology proposed by Feenstra and Romalis (2014), using detailed data on international trade flows and tariffs. We find that African nations tend to import relatively low quality, low price digital goods, as would be expected given their relatively low income per capita. Once we adjust prices for quality differences, digital goods in Africa are sourced at broadly similar prices relative to higher-income countries. If import tariffs, along

[3]The ICP item-level prices for machinery and equipment include import duties and other product taxes paid by the purchaser, the costs of transporting the asset to the place where it will be used, and any charges for installing the asset so that it is ready for use in production. Thus, it captures the final prices to customers, which include factors beyond trade tariffs.

other factors such as transport and installation costs, are added to these quality-adjusted import prices, we conclude that several African nations tend to face relatively high prices for imported digital goods, especially some low-income countries where the tariff burden tends to be higher.[4]

We then examine the likely effects of AfCFTA on digital goods imports. AfCFTA is an important trade agreement encompassing 54 African Union member states. It seeks to foster economic integration by progressively eliminating tariffs on 90 percent of traded goods, promoting trade in services, and implementing rules of origin to ensure preferential treatment of products. By 2030, the AfCFTA has the potential to create a single market of over 1.3 billion people with a combined GDP exceeding $3 trillion.[5]

To assess the likely effects of AfCFTA on digital goods imports, we draw on the detailed tariff schedule of the agreement, and use the framework of Hoekman, Ng, and Olarreaga (2002) to estimate the total demand for imported goods broken down to the 6-digit level of the Harmonized System (HS). The model simulates a counterfactual trade flow resulting from tariff liberalization and compares it with the base year. Despite the comprehensive liberalization expected from the AfCFTA, our analysis indicates that the agreement is unlikely to have a significant impact on reducing tariff protection on digital goods in Africa. The average import-weighted tariffs on these products is expected to decrease by only 0.29 percentage points due to the agreement, from 6.26 percent to 5.97 percent. This result is partly due to the absence of tariff reductions on extra-zone imports of digital goods, which constitute the majority of digital goods imports in AfCFTA, and the limited intra-regional trade in these products. As a result, imports of digital goods are expected to increase only by 0.3% for the whole region.

We then estimate the effects of a full import tariff liberalization on digital goods imports of AfCFTA members towards all countries. We find that such a scenario would lead to an 8% increase in the imports of digital goods. These findings suggest that AfCFTA nations should consider including tariff concessions on digital goods imports from non-member countries, potentially lowering costs significantly, especially in the poorest countries with the highest tariffs on digital goods.

In addition to the articles cited above, our paper is related and contributes to several strands of existing research. First, our work relates to a broader literature on product quality and trade, including Verhoogen (2008), Bastos and Silva (2010), Crozet, Head, and Mayer (2012), Manova and Zhang (2012), Brambilla, Lederman, and Porto (2012), Johnson (2012), Hallak and

[4]This is aligned to patterns of prices for digital machinery, equipment, ans software observed in the ICP data, which are higher in Africa than other regions, including high-income economies (Cruz, Cirera, Hjort, Lang, Konte, and Edet, 2024).

[5]See: https://au-afcfta.org/

Sivadasan (2013), Amiti and Khandelwal (2013), Caron, Fally, and Markusen (2014), Harrigan, Ma, and Shlychkov (2015), Fan, Li, and Yeaple (2015), Bas and Strauss-Khan (2015), Atkin, Khandelwal, and Osman (2017), Bastos, Silva, and Verhoogen (2018) and Bastos, Dias, and Timoshenko (2018). Second, we contribute to the literature on impacts of the effects of international trade agreements on trade flows. Our analysis follows the methodology of Hoekman, Ng, and Olarreaga (2002), who draw on a simple and transparent partial equilibrium model to estimate the impact of duty free access for developing countries to high-income markets (Canada, EU, US and Japan) and compares this with a non-discriminatory reduction of tariff peaks to 5 percent.

Partial equilibrium models are static in nature, allowing only for a comparative static comparison of pre/post policy change when all other variables are held constant. Thus, the dynamics which affect the change are not explicitly modeled, nor can complex variations in the setup be considered. Since these models look at the partial effects – i.e. for one set of markets – of a policy change, they do not capture important feedbacks between markets. Dynamic linkages and market feedbacks can be captured in Computable General Equilibrium (GE) models. However, CGE models are much more complex to set up and require more information than partial equilibrium models, e.g. up-to-date input-output tables, or social accounting matrices. They also provide more aggregate information than partial equilibrium models. Since we focus on a relatively small subset of imports (digital goods imports), for which we require disaggregated data by product and country, we rely only on estimates from a partial equilibrium model, leaving a more comprehensive examination of GE effects for further research.

The rest of the paper is organized as follows. Section 2 describes the sources of data used in the paper, as well as the definition of digital goods. Section 3 documents basic facts about Africa's trade over the period of analysis. Section 4 explains the methodology for estimating quality and quality-adjusted prices, and presents the corresponding estimates on average import prices, quality and quality adjusted prices. Section 5 examines the likely impacts of AfCFTA on the imports of digital goods of member countries. Section 6 compares this scenario with that of a full tariff liberalization on digital goods imports. Section 7 concludes the paper.

2 Data

The empirical analysis in this paper exploits and combines several sources of data, including international trade flows, tariffs, a set of gravity-like variables and a definition of digital goods based on the Bureau of Economic Analysis's (BEA's) Digital Economy list of Digital Inputs. In the remainder of this section, we describe each of these sources in more detail.

2.1 International trade flows and tariffs

Because our goal is to estimate quality and quality adjusted prices for several products, countries, and years, we cannot rely on firm level data which is only sparsely available for a few countries. We draw therefore on export and import data from the UN Comtrade Database for the period 2012- 2019. These data contain information on bilateral export (FOB) and import (CIF) values and quantities at the HS 6-digit level. The data is more disaggregated than the information used by Feenstra and Romalis (2014) who used SITC 4-digits.

We compute the bilateral f.o.b. unit values of traded manufactured goods using reports from the exporting country, which ensures that unit values do not include shipping costs. We use importers' trade reports to calculate c.i.f. unit values using importers' trade reports. These unit values already include the costs of shipping and hence only tariffs need to be added. To this end, we use ad valorem tariffs associated with the most favored nation status or any preferential status from TRAINS.

Following Feenstra and Romalis (2014), we correct for measurement error by dropping trade flows below $50,000 and quantities with less than 1 kg (or missing). We further omit observations in which the ratio of the c.i.f. unit value reported by the importer and the f.o.b. unit value reported by the exporter, for a given four-digit SITC product and year, was less than 0.1 or above 10. To examine the likely effects of AfCFTA, we further use tariff data from UNCTAD, which contains information at the product level on current and expected tariffs (by 2030) after the implementation of the agreement for all country members and their partners.

2.2 Definition of digital goods

Many manufactured products have digital components, and the same product category used in international trade statistics can include some products that have digital components and others that do not. Digital goods are also constantly evolving from a technological point of view. Identifying digital goods in the product-level data used in international trade statistics is therefore not straightforward.

In this paper, we have adopted a broad definition of digital goods. We depart from the Bureau of Economic Analysis (BEA) Digital Economy list of Digital Inputs, which contains 52 6-digit codes of the NAICS classification (see Barefoot, Curtis, Jolliff, Nicholson, and Omohundro (2018)).[6] This is a broad definition of digital inputs used in national statistics, which includes

[6]The BEA reached this list in three steps. First, it developed a conceptual definition of the digital economy.

some goods that are no longer relevant from a technological point of view. For example, the original definition includes items such as "audio tapes, cassette, full length". We therefore restricted the focus to the subset of digital NAICS industries that used digital inputs in a meaningful way. Specifically, we use a table from the BEA Input-Output accounts data from 2012, which contains 405 x 405 industries (identifiable to 6-digit NAICS), to restrict further the original set of digital industries, defined as those that have at least 10% of digital inputs over total inputs. Table A1 in the appendix reports the set of digital goods we identified according to these criteria. We then used a concordance to match these industries to the HS classification used in trade statistics.

2.3 Other variables

We further complement our data set with information on gravity-type variables, notably distance and language, which come from CEPII, as well as GDP and population, which we take from the Penn World Tables.

3 Key features of Africa's imports of digital goods

In this section, we document key stylized facts on Africa's imports of digital goods over the period of analysis. In 2019, Africa imported $59.4 billion worth of digital goods. Figure 1 shows that digital goods constitute a smaller share of total imports of AfCFTA members (about 13 percent) compared to the rest of the world (around 21 percent). The figure also shows that between 2012 and 2019, the relative importance of digital goods in total imports remained relatively stable in AfCFTA, while it increased moderately in the rest of the world, from around 19 percent to 21 percent.

Table A.2 reports the main source markets for the imports of digital goods from AfCFTA members in 2019. We observe that the great majority of digital goods in Africa are sourced from higher-income countries and large emerging economies. Specifically, 35 percent were sourced from China, 27 percent from the European Union, 7 percent from the United States, and 7 percent from India. South Africa is, by far, the main source of digital goods among other AfCFTA members, but accounted only for about 3% of total imports of digital goods. Taken together, other members of AfCFTA accounted for only around 1 percent of total digital goods imports, including Egypt (0.3 percent), Morocco (0.2 percent), Botswana (0.2 percent), Mauritius (0.2

Second, it identified specific goods and services categories within BEA's supply-use framework relevant to measuring the digital economy. Third, BEA used the supply-use framework to identify the industries responsible for producing these goods and services.

percent) and Tunisia (0.1 percent). Therefore, intra AfCFTA trade in digital goods remains minimal.

Regarding importing countries within AfCFTA, we observe a relatively high concentration of digital goods imports in a few countries. Table A.3 reveals that South Africa, Egypt, Nigeria, Morocco and Tunisia collectively accounted for 70 percent of Africa's digital goods imports. Individually, we observe that South Africa accounts for 22.7 percent of AfCFTA's digital goods imports, followed by Egypt with 15.4 percent, Morocco with 13.9 percent, and Tunisia with 5.6 percent. All other countries account individually for less than 3 percent of digital goods imports.

Table A.4. reports the distribution of AfCFTA's digital goods imports across broad ISIC sectors in 2019, defined at the 3-digit level. We observe that the majority of digital goods imports belong to the sectors "office and computing machinery" (16.1 percent), followed by "medical appliances and instruments" (14.5 percent), "general purpose machinery" (12.14 percent), "television and radio transmitters" (9.8 percent), and "special purpose machinery" (8.88 percent).

Despite the heavy reliance on imported digital goods from nations outside AfCFTA, Figure 2 reveals that AfCFTA nations impose relatively high tariffs on digital goods globally, with an average tariff of approximately 5 percent, compared to an average of 2 percent in other regions. Figure 2 further reveals that these tariffs have remained relatively constant. Figure A1 depicts the evolution of average tariffs in AfCFTA in comparison with other regions. We observe that South Asia is the region with the highest import-weighted applied tariffs on digital goods, followed closely by AfCFTA. Furthermore, we observe that there was convergence in tariffs between these two regions, with a significant decline in South Asia and relatively stable tariffs in AfCFTA. In the other regions, tariffs remained relatively stable, at around 4 percent in Latin America and the Caribbean, and below 2 percent in the other regions.

Figure A.2 reports the distribution of tariff incidence across sub-sectors of the digital goods bundle, both in AfCFTA members and in the Rest of the World. We observe that, in addition to the relatively higher level of tariffs on digital goods, in AfCFTA there is wide dispersion across sectors, with an average tariff of 9.7 percent on digital goods belonging to the sector "fabricated metal products", 6.83 percent on "electrical equipment", 5.71 percent on "computer and electronic products", 4.2 percent on "machinery", 6.9 percent on "motor vehicles" and 0.3 percent on "printing and related support activities". In the rest of the world, import tariffs on digital goods are relatively more homogeneous across sectors, with an average tariff of 3.28 percent on "fabricated metal products", 2.64 percent on "electrical equipment", 2 percent on "computer and electronic products", 2.1 percent on "machinery", 3.5 percent on "motor vehicles" and 1 percent on "printing and related support activities".

Looking at the heterogeneity of digital goods tariffs across countries in AfCFTA, Figure A3 reveals that the level of tariff protection on digital goods correlates negatively with income per capita across African countries, with economies like South Africa imposing tariffs as low as 0.9 percent, while the Central African Republic and Cameroon apply tariffs as high as 15 percent. We also observe that tariffs on digital goods are relatively high in large countries (as measured by population size), including Ethiopia, Nigeria and Egypt. Therefore, the scope to reduce the relatively high tariffs on digital goods in AfCFTA is especially high in low-income countries in the region, and such reduction would impact a sizable share of Africa's population.

4 The quality and quality-adjusted prices of Africa's imports of digital goods

It is well-documented that the unit values of internationally traded goods are strongly influenced by differences in quality (Schott, 2004; Hummels and Klenow, 2005; Hallak, 2006; Hallak and Schott, 2011; Feenstra and Romalis, 2014). To undertake meaningful cross-country comparisons of import prices of digital goods, it is therefore important to adjust them for these quality differences. In this section, we present estimates of the quality and quality-adjusted prices of AfCFTA imports of digital goods. We first briefly outline the main features of the methodology we use to estimate the quality and quality-adjusted prices of Africa's imports of digital goods. We then present the corresponding results.

4.1 Methodology

We estimate the quality and quality-adjusted import prices of digital goods following the methodology proposed by Feenstra and Romalis (2014). This approach exploits a pervasive supply-driven feature of trade data to decompose unit values of traded goods into quality and quality-adjusted price components, exploiting both differences in the demand and supply for quality. Previous studies relied mainly on the demand side to identify quality together with a simple supply side to control for the extensive margin (Schott, 2004; Hallak, 2006; Khandelwal, 2010; Hallak and Schott, 2011), assigning higher quality to imports with a higher market share (or to trade flows higher net exports), conditional on price. Feenstra and Romalis (2014) add more structure to the supply side of product quality, by modeling explicitly the endogenous quality choice of heterogeneous firms. The model gives rise to a "Washington apples" effect, whereby goods of higher quality are shipped longer distances (Alchian and Allen, 1964; Hummels and

Skiba, 2004). The positive relationship between quality (and hence f.o.b. export prices) and distance that results from the endogenous quality choice of firms makes it possible to use the exporter f.o.b. unit value to help identify quality.

In particular, the heterogeneous firm trade model features a zero-cutoff-profit condition which determines the marginal exporter. As foreign demand increases, less efficient exporters enter the market, and they produce lower quality goods. This implies that quality and bilateral trade are negatively related from this supply-side equation. Combined with the positive association between trade and quality from the demand side, this makes it possible to obtain a sharper solution for quality than in the previous literature. The solution for quality is governed by cost, insurance and freight (c.i.f.) and f.o.b. prices, as well as model parameters (the elasticity of substitution, a Pareto productivity parameter, as well as a parameter governing non-homothetic demand). The fixed costs of exporting, which play an important role in the quality estimates through the supply side of the model, are captured by a general specification which depend on firm productivity and the size of the market, as well as bilateral gravity-like variables, such as language differences between the exporting and importing countries. Following Feenstra and Romalis (2014), we estimate these parameters using a gravity-type equation implied by their model (see Appendix A.1 for details). We use bilateral trade data at the HS 6-digit level in 2019.

4.2 Results

We estimate the quality and quality-adjusted prices of Africa's imports of digital goods, using detailed data on international trade flows and tariffs, and applying the Feenstra and Romalis (2014) methodology outlined above. We find that African nations tend to import relatively low quality, low price digital goods, as would be expected given their relatively low income per capita. Once quality differences are accounted for, digital goods in AfCFTA are sourced at broadly similar prices relative to higher-income nations, but face relatively higher tariffs, especially in low-income countries.

Panel A in Figure 3 plots average "impure", or non-quality adjusted, unit values of imports of all countries (relative to the United States) and the corresponding income per capita. It reveals that these impure prices display a clear positive relationship with income per capita, and hence tend to be considerably lower in African nations than in richer countries from other continents. Panel B plots a similar graph relating the estimates for the average quality of digital goods with income per capita. We find again a clear and strong positive relationship between the quality of imported digital goods and income per capita, implying that African nations import relatively lower quality digital goods. In the context of the Feenstra and Romalis (2014) framework, this positive relationship between import quality and income per capita is explained by reduced preferences for quality in low-income countries (relative to higher income countries). This effect via consumer preferences clearly dominates a positive supply-side effect: low-income countries tend to import less, sourcing only from the most efficient firms, which tend to sell higher quality goods.

Figure 4 reports average quality-adjusted prices (relative to the United States) across countries with varying income levels. The evidence in this figure reveals that, once quality differences are accounted for, digital goods in Africa are sourced at relatively similar prices to that of higher-income countries. The figure shows only a weakly positive relationship between income per capita and quality adjusted prices, but this relationship is somewhat noisy for AFCFTA nations, with several countries buying at higher prices than richer countries in other continents.

5 The effects of AfCFTA on digital goods imports

In this section, we estimate the likely effects of AfCFTA on the imports of digital goods. AfCFTA is a groundbreaking trade agreement encompassing 54 African Union member states. It seeks to foster economic integration by progressively eliminating tariffs on 90 percent of traded goods, promoting trade in services, and implementing rules of origin to ensure preferential treatment of products. The agreement became operational on 7 July 2019 and officially started on 1 January 2021, with its permanent secretariat in Accra, Ghana. By 2030, the AfCFTA has the potential to create a single market of over 1.3 billion people with a combined GDP exceeding $3 trillion.

The agreement aims to eliminate tariffs on most goods and services, with varying timelines based on country development levels. The overarching goals of AfCFTA are to create a unified market, boost socioeconomic development, reduce poverty, and enhance Africa's global competitiveness. It covers trade in i) goods and services, ii) investment, iii) intellectual property rights, and iv) competition policy.

Our main goal in this section is to estimate the potential growth in digital goods imports towards 2030, when the AfCFTA will be fully implemented. To this end, we draw on the model proposed by Hoekman, Ng, and Olarreaga (2002). This is a partial equilibrium model of the total demand for imported goods and the supply of exported products broken down to the 6-digit level of the Harmonized System (HS). The model simulates a counterfactual trade flow resulting from tariff liberalization and compares it with the base year (in our application, the year 2019). Import demand elasticities, for digital goods, were taken from our previous econometric estimations. For all the other goods, we used GTAP elasticities. In this basic version, we are not considering trade deviation effects.[7]

Before turning to the results, it is important to emphasize that the partial equilibrium framework we adopt allows only for a comparative static comparison of the effects of a policy change when all other variables are held constant. Therefore, the dynamics associated with the change are not explicitly modeled. Since the framework we adopt focuses on the partial effects of a policy change, it does not capture important feedbacks between markets. For example, imports of digital inputs may have important spillovers to other markets, through their effects on firm performance or distribution networks. While dynamic linkages and market feedbacks could potentially be captured in CGE models, these models require more information than partial equilibrium models, e.g. up-to-date input-output tables, or social accounting matrices. They also provide more aggregate information than partial equilibrium models. Since we focus on a relatively small subset of imports (digital goods imports), for which we require disaggregated data by product and country, we rely only on estimates from a partial equilibrium model, leaving a more comprehensive examination of dynamics and general equilibrium effects for further research.

Figure 5 depicts the expected change in import-weighted tariffs on digital goods after the implementation of AfCFTA by 2030 (considering only trade between AfCFTA member countries). This figure reveals that trade in digital goods between AfCFTA countries will experience sizable reductions in import-weighted tariffs, declining from 4.88 percent in 2019 to 0.47 percent on average in 2030. The decline will be especially meaningful in countries that had relatively high tariffs to begin with. This includes several low-income countries such as the Central African Republic, the Republic of Congo, Niger and The Gambia.

However, despite the comprehensive liberalization expected from the AfCFTA, our analysis indicates that the agreement is unlikely to have a significant impact on reducing tariff protection on digital goods in Africa. Figure 6 reveals that the average import-weighted tariff on these products is expected to decrease by only 0.29 percentage points due to the agreement, from 6.26 percent to 5.97 percent. The figure further reveals that tariff reductions on digital goods imports are especially small in South Africa and Egypt, the countries in the region which accounted for a sizable share of digital goods imports from the region. The decline is significantly higher in other countries, including the Central African Republic, Ghana and Mali that had relatively higher tariffs to begin with and a relatively greater reliance on imports of digital goods from the

[7] Appendix A.2 provides more details on the key equations of the model. We also estimated an Armington model, which allows for trade deviation effects, and found very similar qualitative and quantitative results (available upon request).

region.

Figure 7 displays the simulated impacts of AfCFTA on digital goods imports by country member, and for the whole region. The simulation results reveal that imports of digital goods are expected to increase only by 0.3% for the whole region. The small effect of AfCFTA on total digital goods imports of member countries is partly due to the absence of tariff reductions on extra-zone imports of digital goods, which constitute most digital goods imports, and the limited intra-regional trade in these products. Nevertheless, the impacts are higher for some countries in the region, including Zimbabwe, Zambia and Mozambique, which had relatively high tariffs, low imports of digital goods to begin with, and a greater reliance on digital goods imports from the region. Figure 8 depicts the simulated change in the ratio of intraregional digital goods imports to total digital goods imports as a result of AfCFTA. While some low-income countries are expected to experience a noticeable increase in the share of intraregional imports of digital goods, the whole AfCFTA region is expected to observe a minor increase between the ex-ante and ex-post scenarios.

For comparison, in Figure A4 we report the simulated change in total imports due to AfCFTA, drawing once again on the framework of Hoekman, Ng, and Olarreaga (2002), but considering now tariff and trade data on all goods, not just digital goods. We find that AfCFTA is expected to have a larger effect on total goods imports (0.8 percent) than on digital goods imports (0.3 percent). The effects are once again significantly heterogeneous across countries, with Zimbawe, the Central African Republic, Zambia, the Republic of Congo and Mozambique displaying the largest increases.

Besides the quantity of imports, AfCFTA might also be expected to impact the quality of digital goods imports. Since higher income countries tend to export higher-quality products, the moderate increase in the share of digital goods imports sourced from relatively lower-income African countries would be expected to lead to a decrease in the quality of imports. We approximate these expected impacts by assuming that the quality of goods supplied from each country remains constant, but the share sourced from each country changes due to AfCFTA. We draw on the quality estimates by country from the previous section, and simulate the change in the shares using the simulations on the effects of AfFTA on digital goods imports presented above.

In Figure A5, we observe that the simulated change in average quality of digital goods imports is 0.4 percent, being higher in countries that observe a more significant increase in digital goods imports due to AfCFTA. It should be noted, however, that the quality of imported goods tends to be higher than that of goods produced domestically, and therefore the overall quality of digital inputs that is available to firms in the region need not fall.

Taken together, these findings suggest that the AfCFTA negotiations should consider including tariff concessions on digital goods imports from non-member countries, potentially lowering costs significantly, especially in the poorest countries with the highest tariffs on digital goods. We explore the consequences of this scenario in the next section of the paper.

6 The effects of a full unilateral trade liberalization on digital goods imports

In this section, we examine the effects of a full unilateral trade liberalization on the imports of digital goods. Once again, we draw on the partial equilibrium model of Hoekman, Ng, and Olarreaga (2002), but now consider a scenario in which all tariffs on digital goods are reduced to zero.

Figure 9 depicts the simulated impacts of AfCFTA on digital goods imports by country member, and for the whole region. The simulation results reveal that, in this scenario, imports of digital goods would be expected to increase by 8% for the whole region, which compares with the 0.3% in the AfCFTA scenario. The considerably larger effect of full liberalization on total digital goods imports of member countries is due to the presence of tariff reductions on extra-zone imports of digital goods, which constitute the majority of digital goods imports. The impacts would be even higher for some countries in the region, notably the Republic of Congo, the Comoros, Benin, Ghana, Senegal, Tunisia and Cote d'Ivoire, all with rises reaching around 20 percent or more. Figure 10 depicts the simulated change in the ratio of intraregional digital goods imports to total digital goods imports as a result of the full liberalization. It reveals only a relatively small change in this ratio for the whole AfCFTA region, although with considerable heterogeneity across countries.

As discussed above, in addition to the value and quantity of imports, AfCFTA might also be expected to impact the quality of digital goods imports. Since higher income countries tend to export higher-quality products, tariff reductions towards all countries would be expected to change the composition of source countries, as tariffs were higher initially in some countries. As before, we approximate these expected impacts by assuming that the quality of goods supplied from each country remains constant, but that the share sourced from each country changes due to the liberalization. Figure A6 indicates a decline in the average quality of digital goods imports of about 2 percent, reflecting a decline in average quality in most countries, and an increase in Nigeria, Mali, Cote d'Ivoire and Burkina Faso. The decline in average quality is due to the fact that tariffs on digital goods were initially higher relative to emerging countries, such as China, which tend to supply lower quality goods than the US and the EU. A full liberalization would lead to a shift in imports of digital goods towards China, and a reduction in the share of digital goods sourced from the EU, and therefore to reductions in the quality of imports, on average. Notice, however, that the decline in the quality of imports of digital goods is relatively small compared to the increase in its value. Since the quality of imported goods tends to be higher than that of goods produced domestically, the quality of digital inputs that is available to firms in the region would likely increase on average.

Taken together, these findings suggest that the AfCFTA countries should consider including tariff concessions on digital goods imports from non-members, potentially lowering costs significantly, and thus expanding access to imported digital goods, especially in the poorest countries with the highest tariffs on digital goods.

7 Conclusion

A growing body of evidence reveals that digital goods are critical for productivity growth in low-income countries. Since digital goods are mainly produced in advanced economies, the quality and prices at which firms and consumers in developing countries can acquire them in international markets are especially important. In this paper, we used detailed data on international trade flows and tariffs to study Africa's imports of digital goods. We first provided evidence on the relative quality and quality-adjusted prices of Africa's digital goods imports, as well as the current degree of tariff protection they face. We then estimated the likely impacts of AfCFTA on digital goods imports, which we compared with a scenario of full unilateral tariff liberalization towards all countries.

Despite this heavy reliance on imports, Africa imposes relatively high tariffs on digital goods globally, with an average import-weighted tariff of approximately 4 percent, compared to an average of 0.5 percent in other regions. These tariffs have remained relatively constant in Africa, in contrast to significant declines observed in non-African countries over the past decade. Moreover, the level of tariff protection on digital goods correlates negatively with income per capita across African countries.

Applying the methodology proposed by Feenstra and Romalis (2014), we estimate the quality and quality-adjusted prices of Africa's imports of digital goods, using detailed data on international trade flows and tariffs. We report evidence that African nations tend to import relatively low quality, low price digital goods, as would be expected given their relatively low income per capita. Once quality differences are accounted for, digital goods in Africa are sourced at relatively similar prices to that of higher-income countries. If tariffs are summed to these quality-adjusted import prices, along with other relevant factors needed to make these assets ready for use in production, we conclude that several African nations tend to face relatively high prices on digital goods, especially in low-income countries where the tariff burden tends to be higher.[8] These results are aligned with evidence from item-level price data from the World Bank's International Comparison Program on digital machinery, equipment, and software, suggesting that prices in Africa are higher than other parts of the world, when accounting for these other factors.

We then examined the likely effects of AfCFTA on digital goods imports. AfCFTA is a groundbreaking trade agreement encompassing 54 African Union member states. It seeks to foster economic integration by progressively eliminating tariffs on 90 percent of traded goods, promoting trade in services, and implementing rules of origin to ensure preferential treatment of products. By 2030, the AfCFTA has the potential to create a single market of over 1.3 billion people with a combined GDP exceeding $3 trillion.

To estimate the likely effects of AfCFTA on digital goods imports, we used the detailed tariff schedule of the agreement, and applied the model proposed by Hoekman, Ng, and Olarreaga (2002) for the total demand for imported goods broken down to the 6-digit level of the Harmonized System. The model simulates a "counterfactual" trade flow resulting from tariff liberalization and compares it with the base year. Despite the comprehensive liberalization expected from the AfCFTA, our analysis indicates that the agreement is unlikely to have a significant impact on reducing tariff protection on digital goods in Africa. The average import-weighted tariff on these products is expected to decrease by only 0.13 percentage points due to the agreement, from 3.89 percent to 3.76 percent. This result is partly due to the absence of tariff reductions on extra-zone imports of digital goods, which constitute the majority of digital goods imports, and the limited intra-regional trade in these products. As a result, imports of digital goods are expected to increase only by 0.3% for the whole region. These findings suggest that the AfCFTA negotiations should consider including tariff concessions on digital goods imports from non-member countries, potentially lowering costs significantly, especially in the poorest countries with the highest tariffs on digital goods. Indeed, we find that such a scenario would lead to an 8% increase in the imports of digital goods.

By way of conclusion, we would like to emphasize that the partial equilibrium approach we adopted in this paper is likely to provide a lower bound on the effects of tariff reductions on digital goods imports in Africa. Since we estimate the partial effects of a policy change,

[8]Other relevant factors that may contribute to higher prices of digital manufactured goods in these countries may include local taxes, transport cost, and installation costs.

we do not capture potentially important feedbacks between markets. For example, imports of digital inputs may have important spillovers to other markets, e.g. through their effects on firm performance or distribution networks, which can increase income and further increase digital goods imports. We also abstract from other indirect channels by which tariff reductions and other forms of economic integration may impact firm decisions to use imported inputs. In particular, enhanced market access within the AfCFTA region might facilitate firm growth through exports, and thereby make it more likely that firms find it profitable to pay the fixed costs associated with the adoption of digital technologies, in line with the findings of Bustos (2011). We leave for further research a precise quantification of these indirect effects in the African context.

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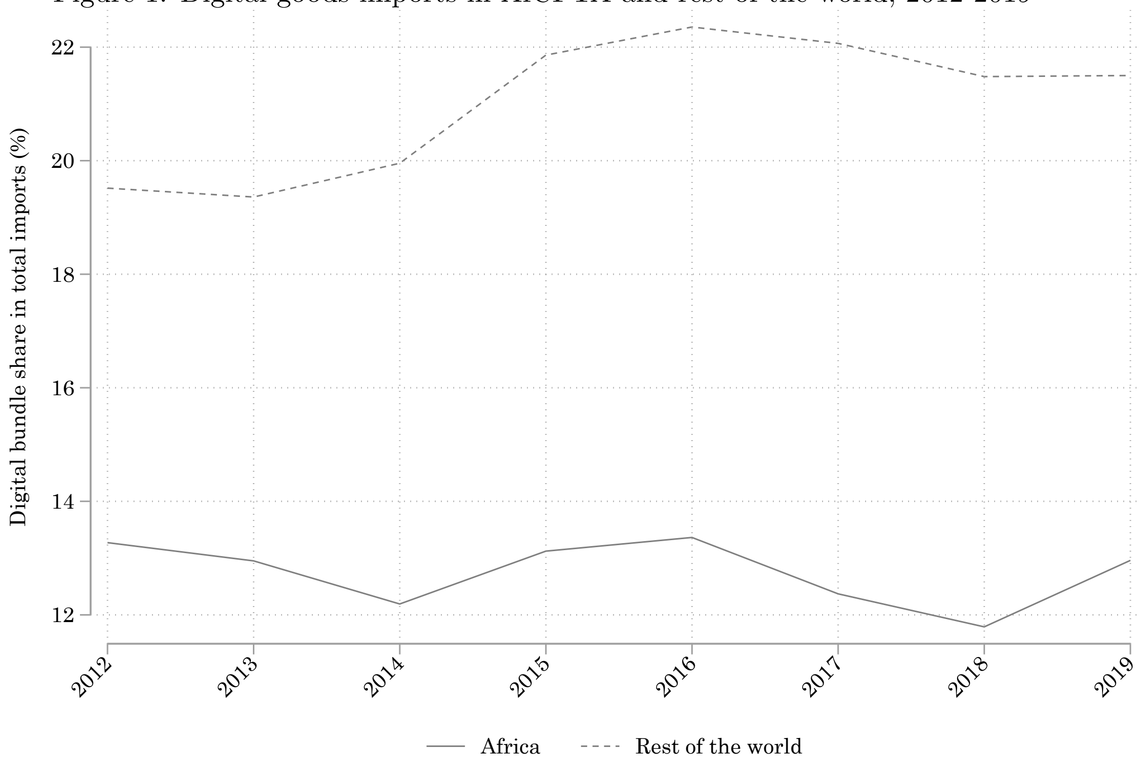
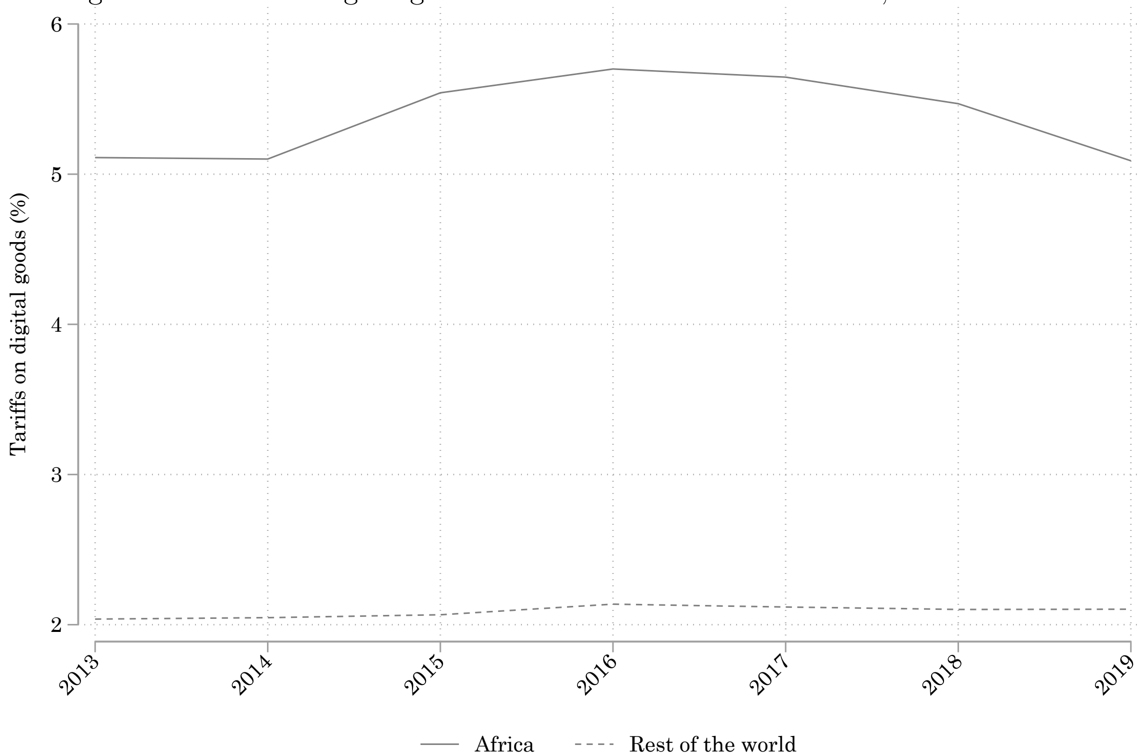
Figure 1: Digital goods imports in AfCFTA and rest of the world, 2012-2019



Notes: Figure depicts the share of the bundle of digital goods imports in total imports in AfCFTA and in the rest of the world over the period 2012-2019. Authors' calculations based on COMTRADE.

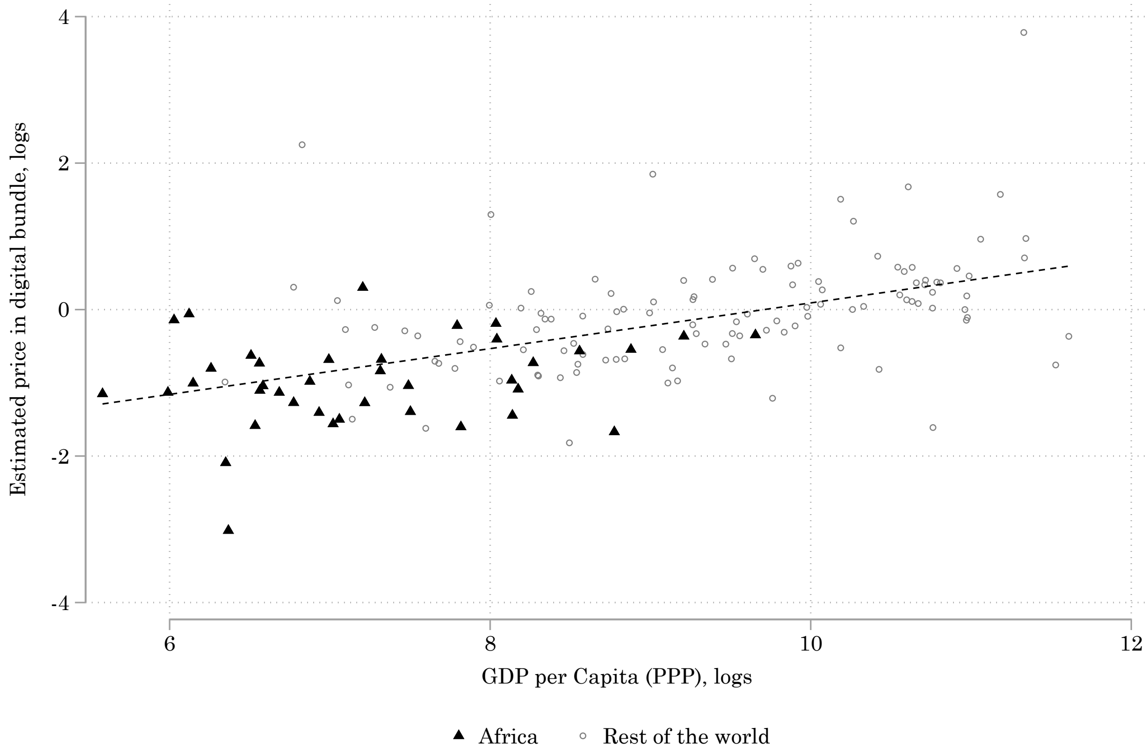
Figure 2: Tariffs on digital goods in Africa and rest of the world, 2012-2019



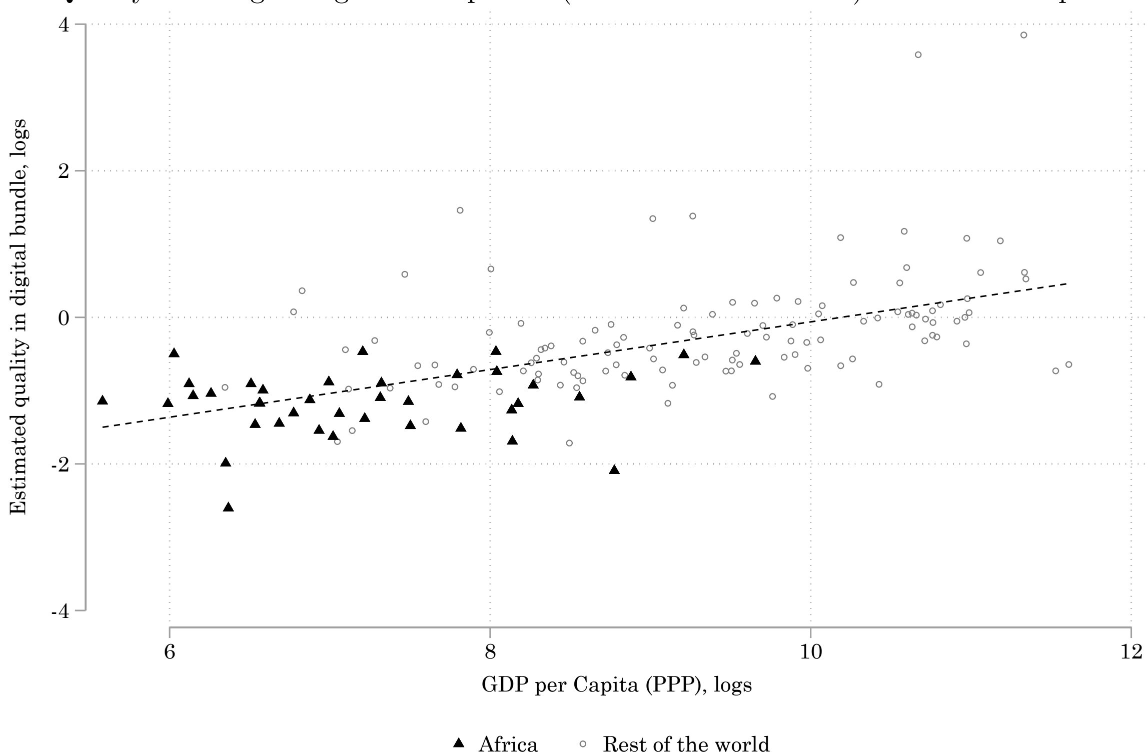
Notes: Tariff is a simple average by country and product. Authors' calculations based on TRAINS.

Figure 3: Average unit values and quality of digital goods imports vs. GDP per capita, 2018

A. Average unit values of digital goods imports (relative to the US) and GDP per capita

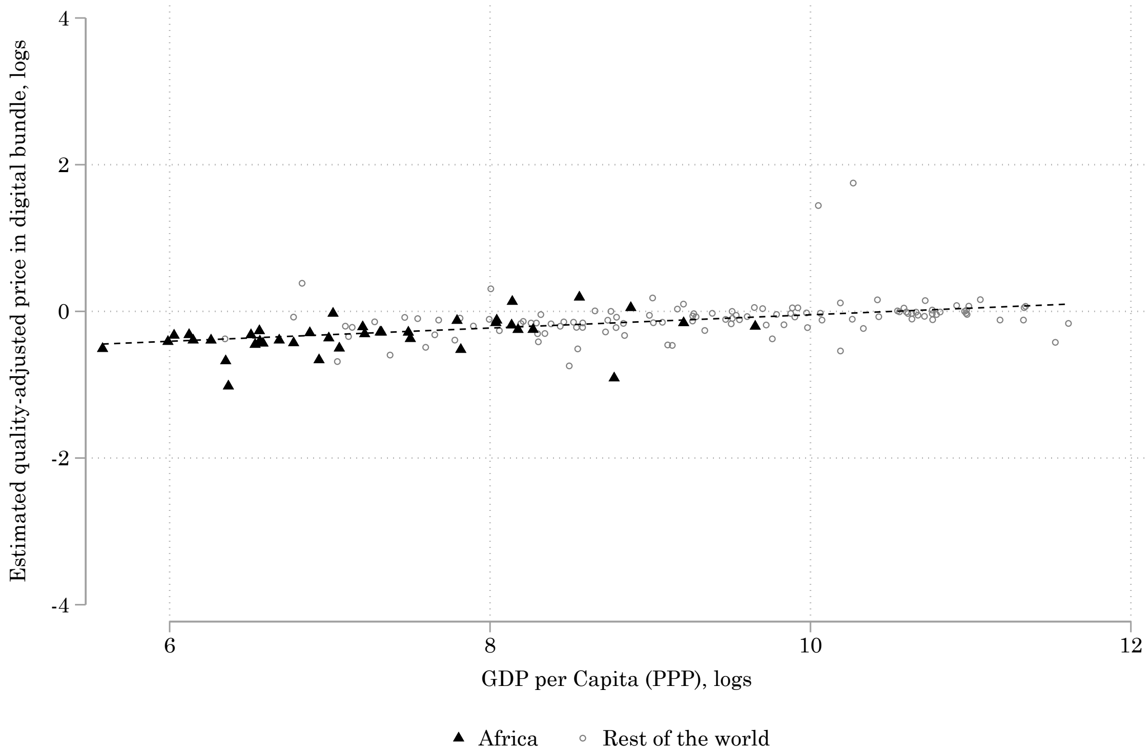


B. Quality of digital goods imports (relative to the US) and GDP per capita



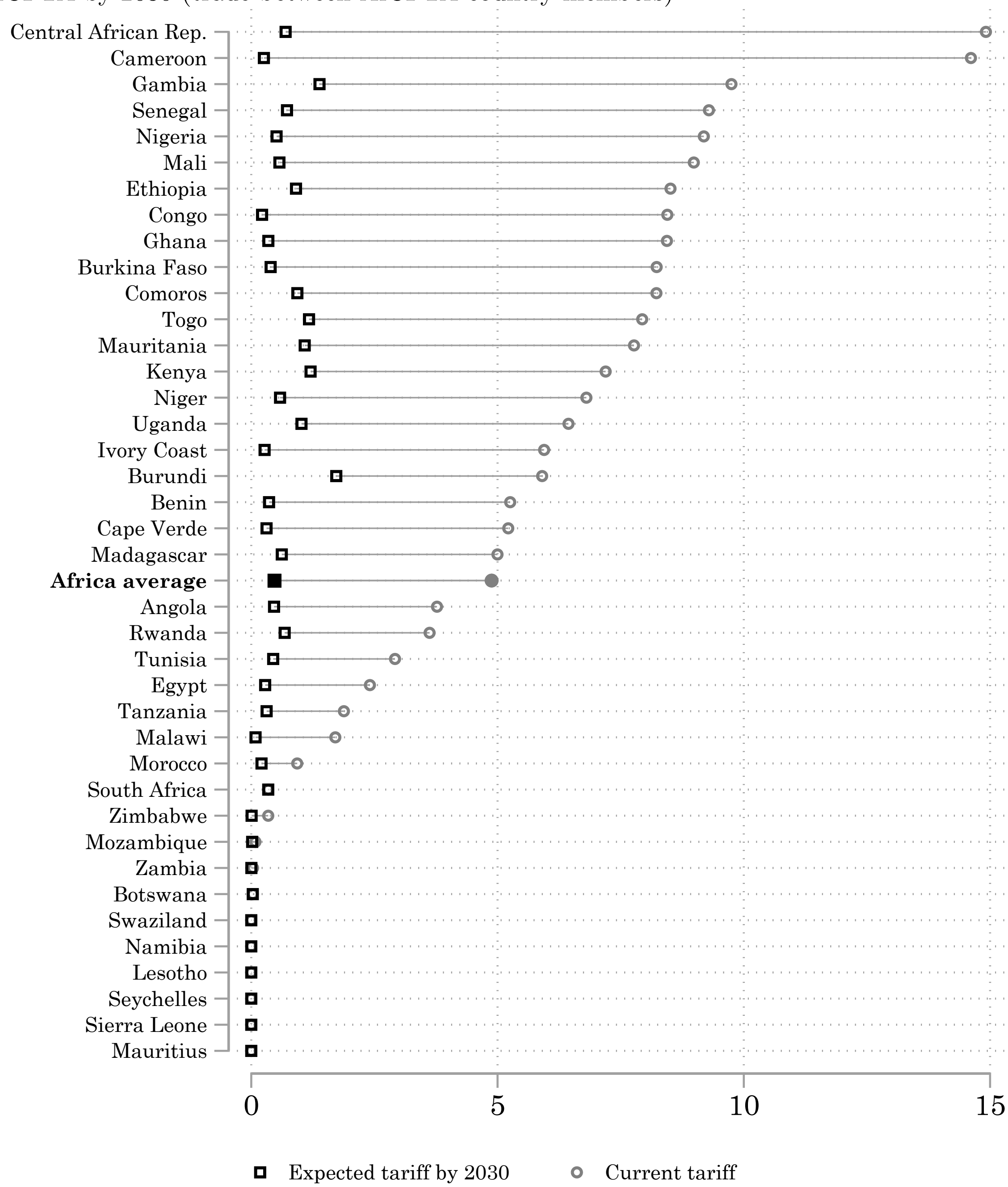
Notes: Authors' calculations based on Feenstra and Romalis (2014) methodology described in section 4.

Figure 4: Quality-adjusted prices of digital goods imports and GDP per capita, 2018



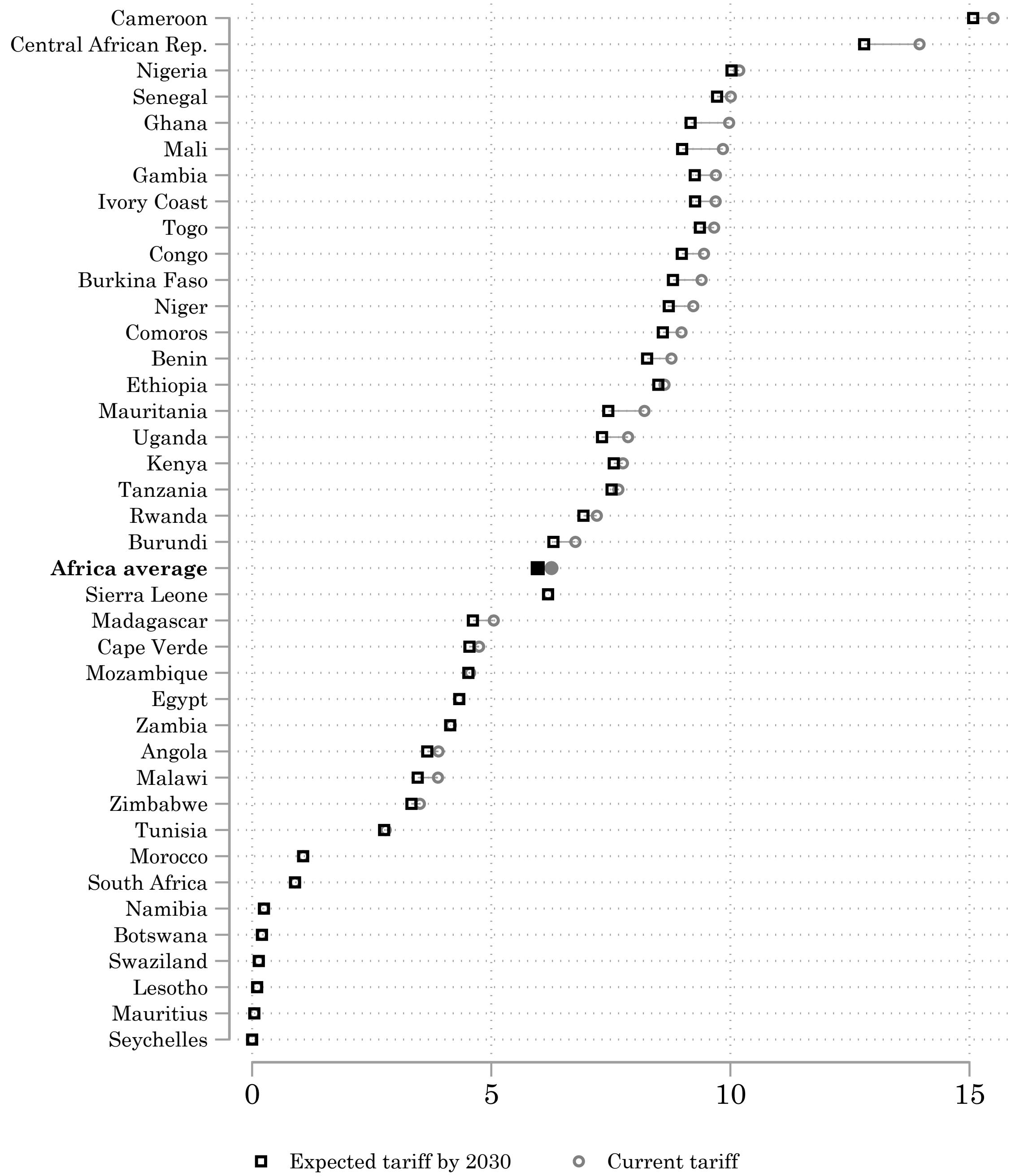
Notes: Figure depicts quality-adjusted prices of digital goods imports (relative to the US) and GDP per capita in 2018. Authors' calculations based on Feenstra and Romalis (2014) methodology described in Section 4.

Figure 5: Expected change in import-weighted tariffs on digital goods after implementation of the AfCFTA by 2030 (trade between AfCFTA country members)



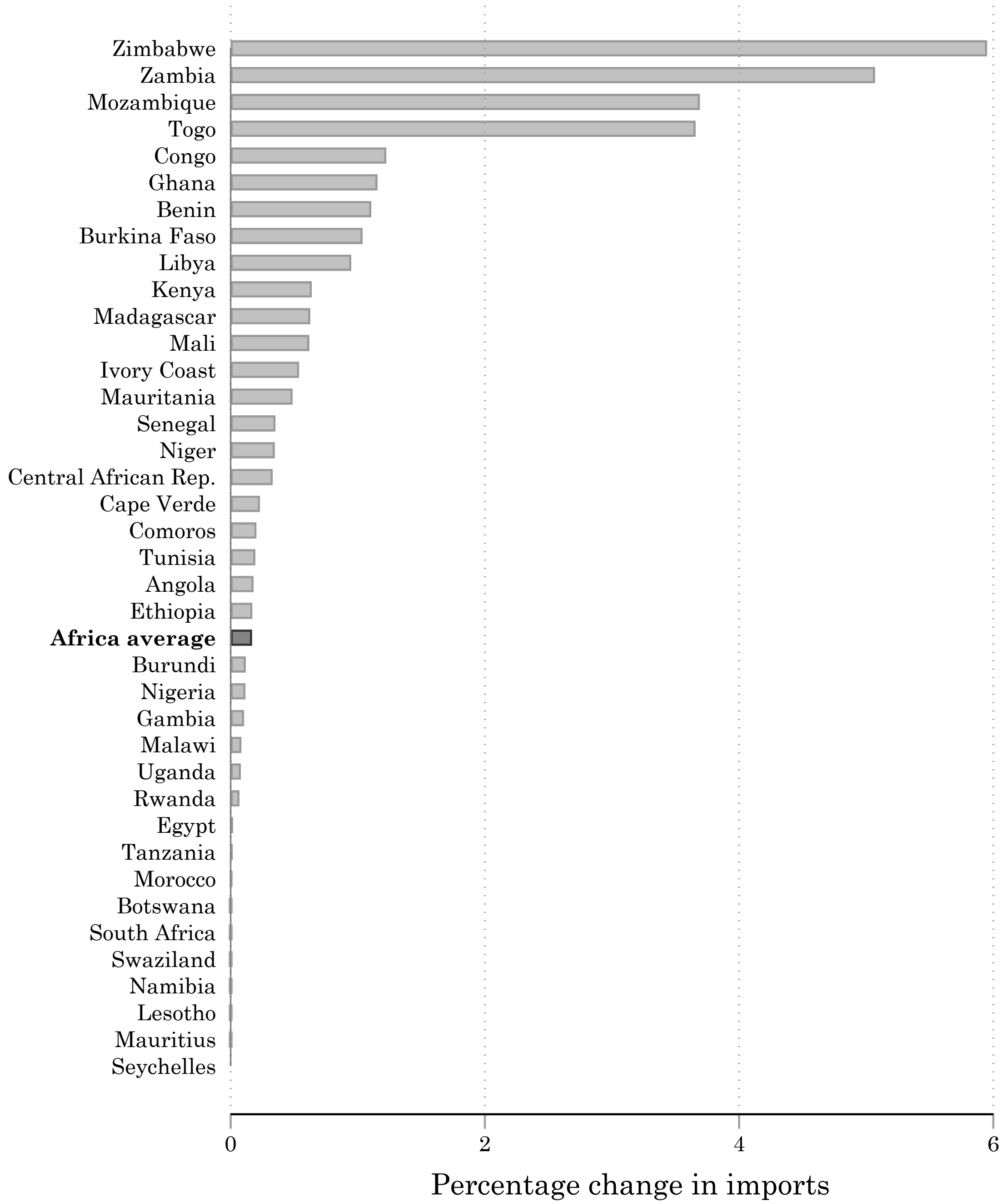
Notes: Tariffs by country are an import-weighted average by product. Considered exporting country members of the AfCFTA only. Africa average is a simple average of these country-level tariffs. Authors' calculations based on UNCTAD and COMTRADE.

Figure 6: Expected change in import-weighted tariffs on digital goods after implementation of the AfCFTA by 2030 (world trade)



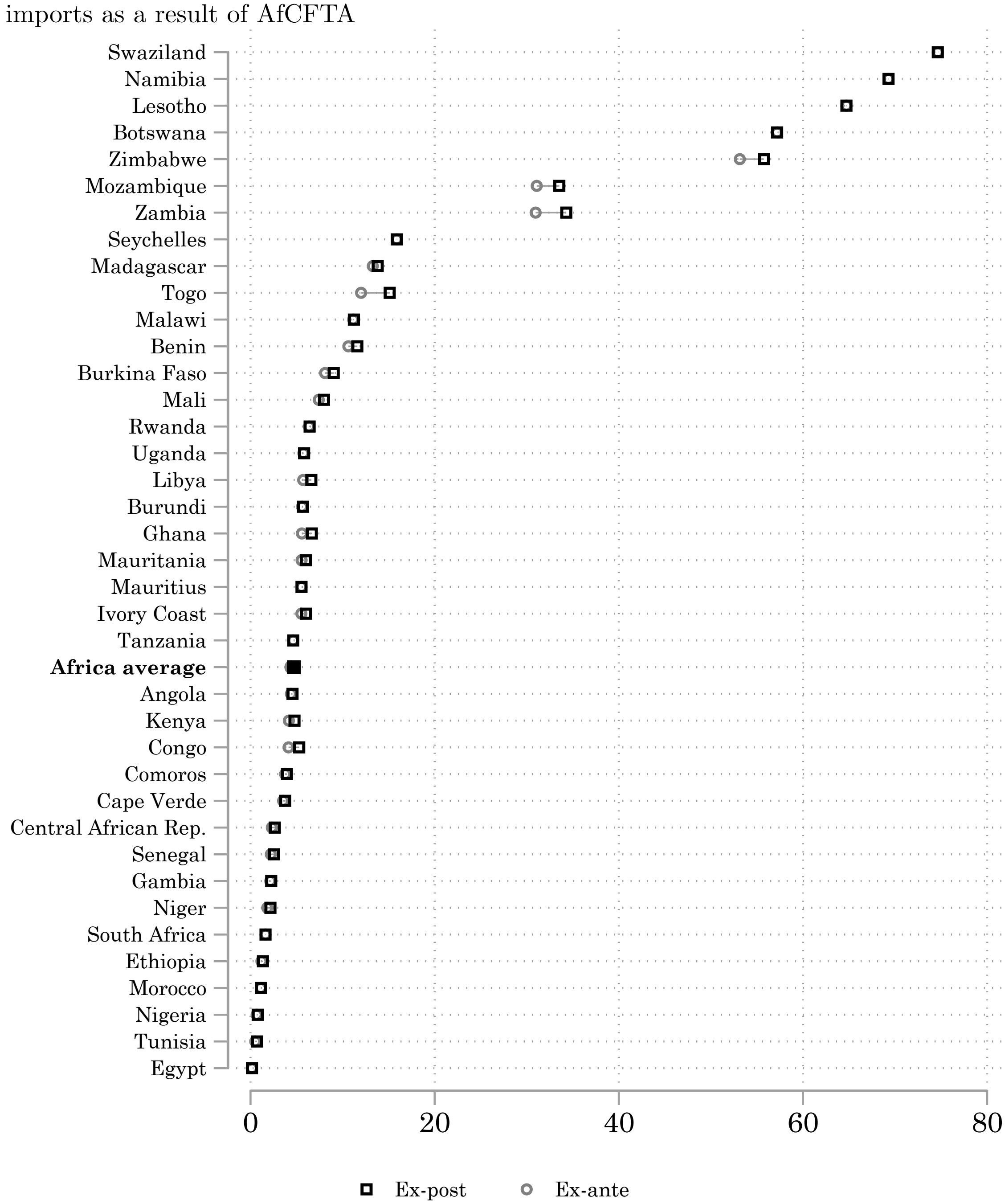
Notes: Tariffs by country are an import-weighted average by product. All exporting countries considered. Africa average is a simple average of these country-level tariffs. Authors' calculations based on UNCTAD, and COMTRADE.

Figure 7: Simulated change in digital goods imports due to AfCFTA



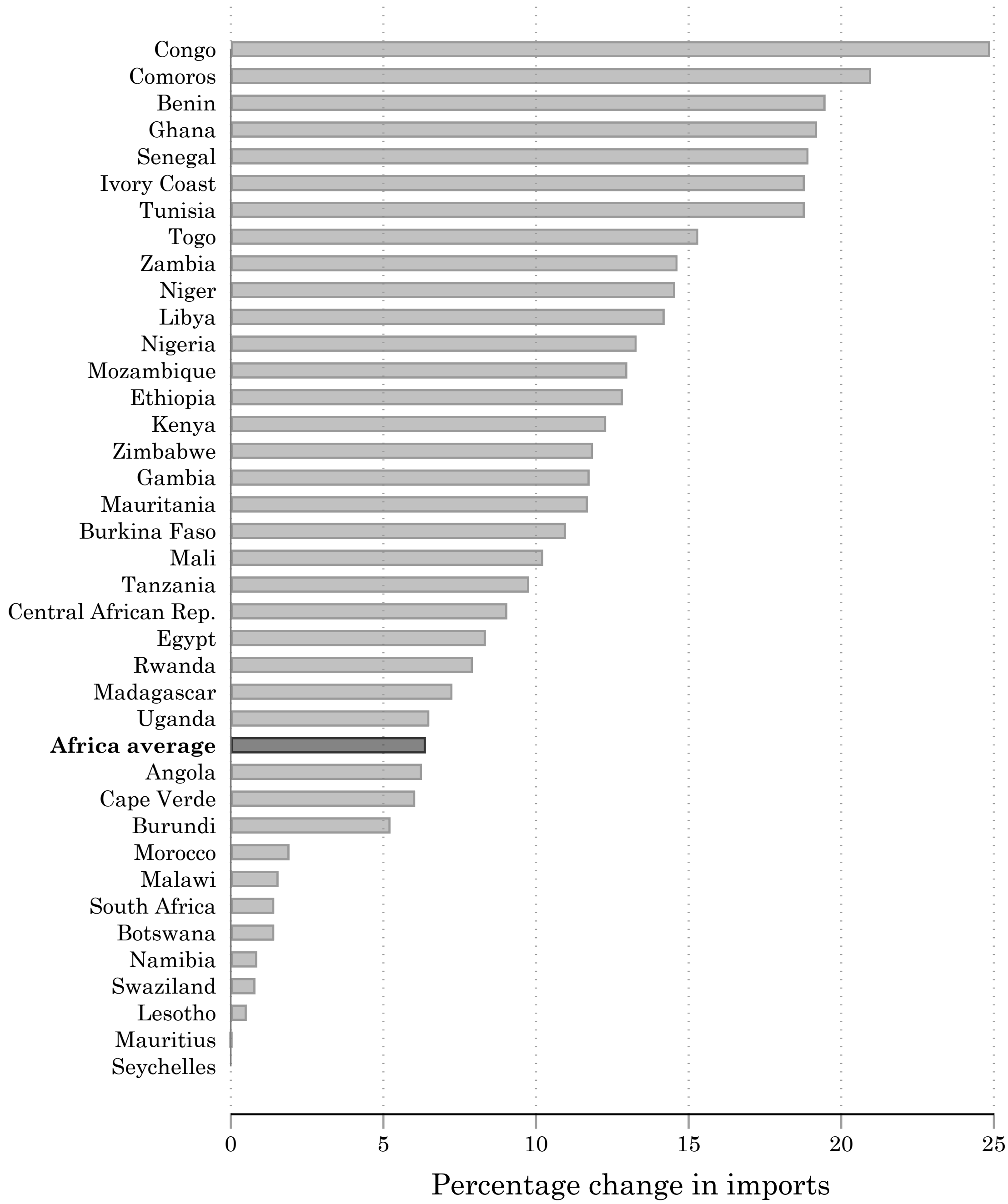
Notes: Figure displays the simulated change in digital goods imports by AfCFTA member (as well as for AfCFTA as a whole) due to the full implementation of AfCFTA.

Figure 8: Simulated change in the ratio of intraregional digital goods imports-to-total digital goods imports as a result of AfCFTA



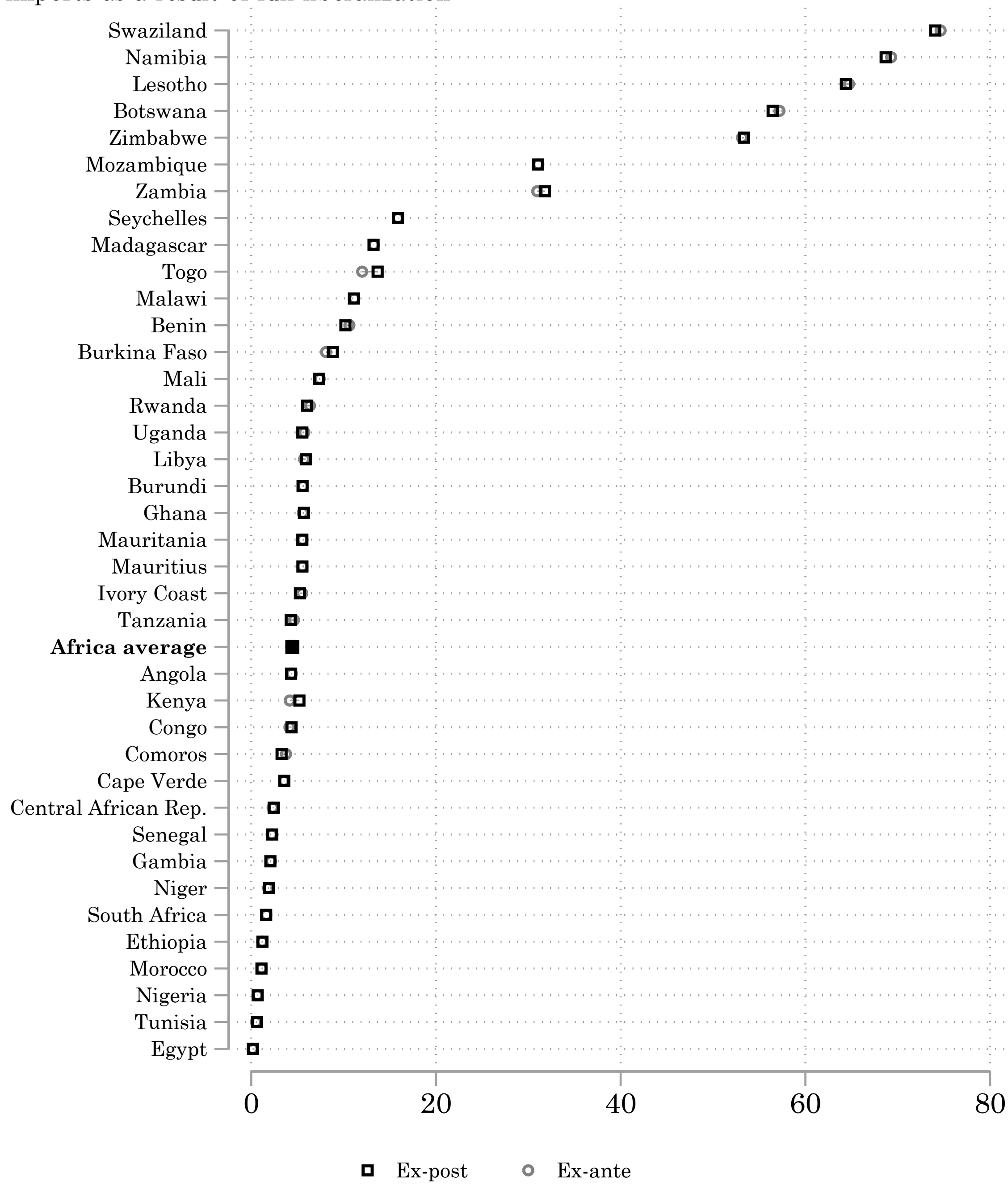
Notes: Figure displays the simulated change in the ratio of intraregional digital goods imports-to-total digital goods imports due to the full implementation of AfCFTA.

Figure 9: Simulated change in digital goods imports due to full tariff liberalization



Notes: Figure displays the simulated change in digital goods imports due to a full tariff liberalization towards all source countries.

Figure 10: Simulated change in the ratio of intraregional digital goods imports-to-total digital goods imports as a result of full liberalization



Notes: Figure displays the simulated change in the ratio of intraregional digital goods imports-to-total digital goods imports due to a full tariff liberalization towards all source countries.

A.1 Details on the methodology for estimating quality and quality-adjusted prices

In this appendix, we provide further details on the implementation of the Feenstra and Romalis (2014) methodology for estimating the quality and quality-adjusted prices of imports of digital goods in Africa. The quality index is estimated for each destination country k, product g from exporter i and year t using importer unit values (uv), exporter unit values (uv^*), import tariffs (tar) on g from i, a set of controls F (e.g. geographical distance, language and country fixed effects) and a set of parameters to be estimated:

$$Qual_{git}^{k} = \left(\left(tar_{ig}^{k} \right)^{\beta_{go}\sigma_g} \left(uv_{git}^{k} \right)^{(\sigma_g - 1)} uv^{*k}_{git} exp \left(\sum_{n} \beta_{gn} F_{ni}^{k} \right) \right)^{\frac{\bar{a}_g \theta_g}{\left(1+\bar{a}_g\theta_g\left(\sigma_{g-1}\right)\right)}} \tag{A1}$$

The quality adjusted unit values UV are estimated simply by dividing the original unit values by the quality indexes $Qual$ for each product g, country i, and year t:

$$UV_{git}^{k} = \frac{uv_{git}^{k}}{Qual_{git}^{k}} \tag{A2}$$

The main parameters in equation (A.1) are estimated for each product g at HS 6 digits and importer k and year t. First, we estimate a general methods of moments (GMM) model using Non-Linear Squares (NLS) due the non-linear nature of equation (A.1). The main parameters are θ (decreasing returns on quality), σ (elasticity of substitution by origin), α (preference for quality in the importer country), and Υ (pareto productivity parameter).

The starting point for estimating the parameters of equation (A.1) is the following gravity equation, where exports X are expressed as the difference between sales of countries i and j to destination k and L is population in i and j (a proxy for the mass of exporters) in each year t:

$$\begin{aligned} \ln X_{git}^{k} - \ln X_{gjt}^{k} = & -A_g^k \left[\left(\ln \bar{uv}_{git}^{k} - \ln \bar{uv}_{git}^{k} \right) - \alpha_g^k \theta_g \left(\ln \bar{uv}^{*k}_{git} - \ln \bar{uv}^{*k}_{git} \right) \right] + \delta_{g0} \left(\ln L_{git} - \ln L_{gjt} \right) \\ & + \delta_{gi} - \delta_{gj} - \sum_{n=1}^{N} B_g^k \beta_{gn} \left(F_{ni}^{k} - F_{nj}^{k} \right) - C_g^k \left(\ln tar_i^k - \ln tar_j^k \right) + \varepsilon_{git}^{k} - \varepsilon_{gjt}^{k} \end{aligned} \tag{A3}$$

where:

$$A_g^k = \frac{(\sigma_g - 1)\left(1 + \gamma_g^k\right)}{1 + \alpha_g^k \theta_g (\sigma_g - 1)},$$

$$B_g^k = \frac{\gamma_g^k - \alpha_g^k \theta_g (\sigma_g - 1)}{1 + \alpha_g^k \theta_g (\sigma_g - 1)},$$

$$C_g^k = \beta_{g0}\left[\frac{\sigma_g\left(1+\gamma_g^k\right)}{1+\alpha_g^k\theta_g\left(\sigma_g-1\right)}\right]-1$$

Notice that in the right-hand side of the equation the c.i.f. unit values uv appear with the negative coefficient $-A_g^k$ because it represents product quality and higher quality leads to greater demand. In contrast, the positive coefficient on the f.o.b. unit value uv^*, $A_g^k\alpha_g^k\theta_g$ is increasing on α_g^k because the impact of quality on demand is stronger in countries with greater preference for quality (higher income countries). Third, the ad valorem tariffs tar_i^k plays a pivotal role in the estimation. In theory, the term β_{g0} in C_g^k is unity because ad valorem tariffs have an impact on consumer prices and fixed costs. In the estimation, we allow for $\beta\neq 1$ because tariffs can have heterogeneous effects on exports.

There are two challenges for estimating the gravity equation (A.3). The first is that both c.i.f. and f.o.b. prices are subject to measurement error, and they are also potentially endogenous due to the simultaneous determination of supply and demand. To address this challenge, we extend the GMM estimation of equation (A.3) by employing a supply specification whereby the specific and iceberg costs depend on distance, ad valorem tariffs and traded quantities.

Feenstra (1994) assumes that supply and demand shocks are uncorrelated. That assumption seems unlikely to hold with unobserved quality in unit values, since a change in quality could shift both supply and demand. However, the demand and supply errors in equation (A.3) are residuals conditional on quality, and the assumption these shocks are orthogonal therefore seems more acceptable. This assumption is the basis of our GMM estimation.

The second challenge is that we are unable to solve for σ_g and γ_g^k because $B_g^k\beta_{gn}$ cannot be estimated separately. We address this challenge by averaging values over time and substituting them in equation (A.3) to obtain a non-linear estimation of the parameters σ, θ and γ. For convenience, we omit the product subscript g in what follows, though all parameters and equations differ by good.

$$\begin{aligned}\left(\ln uv_{it}^k-\ln uv_{jt}^k\right)^2 = &\left[\alpha^k\theta+\frac{\alpha^k\theta}{(1+\omega_2)}\right]\left(\ln uv_{it}^k-\ln uv_{jt}^k\right)\left(\ln uv_{it}^{*k}-\ln uv_{jt}^{*k}\right)\\ &-\frac{\alpha^k\theta^2}{(1+\omega_2)}\left(\ln uv_{it}^{*k}-\ln uv_{jt}^{*k}\right)^2+\frac{\omega_2}{A^k\left(1+\omega_2\right)}\left(\ln X_{it}^k-\ln X_{jt}^k\right)^2\\ &+\left(\frac{\omega_2}{(1+\omega_2)}-\frac{1}{A^k}\right)\left(\ln X_{it}^k-\ln X_{jt}^k\right)\left(\ln uv_{it}^{*k}-\ln uv_{jt}^{*k}\right)\\ &+\left(\frac{\theta}{A^k\left(1+\omega_{22}\right)}-\frac{\alpha^k\omega_2\theta}{(1+\omega_2)}\right)\left(\ln X_{it}^k-\ln X_{jt}^k\right)\left(\ln uv_{it}^{*k}-\ln uv_{jt}^{*k}\right)\\ &+Controls_{it}^k+\mu_{it}^k\end{aligned}\tag{A4}$$

where

$$Controls_{ij}^{k} = \frac{1}{A^{k}\left(1+\omega_{2}\right)}\left[\left(\eta_{0}-1\right)\left(\ln tar_{it}^{k}-\ln tar_{jt}^{k}\right)+\omega_{1}\left(\ln dist_{i}^{k}-\ln dist_{j}^{k}\right)\right]$$
$$\times\left[\delta_{0}\left(\ln L_{it}-\ln L_{jt}\right)+\delta_{i}-\delta_{j}-B^{k}\beta'\left(F_{it}^{k}-F_{jt}^{k}\right)-C^{k}\left(\ln tar_{it}^{k}-\ln tar_{jt}^{k}\right)\right]$$

and the error term:

$$\mu_{it}^{k} = \frac{\left(\varepsilon_{it}^{k}-\varepsilon_{jt}^{k}\right)}{A^{k}\left(1+\alpha_{2}\right)}\left[\delta_{i}-\delta_{j}+\delta_{0}\left(\ln L_{it}-\ln L_{jt}\right)-B^{k}\beta'\left(F_{i}^{k}-F_{j}^{k}\right)+\varepsilon_{it}^{k}-\varepsilon_{jt}^{k}\right]$$
$$+\frac{\left(\varepsilon_{it}^{k}-\varepsilon_{jt}^{k}\right)}{A^{k}\left(1+\omega_{2}\right)}\left[\left(\eta_{0}-1\right)\left(\ln tar_{it}^{k}-\ln tar_{jt}^{k}\right)+\omega_{1}\left(\ln dist_{i}^{k}-\ln dist_{j}^{k}\right)\right].$$

We treat the country fixed effects, sectoral labor force, distance, tariffs, and language for the fixed costs of exporting as exogenous, because they are uncorrelated with the demand and supply shocks. We further assume that the supply and gravity shocks are uncorrelated, so that $E\mu_{it}^{k} = 0$ for each source country i and destination k. Substituting these terms, we obtain an equation that is nonlinear in the parameters θ and σ. For the estimation, we average the variables in over time, which eliminates the time subscript and gives a cross-country regression that can be estimated with NLS.

Another challenge is to incorporate the exporter fixed effects interacted with distance and tariffs. The list of countries varies by product, so it is difficult to incorporate these interactions directly into the NLS estimation. Instead, we first regress the other variables on the source country fixed effects and their interaction terms, and then estimate the gravity equation using the residuals obtained from these preliminary regressions. The source country fixed effects are needed to control for the measurement errors in the c.i.f. and f.o.b. unit values, which we assume are independent of each other and of the export values. Then the variance of the measurement errors appears in the error term after averaging over time, and the source country fixed effects absorb these variances.

A final challenge is to estimate the destination country's preference for quality, α_{t}^{k}. Equation (A.5) provides us with a method to estimate these preferences using data on f.o.b. unit values, which we assumed to be linked to f.o.b. prices in $\ln uv_{it}^{*\,k} = \ln p_{it}^{*\,k} + u_{it}^{*\,k}$, with measurement error $u_{it}^{*\,k}$. We model α_{t}^{k} as depending on real GDP per capita ($RGDL$) of country k from the Penn World Table. Assuming specific transport costs depend on distance, we estimate:

$$\ln uv_{it}^{*\,k} = x_{it} + x_{1}dist_{i}^{k} + \ln\left[\left(\frac{1}{1-\alpha_{t}^{k}\theta}\right)\left(\frac{\sigma}{\sigma-1}\right)-1\right] + u_{it}^{*\,k} \tag{A5}$$

where

$$\alpha_t^k = 1 + \lambda \ln \left(\frac{RGDPL_t^k}{RGDPL_t^{US}} \right)$$

The estimation starts by assuming $\alpha = 1$. After the first iteration, a second regression is estimated to obtain values of α for each importer, based on the hypothesis that quality preference is positively related to income. These new values are used to determine θ and σ, to start the process again. This estimation is run iteratively until the change of α is not significant.

A.2 Details on the model for estimating the effects of tariff liberalization

In this appendix, we offer details on the implementation of the framework proposed by Hoekman, Ng and Olarreaga (2002), which we employ for simulating the effects of AfCFTA and a full tariff liberalization towards all countries in the imports of digital goods.

A.2.1 The model

The import demand for each HS product at the 6-digit level of country i is given by:

$$M_i = \frac{A_i}{\left[P_w \left(1 + T_i\right)\right]^E} \tag{A6}$$

where T_i is the MFN (Most Favored Nation) tariff in country i; A_i is a demand parameter in country i; and E is the import demand elasticity. Import demand elasticities are specific at the product and country level, and at the 6-digit HS classification level. These elasticities were obtained from the Feenstra and Romalis (2014) methodology for digital goods, and from GTAP for the remainder goods.

The export supply from country j to country i for each year n is given by:

$$X_{j \to i} = B_j [P_w \left(1 + T_i \Pi_{i \to j}\right)]^{\Theta} \tag{A7}$$

where Θ is the elasticity of export supply, which is calibrated equal to 1.5, in line with the standard values used by Francois and Hall (2006). $\Pi_{i \to j}$ is the level of tariff preferences granted by country i to the exports of j in year n. Thus, $\Pi_{i \to j}$ if i's imports from j must pay the MFN tariff. Conversely, if $\Pi_{i \to j} = 1$, then j's exports enter duty-free in i. On the other hand, B_j it is a supply scale parameter.

The international equilibrium price, free of taxes and tariffs, is obtained by solving the market equilibrium conditions for each product:

$$p_w = \underset{\text{Pw}}{\text{argsol}} \left[M_i - X_j = 0 \right] = \left[\frac{A_i}{B_j \left(1 + T_i \Pi_{i \to j}\right)^{\Theta} \left(1 + T_i\right)^{E}} \right]^{\frac{1}{(E+\Theta)}} \tag{A8}$$

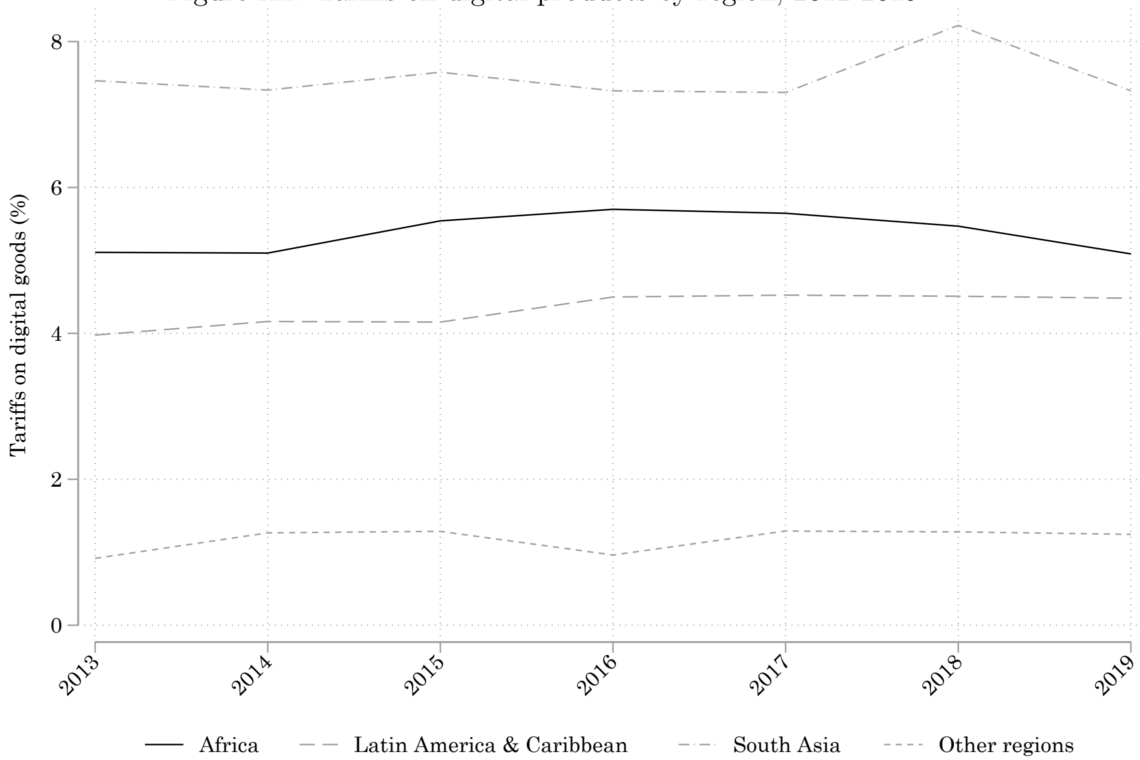
The supply and demand parameters are calibrated as follows:

$$B_j = \frac{X_{j \to i}}{\left[P_w \left(1 + T_i \Pi_{i \to j}\right)\right]^{\Theta}}; A_i = M_i \left[P_w \left(1 + T_i\right)\right]^{E} \tag{A9}$$

All supply and demand parameters are calibrated at the 6-digit level of the harmonized system using data provided by TRAINS (2010). With the estimates of A_i and B_j as supply and demand parameters, the model estimates the levels of imports and exports that arise because of the preferences contemplated in the offers originally submitted by AfCFTA countries.

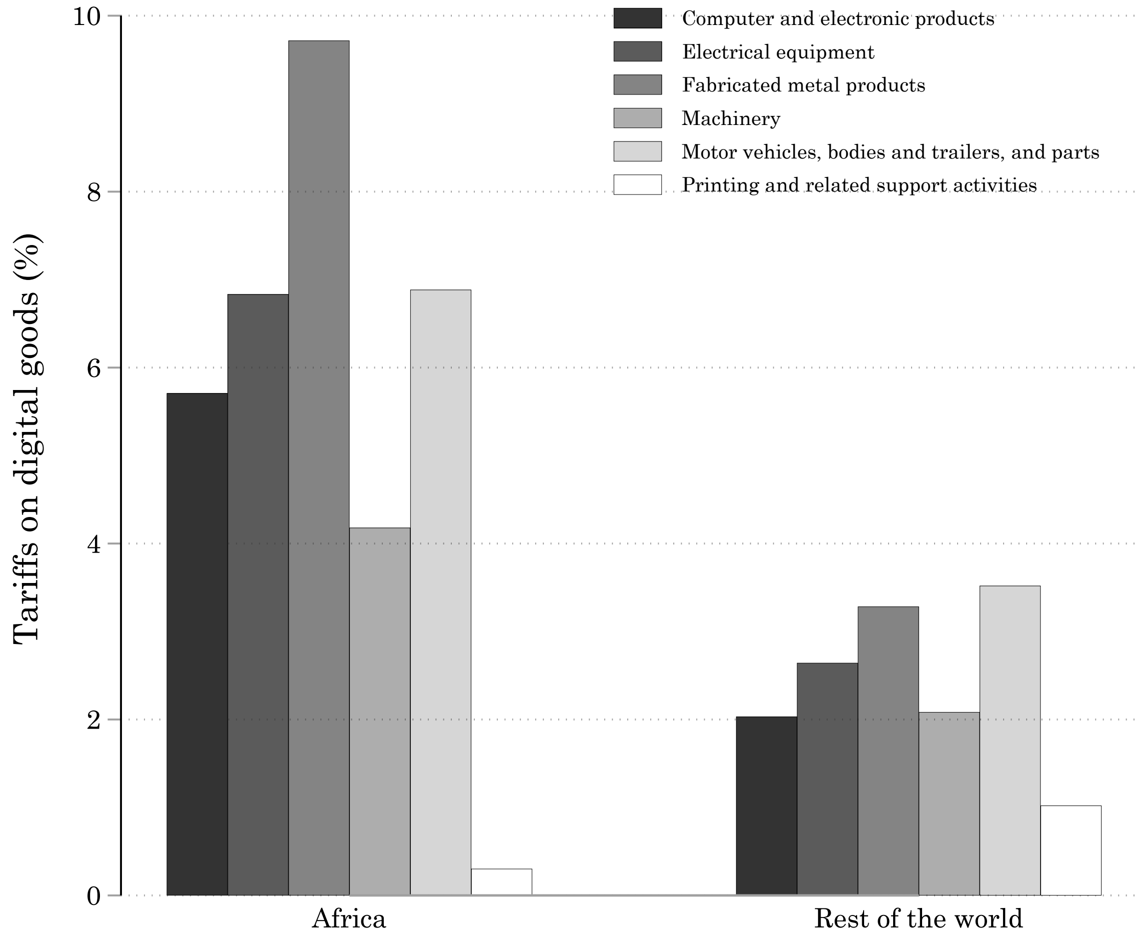
A.3 Appendix Figures and Tables

Figure A1: Tariffs on digital products by region, 2012-2019



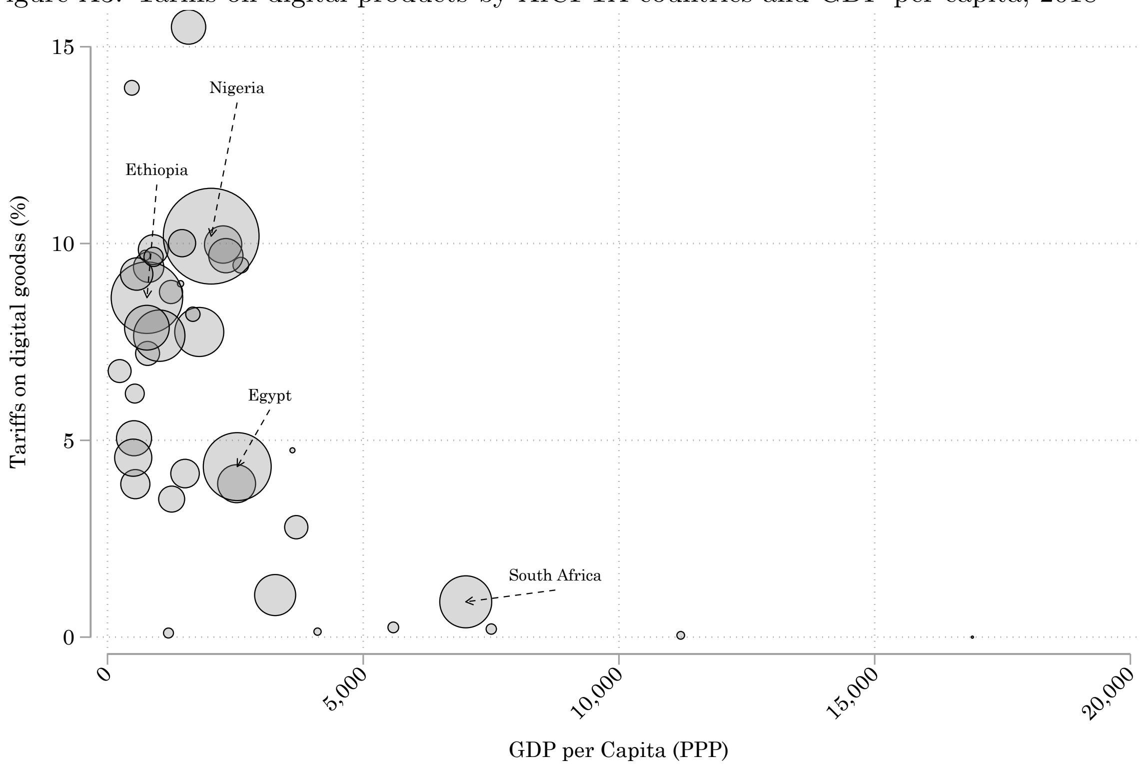
Notes: Tariff is a simple average by country and product. Authors' calculations based on TRAINS.

Figure A2: Tariffs on digital products in Africa and rest of the world, by type of good, 2018



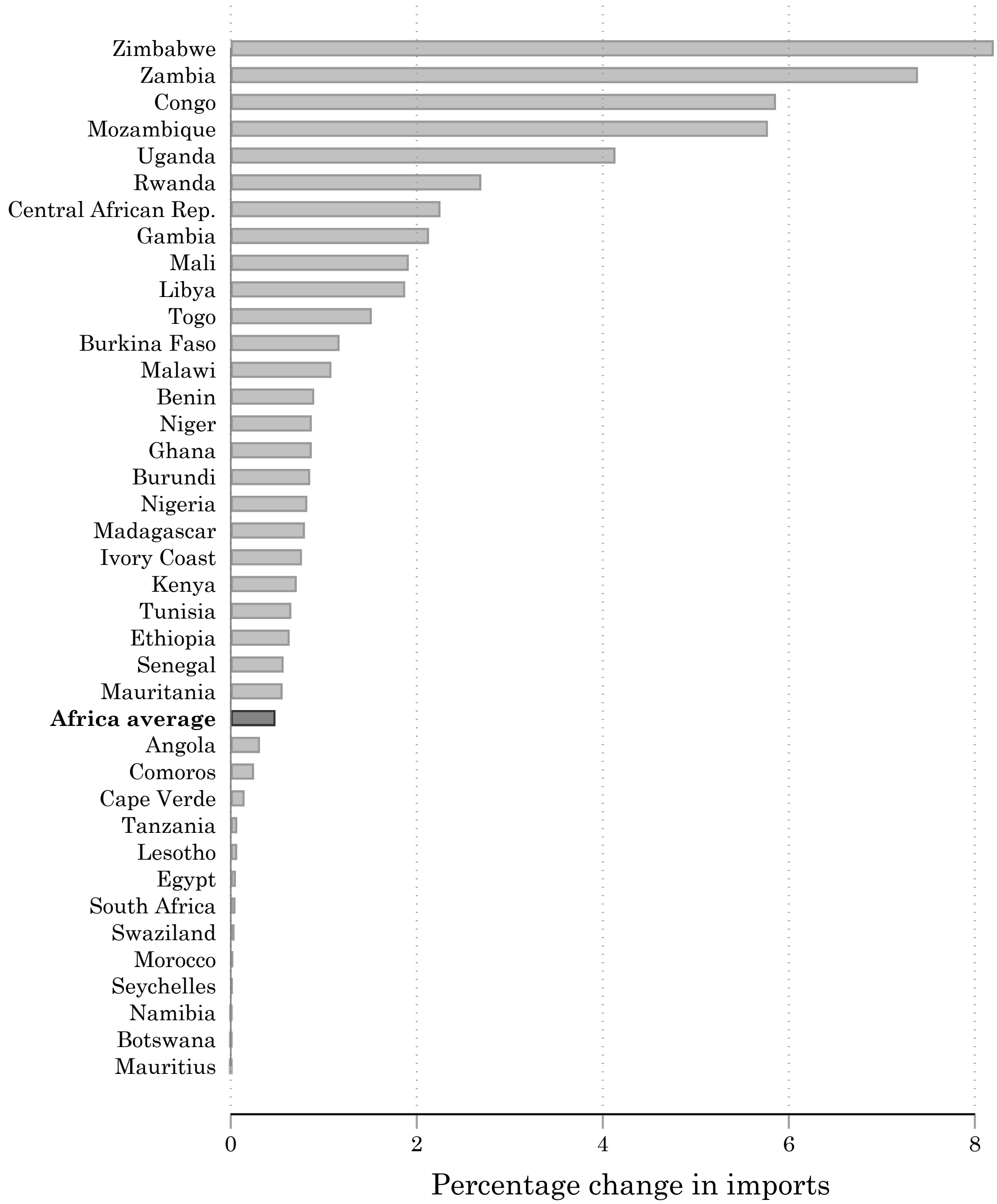
Notes: Tariff is a simple average by country and product. Authors' calculations based on TRAINS.

Figure A3: Tariffs on digital products by AfCFTA countries and GDP per capita, 2018



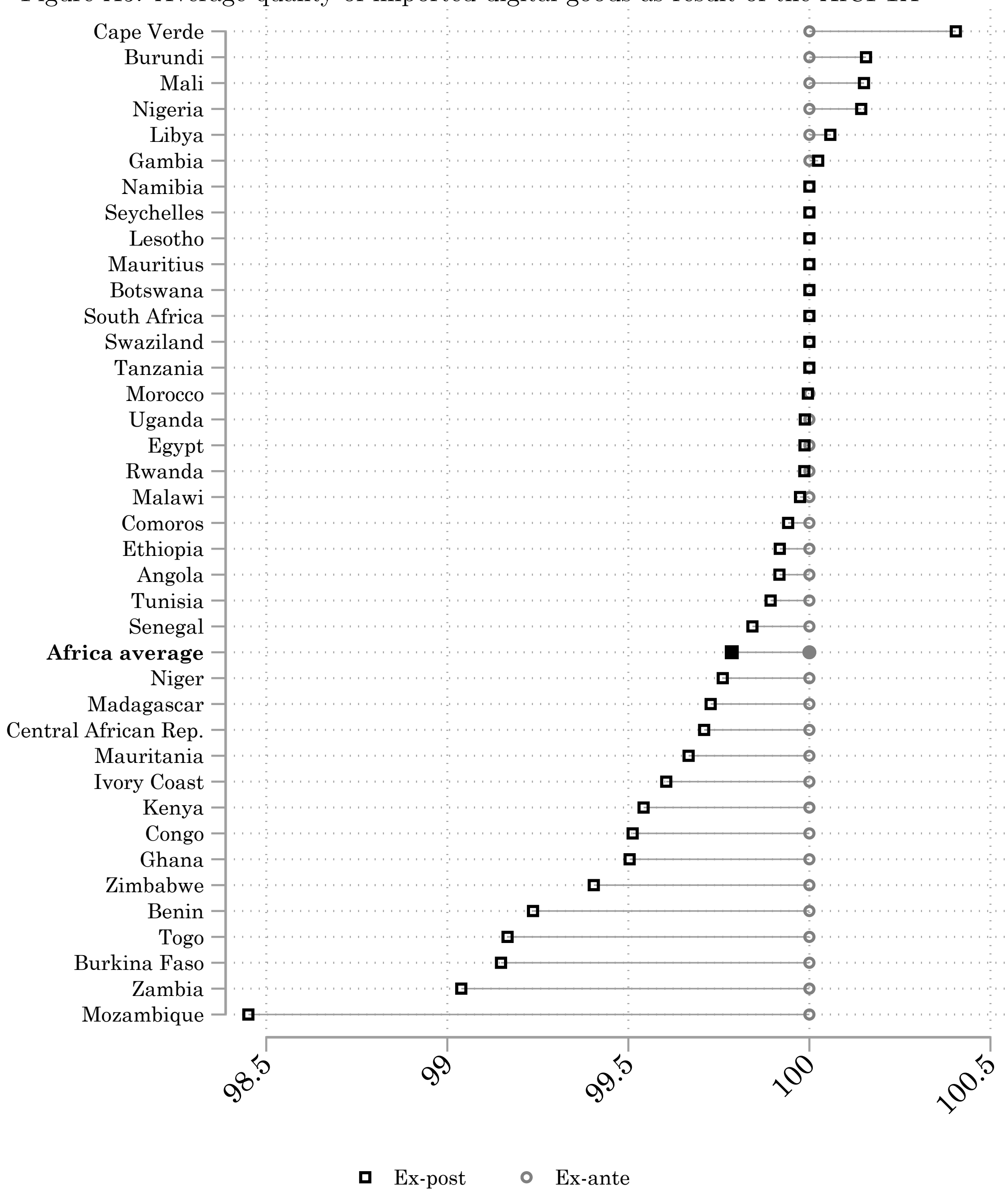
Notes: Tariff is an imported-weighted average by country and product. The circles are proportional to the population of each country. Authors' calculations based on TRAINS.

Figure A4: Simulated change in total imports due to AfCFTA



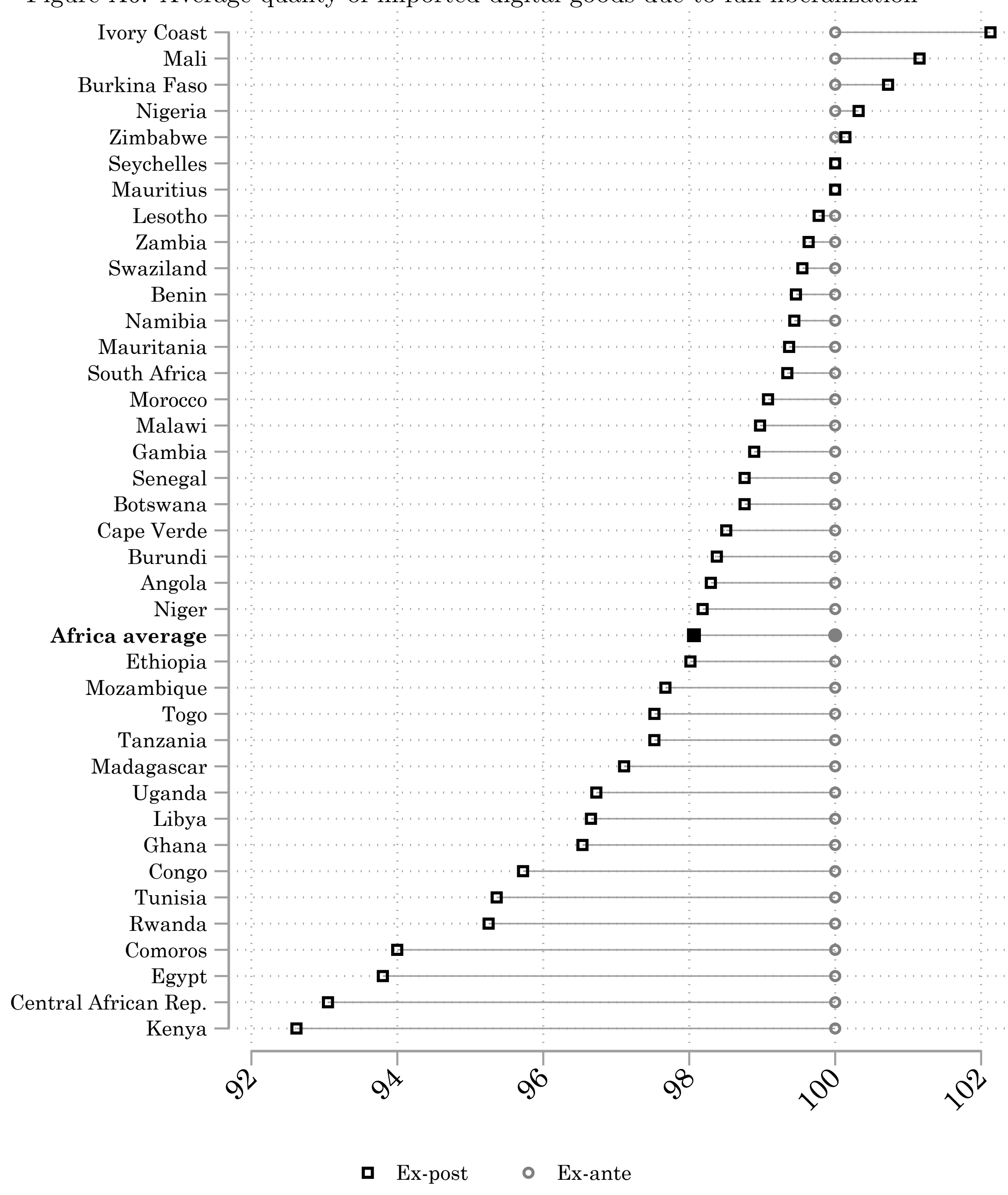
Notes: Figure displays the simulated change in total imports by AfCFTA member (as well as for AfCFTA as a whole) due to the full implementation of AfCFTA.

Figure A5: Average quality of imported digital goods as result of the AfCFTA



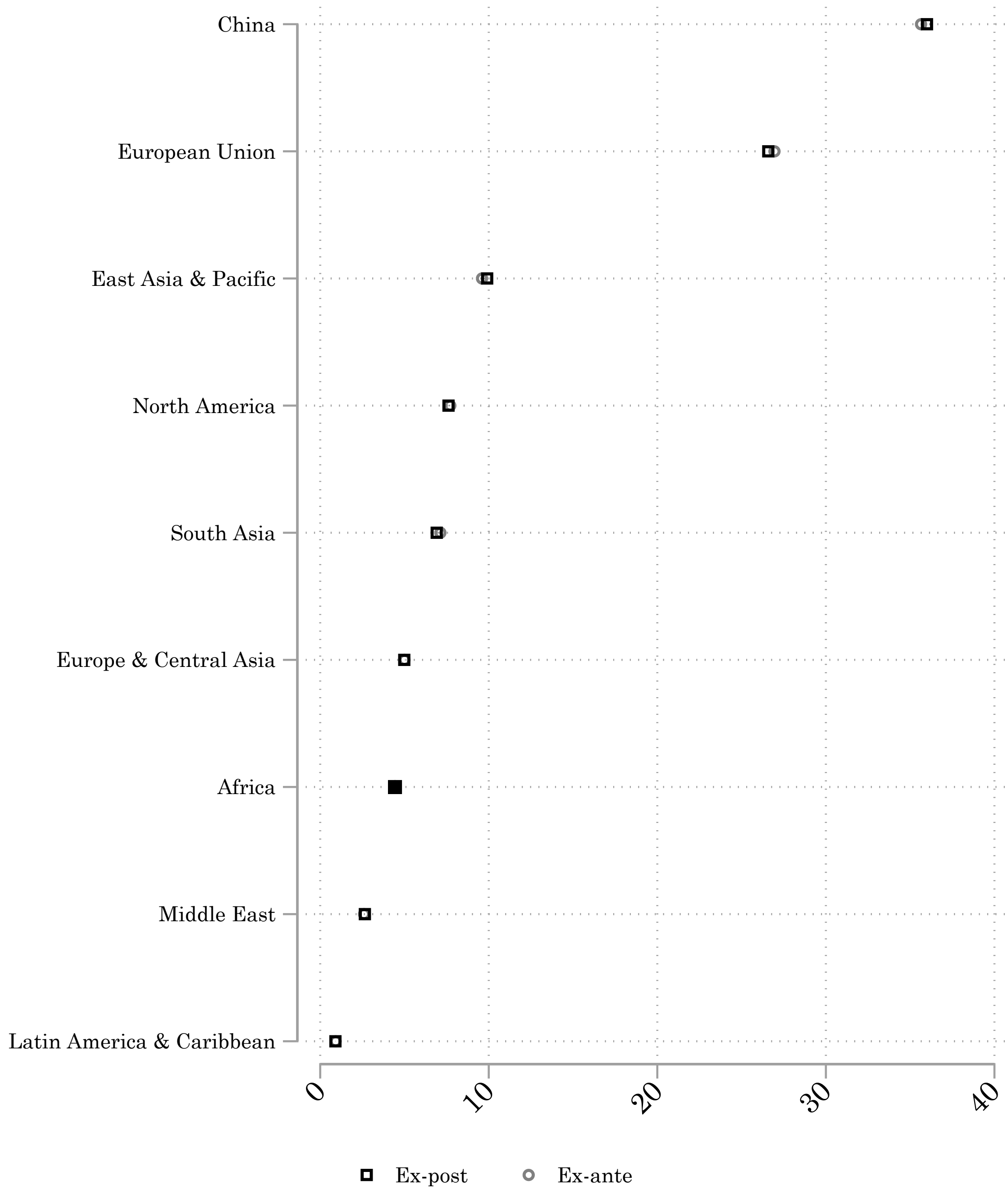
Notes: Figure depicts expected change in the quality of digital goods due to the implementation of AfCFTA. Product quality by source country is estimated using the Feenstra and Romalis (2014) methodology, drawing on data for 2019 and is assumed to be constant. Estimated product quality changes are driven by changes in the shares of digital goods imports from each source country due to the implementation of AfCFTA.

Figure A6: Average quality of imported digital goods due to full liberalization



Notes: Figure depicts expected change in the quality of digital goods due to the implementation of a full tariff liberalization towards all countries. Product quality by source country is estimated using the Feenstra and Romalis (2014) methodology, drawing on data for 2019 and is assumed to be constant. Estimated product quality changes are driven by changes in the shares of digital goods imports from each source country due to the implementation of the full tariff liberalization.

Figure A7: Change in AfCFTA sources of digital goods due to full liberalization



Notes: Figure depicts expected change in the share of each source in AfCFTA's imports of digital goods due to the full liberalization.

Table A1: Digital products, list of NAICS

NAICS6	NAICS6 Description
334413	Semiconductor and Related Device Manufacturing
323120	Support Activities for Printing
334419	Other Electronic Component Manufacturing
334519	Other Measuring and Controlling Device Manufacturing
334417	Electronic Connector Manufacturing
332913	Plumbing Fixture Fitting and Trim Manufacturing
335999	All Other Miscellaneous Electrical Equipment and Component Manufacturing
333992	Welding and Soldering Equipment Manufacturing
333999	All Other Miscellaneous General Purpose Machinery Manufacturing
336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing
333318	Other Commercial and Service Industry Machinery Manufacturing
333997	Scale and Balance Manufacturing
334118	Computer Terminal and Other Computer Peripheral Equipment Manufacturing
334210	Telephone Apparatus Manufacturing
334111	Electronic Computer Manufacturing
334112	Computer Storage Device Manufacturing
334418	Printed Circuit Assembly (Electronic Assembly) Manufacturing
333242	Semiconductor Machinery Manufacturing
335311	Power, Distribution, and Specialty Transformer Manufacturing
334416	Capacitor, Resistor, Coil, Transformer, and Other Inductor Manufacturing
334510	Electromedical and Electrotherapeutic Apparatus Manufacturing
334290	Other Communications Equipment Manufacturing
334220	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing
334310	Audio and Video Equipment Manufacturing
334614	Software and Other Prerecorded Compact Disc, Tape, and Record Reproducing
334613	Blank Magnetic and Optical Recording Media Manufacturing
334511	Search, Detection, Navigation, Guidance, Aeronautical, Nautical, Instrument Manufacturing
334513	Instruments Manuf. for Measuring, Displaying, and Controlling Industrial Process Variables
334412	Bare Printed Circuit Board Manufacturing
334515	Instrument Manufacturing for Measuring and Testing Electricity and Electrical Signals
335929	Other Communication and Energy Wire Manufacturing
335921	Fiber Optic Cable Manufacturing
336411	Aircraft Manufacturing
333316	Photographic and Photocopying Equipment Manufacturing
333314	Optical Instrument and Lens Manufacturing
334516	Analytical Laboratory Instrument Manufacturing
334517	Irradiation Apparatus Manufacturing
334514	Totalizing Fluid Meter and Counting Device Manufacturing
334512	Automatic Environmental Control Manuf. for Residential, Commercial, and Appliance Use
336414	Guided Missile and Space Vehicle Manufacturing

Table A2: Digital goods imports of AfCFTA by source, 2019

Source country	% of total
China	35.35
European Union	26.83
United States	7.42
India	7.04
South Africa	3.06
Viet Nam	2.59
United Kingdom	2.21
United Arab Emirates	2.18
Japan	1.68
Korea, Rep.	1.62
Türkiye	1.30
Hong Kong SAR, China	1.14
Switzerland	0.84
Malaysia	0.76
Singapore	0.63
Mexico	0.61
Thailand	0.53
Canada	0.52
Australia	0.34
Egypt, Arab Rep.	0.30
Brazil	0.27
Norway	0.26
Russian Federation	0.26
Israel	0.24
Philippines	0.23
Morocco	0.23
Botswana	0.22
Indonesia	0.19
Mauritius	0.18
Tunisia	0.13

Notes: Table reports the share of each source country in total imports of digital goods by AfCFTA members in 2019.

Table A3: Digital goods imports of AfCFTA by member country, 2019

AfCFTA member	% of total
South Africa	22.71
Egypt, Arab Rep.	15.38
Nigeria	13.94
Morocco	12.67
Tunisia	5.61
Kenya	2.88
Ethiopia	2.86
Libya	2.79
Angola	2.54
Ghana	1.58
Côte d'Ivoire	1.55
Tanzania	1.38
Senegal	1.33
Mozambique	1.26
Zambia	1.15
Mauritius	1.01
Botswana	0.96
Uganda	0.94
Namibia	0.91
Mali	0.73
Burkina Faso	0.70
Rwanda	0.65
Zimbabwe	0.59
Niger	0.54
Malawi	0.54
Madagascar	0.45
Congo, Rep.	0.41
Mauritania	0.39
Central African Republic	0.26
Lesotho	0.25
Togo	0.23
Eswatini	0.22
Benin	0.19
Seychelles	0.17
Cabo Verde	0.11
Burundi	0.10
Gambia	0.05
Comoros	0.01

Notes: Table reports the share of each AfCFTA member in total imports of digital goods by AfCFTA in 2019.

Table A4: Digital goods imports of AfCFTA by type of good, 2019

ISIC3 Code	ISIC3 Description	% of total
300	Office and computing machinery	16.05
331	Medical appliances and instruments	14.45
291	General purpose machinery	12.14
322	Television and radio transmitters	9.77
292	Special purpose machinery	8.88
323	Television and radio receivers	6.13
313	Insulated wire and cable	4.88
321	Electronic valves and tubes	4.47
319	Other electrical equipment	4.26
311	Electric motors and generators	4.25
312	Electricity distribution and apparatus	4.06
353	Aircraft and spacecraft	4.02
289	Other fabricated metal products	3.33
221	Publishing	1.35
332	Optical and photographic equipment	0.45
333	Watches and clocks	0.43
242	Other chemical products	0.41
293	Domestic appliances	0.21
233	Processing of nuclear fuel	0.13
352	Railway and tramway locomotives	0.09
252	Plastics products	0.08
222	Printing and related activities	0.08
369	Other manufacturing	0.03
315	Electric lamps and equipment	0.02
272	Precious and non-ferrous metals	0.01
241	Basic chemicals	0.00

Notes: Table displays the share of digital goods imports by sectors, defined according do ISIC 3-digits, of AfCFTA members in 2019.