Export capacity and capital stock augmentation through imports: Evidence from Sub-Saharan African countries

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ORIGINAL ARTICLE

Export capacity and capital stock augmentation through imports: Evidence from Sub-Saharan African countries

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Abstract
This paper investigates the capital goods imports of Sub-Saharan African (SSA) countries from 2002 to 2017. The composition of capital goods imports has become less diverse over time in more than half of the countries studied. Colonial ties no longer determine the sourcing of capital goods as China is now the top source. Trade gravity regressions using the Poisson pseudo-maximum-likelihood estimator show that bilateral exports of non-primary products by SSA countries and their low-income peers are associated with increased net stock of imported general-purpose capital goods. Additionally, there is evidence that the net stock of some types of imported equipment and machinery is associated with increased non-primary exports of items utilising these capital goods with elasticity estimates ranging from 0.10 to 1.10. Thus, there is some form of economic restructuring in the region gleaned from increased exports of non-primary products brought about by capital stock augmentation through imports.

KEYWORDS
capital goods, equipment and machinery imports, export capacity, PPML estimator, Sub-Saharan Africa

JEL CLASSIFICATION
F14, O14

1 | INTRODUCTION

The 2017 Africa Competitiveness Report (World Economic Forum, 2017: xiii) makes a sobering observation: 'Most competitiveness challenges highlighted in the *Africa Competitiveness Report* series since its first publication, almost 10 years ago, persist. These include large infrastructure deficits, significant skill mismatches, slow adoption of new technologies, and weak institutions. These factors … emerge as the main bottlenecks that prevent African economies from offering an environment that facilitates better employment and entrepreneurship opportunities to its citizens …' This study tackles two of these major roadblocks to improved competitiveness in Sub-Saharan African (SSA) countries: large infrastructure deficits and the slow adoption of technologies.

According to the World Economic Forum (2017), the average scores of the infrastructure and technology readiness pillars of the Global Competitiveness Index (GCI) for the SSA countries are 2.78 and 2.91, respectively.[1] SSA countries' low scores in these two pillars and in the other 10 pillars of the GCI are a concern as these pillars are widely believed to be important drivers of medium- and long-term growth and, ultimately, critical to improving peoples' standards of living. Despite an almost identical average real GDP per capita in 1980 of about $3200 (in 2017 PPP dollars) for both SSA and ASEAN-5[2] countries, gaps in the average scores of the GCI pillars between these two groups of countries may explain why the average real GDP per capita (in 2017 PPP dollars) of the ASEAN-5 countries ($12,797) is more than three times the average of the SSA countries ($3982) by 2019 (International Monetary Fund, 2021).

Sub-Saharan African countries can close the large electricity and telephone infrastructure deficits or improve their technology readiness through the sourcing of capital equipment and machinery abroad. Technology embodied in imported capital goods has the potential to boost firm productivity. Imported capital goods with broad uses, such as electricity generators, could enhance the productivity of a wide range of firms, whereas the productivity effects of imported capital goods with specific uses, such as machinery for making paper, are limited to firms using such machinery. Because such imports augment a country's physical capital stock, they could generate new employment and production opportunities and lead to a diversification of a country's economic base.

Because employment and output data are not readily available at the industry level for SSA countries, this research paper uses an indirect approach to investigate the potential productivity or economic diversification effects of capital stock augmentation through imports. The paper's main thesis is that these effects could be gleaned indirectly from increased export capacity. Although this approach is imperfect, the availability of detailed bilateral trade data makes this undertaking possible and worthwhile.

Melitz's (2003) model links firms' capacity to export with their productivity levels. Melitz shows that the most productive firms service both domestic and foreign markets, firms with intermediate productivity levels only service the domestic market, and the least productive firms would exit. In other words, only the most productive firms have the capacity to export. Bas and Strauss-Kahn (2014) build on Melitz's model by introducing intermediate inputs, which could be sourced domestically or imported from Northern or Southern countries. Intermediate inputs from Northern countries are assumed to have a higher technological content, whereas those from Southern countries are cheaper. The authors show that access to a wider variety of imported inputs and the availability of better quality imported inputs improve firms' productivity thereby increasing their export capacity. Access to a wider range of intermediate goods via imports means that firms could select and use inputs that better complement their existing production structures (complementarity channel), whereas the availability of higher quality intermediate goods via imports implies diffusion of knowledge embodied in the imported inputs (technology channel). Both channels not only enhance firms' capacity to export but also expands the scope of what they can export. Bas and Strauss-Kahn (2014) assume one type of capital. Relaxing this assumption and differentiating between domestically- and foreign-sourced capital equipment and machinery (the central idea driving this paper's empirical work) would not alter the essence of Bas and Strauss-Kahn's message. Moreover, because 'imported machinery is bundled with "knowledge" in various forms: blueprints, installation support, quality control software and services of trained engineers and supervisors. …

[1]The GCI indices range from 1 to 7 with 7 being the best or highest score. The infrastructure pillar includes transport and electricity and telephone infrastructure while the technology readiness pillar includes technology adoption and information and communication technology (ICT) use.

[2]ASEAN-5 includes Indonesia, Malaysia, the Philippines, Thailand and Vietnam. For reference, the average scores for the infrastructure and technology readiness GCI pillars for the ASEAN-5 countries are 4.46 and 3.95, respectively (World Economic Forum, 2017).

and is typically of newer vintage than domestically produced machinery', their use also increases productivity thereby enhancing firms' capacity to export (Mody & Yilmaz, 2002: 24). Increased productivity enables firms to overcome a major barrier to exporting (i.e. fixed cost of exporting). Such a conclusion would hold true not just at the firm level, but in the aggregate (i.e. industry and country levels).

The paper makes a two-fold contribution: First, the extent and composition of SSA countries' imports of capital equipment and machinery with broad and industry-specific uses are documented. This provides a much-needed brief on whether and by how much SSA countries have augmented their capital stock through imports, both by type and source of imported capital goods for the 2002–2017 period. Second, the export effect of capital stock augmentation through imports is investigated using both general-purpose and industry-specific equipment and machinery imports. To the best of my knowledge, this type of quantification has not been done before for the SSA region.

To preview the results, for a majority of SSA countries, telecommunications equipment is now the top capital goods import. The continued dominance of the oil and mining sectors in the SSA region is apparent in the types of equipment and machinery imported. The composition of capital goods imports has become less diverse over time in more than half of the 48 SSA countries studied. Moreover, data show that colonial ties no longer determine the sourcing of capital goods as China is now the top source of equipment and machinery for most SSA countries. Trade gravity regressions using the Poisson pseudo-maximum-likelihood (PPML) estimator show that the non-primary exports of SSA countries and their low-income peers increase with the net stock of imported general-purpose capital goods such as electricity generators and telecommunications equipment. Electricity is necessary for the processing of raw materials into manufactures while telecommunication services lower the cost of coordination along the value chains. Additionally, there is some evidence that the net stock of some types of imported equipment and machinery is associated with increased non-primary exports of items using these imported capital goods. The import–export elasticity estimates range from 0.10 (preparations of vegetables, fruits and nuts) to 1.10 (articles of plastics, rubber, woods and cork). Although primary exports continue to dominate the SSA region's exports with a 54% share in 2014–2017, this is lower than the 65% share in 2006–2009. Thus, there appears to be some form of economic restructuring in the region gleaned from increased non-primary exports brought about by capital stock augmentation through imports.

The remainder of this paper is organised as follows: Related literature is reviewed in the next section. Section 2 also includes the theoretical framework underlying the empirical work. Section 3 discusses the data used, documents the extent and type of capital stock augmentation via imports and studies the link between countries' imports of capital equipment and machinery and subsequent non-primary exports. Section 4 contains an extensive discussion of the main findings and includes some concluding remarks.

2 | RELATED LITERATURE AND THEORETICAL FRAMEWORK

2.1 | Related literature

This paper is related to the literature studying the nexus between growth and investments in infrastructure and capital equipment regardless of source. De Long and Summers (1991) is an early contribution. For the 1960–1985 period covering 61 countries, the authors find that a one percentage point increase in the equipment investment-to-GDP ratio is associated with about a third of a percentage point increase in GDP per worker growth per year. Studying 42 SSA countries in 1999–2011, Ghazanchyan and Stotsky (2013) find that a percentage point increase in the private investment-to-GDP ratio is associated with about one-tenth of a percentage point increase in GDP per capita, but they find no evidence that public investments contribute to per capita income growth. Other studies use specific forms of capital investments. For example, Calderón and Servén (2010) obtain synthetic infrastructure quantity and quality indices by combining information on electric power, telecommunications and roads. Controlling for other country characteristics such as human capital endowment, trade openness and governance, the authors find that per capita GDP growth in Sub-Saharan African countries increases by 0.7% per year in 2001–2005 relative to 1991–1995 due to infrastructure development. The growth rate would have been 1.2% per year if not for the deterioration in the quality of infrastructure in the region.

The broad literature on technology diffusion via imports of capital goods and its implications on growth and productivity is most pertinent to the current research. This strand of literature is typified by Lee's (1995) early contribution. The author uses data for 89 countries and shows that per capita income growth in the 1960–1985 period increases with the ratio of foreign-to-domestic capital goods usage. This is because capital goods imported from developed countries are comparatively cheaper and, when combined with domestic capital goods, increase the efficiency of the country's capital stock. However, Lee's (1995) findings may be an artefact of 'the difference between equipment and non-equipment investment rather than the difference between imported and domestic capital goods' (Mazumdar, 2001: 211). Mazumdar (2001) improves on Lee's (1995) work by properly measuring imported and domestic equipment investment. Data from a panel of 30 least-developed countries show that per capita income growth increases (decreases) with imported (domestic) equipment investment. Caselli and Wilson (2004) study the determinants of nine types of capital goods imports using data for up to 38 countries for 1970–1995. The authors find a huge variation in the types of capital goods imported by these countries primarily due to whether the countries have complementary factors or appropriate institutions where these could be used efficiently. For example, computing equipment imports (compared to fabricating equipment imports) are positively associated with the average years of schooling. Moreover, Caselli and Wilson (2004) find suggestive evidence that productivity differences across countries may partly be attributed to the composition of their capital goods imports.

There is also evidence in the literature that broad economic outcomes improve with capital stock augmentation via imports using data for SSA countries. For example, Haacker (2010) estimates that investments in information and communication technologies (ICTs) contribute to about a 0.16 percentage point increase in GDP growth for Ethiopia and Nigeria for the 1990–2006 period. Similar evidence is found at the micro level. Using a panel of 340 manufacturing firms in Botswana in 1985–2010, Habiyaremye (2013) finds a positive correlation between firms' imports of equipment and productivity growth. The productivity-enhancing effect of imported capital equipment is confirmed by Nyantakyi and Munemo (2017) using firm-level data from Ghana, Kenya and Tanzania. Moreover, the authors find that the productivity-enhancing effect varies across industries and is larger for firms that are more distant from their industry's best available technology standards.

Past literature has also documented some African countries' overreliance on imported capital goods. For example, Eaton and Kortum (2001) study the capital goods imports of 34 countries in 1985. They find that almost all of Malawi's equipment absorption (gross production + imports − exports) is imports, whereas Kenya has the lowest import share (60%) among the five SSA countries in the study. Colonial ties are found to be important determinants of imports of capital goods. The United Kingdom is the main source for Kenya, Malawi and Nigeria, whereas France is the main source for Mauritius and Morocco.

Prior research investigating the linkage between equipment imports and subsequent exports is sparse. Mody and Yilmaz (2002) and Barba Navaretti, Marzio and Mattozzi (2004) are early contributions. Mody and Yilmaz (2002) study the link between (overall) imported machinery and manufactured export prices for 36 countries from 1967 to 1990. They find that imported machinery contributes to lower export prices via the cost reduction channel. The estimated export price elasticities of machinery imports are -0.052 and -0.072 for developed and exported-oriented developing economies, respectively. Barba Navaretti, Marzio and Mattozzi (2004) investigate whether there is a correlation between the quality of textile exports and the skill intensity of textile machinery imports used in the production of these items. Unit values are used to measure textile quality. A positive correlation is found between textile export unit values of select Central and Eastern European and Southern Mediterranean countries to European Union countries and the skill intensity of their textile machinery imports in the 1988–1996 period. This result is consistent with the notion that technology embodied in machinery imports allows firms to move to higher value-added products.

2.2 | Theoretical framework

Before discussing the data and empirical methodology, it is valuable to sketch the theoretical framework underlying the empirical work.[3] Consider Bas and Strauss-Kahn's (2014) model with two broad types of capital equipment and machinery (the current paper's central idea) instead of one. For any final good p, output (y) is a function of labor (L), capital (K_d, domestic- and K_f, foreign-sourced) and intermediate inputs (M_{ij}):

$$y = \varphi L^{\eta} K_d^{\delta} K_f^{\beta} \prod_{j \in \{D,N,S\}} \prod_{i=1}^{I} \left(M_{ij}\right)^{\alpha_i},$$

where φ accounts for firm heterogeneity in initial productivity levels (Melitz, 2003), factor shares $\eta + \delta + \beta + \sum_{i=1}^{I} \alpha_i = 1$ (Cobb–Douglas production function), j is the source of intermediate inputs: domestic (D), Northern (N, developed) or Southern (S, developing) countries, and i is the intermediate good type ($i = 1, \ldots,$ I). Following established literature, Bas and Strauss-Kahn (2014) assume symmetric production of all intermediate inputs denoted as $\overline{m}_j$. Intermediate input use then is $M_{ij} = \left(N_{ij}\chi_{ij}\right)^{\frac{\sigma_i}{\sigma_i - 1}} \overline{m}_j$, where N_{ij} is the number of varieties of an intermediate input i, $\chi_{ij} > 1$ for inputs from Northern countries (assumed to have a higher technology content), equal to 1 otherwise, and σ_i is the elasticity of substitution across the different varieties in i. Define $\overline{m}_j = \frac{\overline{M}_{ij}}{N_{ij}\chi_{ij}}$, output can be rewritten as follows:

$$y = \varphi L^{\eta} K_d^{\delta} K_f^{\beta} \prod_{j \in \{D,N,S\}} \prod_{i=1}^{I} \left(\overline{M}_{ij}\right)^{\alpha_i} \left(N_{ij}\chi_{ij}\right)^{\frac{\alpha_i}{\sigma_i - 1}}.$$

From this, it follows that (total factor) productivity (A), $A = \varphi \prod_{i=1}^{I} \left(N_{iN}\chi_{iN}\right)^{\frac{\alpha_i}{\sigma_i - 1}} \left(N_{iS}\right)^{\frac{\alpha_i}{\sigma_i - 1}}$ (factoring out all inputs: labor, capital and intermediate inputs). Notice that access to a wider variety of imported inputs (N_{ij}) and the availability of better quality imported inputs (χ_{ij}) improve firms' productivity, which potentially increases their profits. This key result from Bas and Strauss-Kahn holds even with heterogeneous capital. To underline the model's utility to the current paper's empirical work, consider the following cases:

Case 1. Final good p does not require foreign capital equipment or machinery (K_f) in its production: $\beta = 0$. This is the case implicitly tackled by Bas and Strauss-Kahn (2014). They show that any firm x will start exporting good p if its export profit (π_x) is positive: $\pi_x = \frac{r_x}{\phi} - F_x > 0$, where r_x is firm export revenue, ϕ is the elasticity of substitution across all final goods and F_x includes the sum of three kinds of fixed costs: production, exporting and importing.

Case 2. Final good p requires K_f but it is not imported[4]: $\beta > 0$, $K_f = 0$. This means that no domestic production will occur ($y = 0$), so no export of good p will be observed.

Case 3. Final good p requires K_f and these can be imported: $\beta > 0$, $K_f > 0$. Domestic production will occur and as in Case 1, any firm x will start exporting good p only if its export profit (π_x) is positive. This key result from Bas and Strauss-Kahn (2014) holds with the addition of this complication: $\beta > 0$, $K_f > 0$.

There are no barriers to the importation of intermediate imports in Bas and Strauss-Kahn's model. Their key result holds that even if there were import tariffs on the intermediate inputs, tariffs would

[3]Much of this section is from Bas and Strauss-Kahn (2014).

[4]Potential reasons include prohibitive purchase cost, unwarranted technical barriers to trade, high import tariffs, to name a few.

merely increase the marginal cost of exporting each unit and shift the threshold before a firm exports a good. For the purposes of this paper, because the export data involve over a thousand non-primary items, it is impractical to identify and quantify all the intermediate inputs used in the production of each item; thus, an indicator related to importing countries' trade regime openness is used as a proxy for the use of imported intermediate inputs.

Eaton and Kortum's (2001) paper completes the theoretical framework. In their model, the production of capital goods is assumed to occur in Northern countries. Capital goods are traded from North to South. The South is assumed to produce only final goods and export these to the North. Because capital goods are inputs to the production process, the output of final goods in the South increases with increased imports of capital goods. The authors introduce heterogeneity in the production of capital goods. This heterogeneity is across types of capital goods produced and across countries in the North producing these items. The authors show that a country would import a given capital good type from the source country that offers this at the lowest effective cost. It is important to mention that although Eaton and Kortum's (2001) model primarily explains variations in the sourcing of capital goods imports across source countries, it is also useful for an alternate purpose: Studying whether increased imports of a specific type of capital goods is associated with increased exports of items using this specific type of capital goods.

The next section details the data and empirical methodology used to study SSA countries' capital stock augmentation by way of imports and the subsequent export capacity effect of general-purpose and industry-specific equipment and machinery imports at the most detailed level possible.

3 | CAPITAL STOCK AUGMENTATION THROUGH IMPORTS AND THE IMPORT–EXPORT LINK

3.1 | Trade data

It is necessary to first identify the largest exporters of equipment and machinery. The United Nations' (2019) Commodity Trade Statistics (UN Comtrade) database classifies traded items into their main end-use, referred to as Broad Economic Categories (BEC) classification scheme. Finished capital goods fall under BEC 41.[5] Because countries have more incentive to track imports (e.g. for duty collection), import data are typically preferred over export data. Using all countries' reported import of equipment and machinery, the top 30 source countries are identified for each year between 2002 and 2017. A total of 32 source countries are in the top 30 for at least five of the 16 years of the analysis period.[6] These source countries account for 92%–93% of worldwide imports of capital goods each year.

Trade data at the six-digit Harmonized System (HS) code level are also available from the UN Comtrade database. HS code definitions for 2002 are used throughout the paper. This is why the analysis period starts in 2002.[7] At the six-digit HS level, it is possible to track whether imported capital goods have broad (e.g. steam turbines) or industry-specific (e.g. textile spinning machines) uses. Using the HS–BEC concordance provided by the UN Statistics Division, 627 six-digit HS codes are identified as finished capital goods (BEC 41). The evolution of the scale and composition (at the finest level possible) of SSA countries' capital goods imports are tracked to assess countries' investments in capital goods and changes (if any) in their export capabilities. As previously mentioned, import data are preferred over export data when studying bilateral trade. However, SSA countries provide less information than other countries. Thus, export data from SSA countries' trading partners are used instead. To focus the analysis,

[5]Parts and accessories of capital goods fall under BEC 42; these are not included in the analysis.

[6]Appendix A lists these 32 top sources of capital goods. Taiwan (a major source of some types of capital goods) is not included in the analysis as Taiwanese data are not separately identifiable in the UN Comtrade database.

[7]HS code definitions change regularly. When definitions change, the correspondence between old and new codes is either 1:1, n:1, 1:n or n:n.

only exports to SSA countries and their low-income peers (mirror imports[8]) are analysed below.[9] Country coverage appears in Appendix A.

3.2 | Capital stock augmentation through imports

Table 1 shows the importance of capital goods imports relative to countries' total imports from the top 32 sources of capital goods. For exposition ease, data are summarised into four periods. The median shares are 14%–17% for both SSA countries and their low-income peers. The median market shares of the top 10 exporters of capital goods for the first 4-year period (2002–2005) appear in Table 2. Data show a steady increase in China's market share in both sets of countries. China's rank as a capital goods source for SSA countries improves to first place from fifth place, with a median market share of 34% for 2014–2017, up from a 6% median market share in 2002–2005.[10] This mostly comes at the expense of French exporters: France's median market share among SSA countries drops to 5% in 2014–2017 from 13% in 2002–2005. Exporters from Germany, Italy and the United Kingdom also experience a drop in their median market shares. These indicate that unlike observations made by Eaton and Kortum (2001) using data in the 1980s, colonial ties are less important now in SSA countries' sourcing of capital goods. A similar pattern is observed for the sourcing of capital goods by non-SSA low-income countries.

TABLE 1 Capital goods imports as percent of total imports.

	2002–2005	2006–2009	2010–2013	2014–2017
	Sample: SSA countries			
No. of countries	46	46	48	48
Mean	14.7	16.6	16.0	15.5
Std. Deviation	6.5	7.4	6.9	6.4
Maximum	38.1	34.1	35.0	29.8
75th percentile	18.9	21.8	18.9	19.9
Median	14.2	16.8	15.9	14.4
25th percentile	10.6	11.1	11.3	11.2
Minimum	1.7	1.7	3.0	4.6
	Sample: Non-SSA low-income countries			
No. of countries	25	25	25	25
Mean	14.4	14.4	14.7	14.1
Std. deviation	4.9	5.1	5.0	4.6
Maximum	25.8	23.3	29.6	24.7
75th percentile	17.9	18.2	16.7	16.5
Median	14.8	14.4	15.3	15.0
25th percentile	11.0	10.7	11.6	12.0
Minimum	6.5	3.2	5.0	4.4

Note: Author's calculations using data from the UN Comtrade Database. Imports are from the top 32 exporters of capital goods as described in the text.

[8]For brevity, mirror imports are referred to as imports throughout the paper.
[9]The World Bank's income classification scheme for 2002 is used throughout. The comparison group is all other low-income countries as 40 of the 48 SSA countries in the sample are classified as low-income countries in 2002. The comparison group includes 25 low-income countries.
[10]For non-SSA low-income countries, China's median market share in 2014–2017 is 38%, up from a 14% share in 2002–2005.

TABLE 2 Median market shares of select top exporters of capital goods.

Exporter	2002–2005	2006–2009	2010–2013	2014–2017
	Sample: SSA countries, in percent			
France	13.0	11.9	6.0	4.6
Germany	8.3	7.0	6.5	5.5
United States	7.8	6.2	6.0	5.0
Italy	6.2	4.7	4.9	4.3
China	6.2	19.9	28.6	33.5
United Kingdom	4.9	3.7	3.8	2.7
Belgium	3.0	2.8	2.2	2.1
Netherlands	2.9	2.5	2.0	2.3
Sweden	2.1	2.1	1.7	1.2
Japan	1.4	1.3	1.3	0.8
	Sample: Non-SSA low-income countries, in percent			
China	13.5	29.8	32.9	38.4
Germany	9.9	7.4	4.8	5.5
Japan	6.5	2.8	3.3	2.9
United States	6.3	5.6	3.6	3.4
Italy	4.6	2.1	2.6	2.2
France	3.3	1.8	1.0	0.7
Rep. of Korea	2.5	2.8	2.7	2.4
United Kingdom	2.1	1.6	0.9	1.0
Singapore	2.0	6.4	3.4	3.1
Sweden	1.6	1.1	0.7	0.6

Note: Author's calculations using data from the UN Comtrade Database. Capital goods exporter lists are sorted according to their market share in 2002–2005.

Table 3 provides the top capital goods source for each of the SSA countries for two periods: 2002–2005 and 2014–2017, with each source country's market share.[11] Note that France was the top source of capital goods in 19 countries in the first period with a market share as high as 80% in Comoros. By 2014–2017, China has become the top source for 34 of the 48 SSA countries. This switch is observed as early as 2006–2009 with China as the top source for 22 SSA countries. China's market share is largest in Zimbabwe at 54% and lowest in Eswatini at 22%.[12] A possible reason why China has become an important source of capital goods is that Chinese equipment is more appropriate for SSA countries and is a cheaper alternative.[13] Evidence consistent with these hypotheses is documented by Hanlin and Kaplinsky (2016) using in-depth interviews and surveys conducted in 2012–2015 in three East African countries for three types of equipment. The authors find that acquisition costs for Chinese equipment are lower because they are less complex. Also, although these have shorter lifespans and experience more frequent breakdowns, they are cheaper to maintain and repair due to local availability of parts and talent.[14]

[11]Information for 2006 to 2013 are available in Appendix S1. Supporting Information (online appendix).

[12]Except for Eswatini, by 2018, all SSA countries have established diplomatic relations with China.

[13]This could also be a direct consequence of the Forum on China–Africa Cooperation (FOCAC), which was founded in 2000, and has been the main venue for collective dialogue between China and the 53 African FOCAC member states.

[14]For example, the authors find that the acquisition cost of two-wheeled tractors (tillers) in Tanzania is 40%–50% cheaper if sourced from China instead of Japan, and the maintenance and repair of Japanese tillers are four times more expensive than those from China despite having a longer life (7–12 years vs 3–4 years). For Africa as a whole, Hanlin and Kaplinsky (2016) find that China's market share for rice tillers increased from 2% to 34% in the 2000–2014 period. For sewing machines and wood working machines, China's market share increased from 13% to 68% and 4% to 28%, respectively.

TABLE 3 Sources of capital goods imports for Sub-Saharan African countries: concentration index, top source and percent share of the top source, 2002–2005 and 2014–2017.

Country	2002–2005 Concentration index	2002–2005 Top source	2002–2005 Share, %	2014–2017 Concentration index	2014–2017 Top source	2014–2017 Share, %
Angola	0.374	Rep. of Korea	59.6	0.174	Rep. of Korea	32.2
Benin	0.234	France	35.7	0.314	China	53.3
Botswana	0.104	Germany	17.2	0.153	China	32.9
Burkina Faso	0.319	France	54.6	0.119	France	27.0
Burundi	0.116	Belgium	17.3	0.164	China	28.3
Cabo Verde	0.143	Spain	23.1	0.135	Spain	21.9
Cameroon	0.240	France	45.9	0.178	China	35.2
Central African Rep.	0.166	France	32.4	0.096	France	16.1
Chad	0.203	France	33.1	0.150	China	30.6
Comoros	0.637	France	79.5	0.308	China	42.6
Congo	0.189	France	38.1	0.254	Rep. of Korea	46.1
Côte d'Ivoire	0.236	France	44.6	0.132	France	23.9
Dem. Rep. of the Congo	0.212	Belgium	34.7	0.247	China	46.3
Equatorial Guinea	0.237	United States	38.0	0.180	United States	28.1
Eritrea	0.309	Italy	53.4	0.326	China	52.8
Eswatini	0.104	Rep. of Korea	20.0	0.132	China	22.2
Ethiopia	0.103	Italy	21.0	0.257	China	48.2
Gabon	0.295	France	52.3	0.164	China	28.4
Gambia	0.178	United Kingdom	29.5	0.169	China	36.7
Ghana	0.084	United Kingdom	12.7	0.190	China	40.1
Guinea	0.137	France	30.6	0.282	China	50.5
Guinea-Bissau	0.132	France	20.4	0.094	France	16.3
Kenya	0.086	United Kingdom	16.2	0.221	China	43.9
Lesotho	0.262	Germany	46.9	0.272	China	48.7
Liberia	0.332	Spain	56.1	0.481	Rep. of Korea	68.2
Madagascar	0.201	France	40.7	0.211	China	40.7
Malawi	0.084	United Kingdom	15.4	0.187	China	35.0
Mali	0.310	France	53.5	0.120	France	23.3
Mauritania	0.209	France	41.6	0.128	China	24.0
Mauritius	0.121	Finland	22.7	0.131	China	29.6
Mozambique	0.136	France	31.9	0.246	China	47.2
Namibia	0.101	Germany	21.5	0.166	China	34.1
Niger	0.259	France	46.1	0.164	France	28.3
Nigeria	0.088	United Kingdom	13.9	0.178	China	37.2
Rwanda	0.128	Germany	24.4	0.123	Hong Kong	25.3
Sao Tome and Principe	0.302	Germany	51.2	0.144	Hong Kong	27.1
Senegal	0.280	France	50.4	0.154	China	30.9

(Continues)

TABLE 3 (Continued)

Country	2002–2005 Concentration index	2002–2005 Top source	2002–2005 Share, %	2014–2017 Concentration index	2014–2017 Top source	2014–2017 Share, %
Seychelles	0.102	France	18.2	0.102	Spain	24.8
Sierra Leone	0.167	Germany	33.6	0.141	China	31.9
Somalia	0.200	China	31.6	0.301	China	52.7
South Africa	0.088	Germany	21.4	0.120	China	27.3
South Sudan	-			0.269	China	47.1
Sudan	-			0.257	China	47.4
Togo	0.250	France	45.7	0.261	China	36.6
Uganda	0.085	United Kingdom	16.3	0.233	China	45.0
United Rep. of Tanzania	0.084	China	14.8	0.314	China	54.3
Zambia	0.103	China	22.9	0.213	China	42.9
Zimbabwe	0.115	China	19.7	0.316	China	54.4

Note: Author's calculations using data from the UN Comtrade Database. The concentration index is the sum of squared proportional shares from each of the top 32 source countries.

As China became the main source of capital goods in a majority of SSA countries, the sourcing of imported capital goods became more concentrated over time for more than half of 46 SSA countries with data for the entire 2002–2017 period (Table 3).[15] In the most recent period, Liberia's and Guinea-Bissau's capital goods sources are the most (0.481) and least (0.094) concentrated with 68% and 16% sourced from South Korea and France, respectively.

Besides country source, to the extent possible, capital goods are classified according to main use: general purpose and industry specific.[16] Capital goods with broad uses potentially expand countries' overall production capacity, whereas industry-specific equipment and machinery potentially expand production capacity only in specific industries. For example, importing knitting machinery expands textile and apparel production capacities, so countries' textile and apparel exports might increase in subsequent periods.

Between 2002 and 2017, SSA countries imported US$456.9 billion worth of capital goods, with more than half in the last two periods alone (Table 4, Panel A). In nominal terms, imports increased in all periods except the last. General-purpose capital goods account for about 40% of capital goods imports, with telecommunications equipment having the largest share. This is consistent with Calderón's (2009) observation that SSA countries are addressing their deficiencies in telecommunication services. The imports have contributed to an increase in the number of mobile phone subscriptions from 6.9 (2002–2005) to 73.1 (2014–2017) per 100 people (The World Bank, 2021a) and perhaps to improvements in the quality of telecommunication services in Africa noted by Calderón (2009). Electric and electricity-generating equipment have a 6%–9% share for the entire period of analysis. In nominal terms, imports increased from US$3.2 billion in 2002–2005 to US$11.3 billion in 2014–2017 thereby contributing to an increase in the SSA population's access to electricity from 30% in 2002–2005 to 41% in 2014–2017 (The World Bank, 2021a). This increase, however, is still insufficient to close the continent's

[15]The source concentration index is based on the Hirschman–Herfindahl index (HHI), which is the sum of the squared source country market shares. Higher index values indicate more concentration, with 1 indicating only one country as import source.

[16]Each capital good's broad or industry specific end-use is established using the HS and end-use concordance from the US Bureau of Census. Since the Census' concordance uses 10-digit HS codes, it is possible that a six-digit HS code cannot be matched to a unique five-digit end-use codes. If the correspondence between six-digit HS and five-digit end-use codes is not one-to-one, then three- or two-digit end-use codes are used instead. This correspondence is available from the author upon request.

TABLE 4 Sub-Saharan African countries' capital goods imports in 2002–2017, by the main end-use.

	2002–2005	2006–2009	2010–2013	2014–2017
A. All top 32 sources				
Total, in billion USD	54.0	109.5	149.0	144.3
Growth rate, in percent		102.6	36.1	−3.1
	Shares, percent of capital goods imports			
General purpose (total share)	*40.4*	*41.1*	*37.3*	*39.6*
Electric and electric generating equipment	6.0	8.5	8.4	7.9
Computers and peripherals	9.7	7.1	7.4	7.2
Telecommunications equipment	18.9	20.4	16.5	18.8
Business machinery, except computers	1.3	1.2	1.1	1.3
Scientific, hospital and medical machinery	4.5	3.9	4.0	4.4
Sector specific (total share)	*42.4*	*42.6*	*43.2*	*41.9*
Oil drilling, mining and construction machinery	12.9	13.5	12.9	10.5
Industrial and services machinery	28.1	27.7	28.5	29.6
Agricultural machinery and equipment	1.3	1.3	1.7	1.8
Other	*17.2*	*16.3*	*19.6*	*18.6*
B. China only				
Total, in billion USD	4.2	20.8	38.3	47.9
Growth rate, in percent		397.1	84.4	25.0
	Shares, percent of capital goods imports			
General purpose (total share)	*50.5*	*54.1*	*44.1*	*42.9*
Electric and electric generating equipment	11.6	11.8	10.5	9.1
Computers and peripherals	9.0	6.9	8.8	7.8
Telecommunications equipment	26.5	32.2	21.3	21.8
Business machinery, except computers	1.6	1.2	1.5	1.9
Scientific, hospital and medical machinery	1.8	2.0	2.0	2.4
Sector specific (total share)	*29.4*	*32.2*	*39.4*	*38.7*
Oil drilling, mining and construction machinery	4.9	11.1	11.7	9.1
Industrial and services machinery	23.5	20.4	26.8	28.7
Agricultural machinery and equipment	1.0	0.7	0.8	0.9
Other	*20.1*	*13.7*	*16.5*	*18.4*

Note: Author's calculations using data from the UN Comtrade Database.

large deficit in power generation. According to Foster and Briceño-Garmendia (2010), Africa needs to spend close to US$93 billion per year (15% of the region's GDP) to address the continent's infrastructure deficit, with about 40% on power generation.

For the entire period of analysis, another 42% of capital goods imports are sector-specific, with equipment and machinery used in oil drilling, mining and construction comprising 11%–14% of SSA countries' capital goods imports. Industrial and services machinery account for close to 30% and agricultural equipment and machinery has a 1%–2% share. About a fifth of the imports are not classifiable into general-purpose use or sector-specific use either because HS and end-use matching is not feasible or HS and end-use matching can only be done at a broad level (two-digit level rather than at the five- or three-digit level).[17] Panel B of Table 4 provides information on SSA countries' capital goods

[17]See the previous footnote for details.

imports from China. Note that China's overall market share increased from 8% to 33% with imports growing at a much faster rate in each period. Telecommunications equipment comprises a much larger share of capital goods imports from China especially in the first two periods.

Table 5 contains the breakdown of industrial and services machinery imports. The relative importance of each type of equipment changed over time: It increased for some types (e.g. food and tobacco machinery) and declined in others (e.g. metal working machine tools). For the entire period, materials handling equipment (e.g. conveyors or cranes) has the largest share at 14%–19% of industrial and services machinery imports. Together with the previous observation that oil drilling, mining and construction machinery comprise about 11%–14% of capital goods imports (Table 4), this suggests the continued dominance of the oil and mining sectors in the region. Perhaps as an immediate consequence of the end of the textile and apparel quota regime in 2005, the share of textile and sewing machines dropped from 4.4% to 2% starting in 2006. As a share of all industrial and service machinery, SSA countries import less food, tobacco, pulp and paper machinery and import more photo and service industry machinery from China (Table 5, Panel B).

TABLE 5 Sub-Saharan African countries' industrial and services machinery imports in 2002–2017.

	2002–2005	2006–2009	2010–2013	2014–2017
A. All top 32 sources				
Total, in billion USD	15.2	30.4	42.5	42.7
Growth rate, in percent		99.8	40.0	0.5
Industrial and services machinery	*Shares, percent of industrial and services machinery*			
Industrial engines	4.4	4.1	4.8	5.0
Food and tobacco machinery	6.1	6.5	7.3	7.3
Metalworking machine tools	6.5	6.6	5.6	4.8
Textile and sewing machines	4.4	2.1	2.0	2.4
Wood, glass and plastic machinery	7.1	6.1	5.6	6.0
Pulp and paper machinery	8.7	6.5	5.5	5.0
Measuring, testing and control instruments	7.1	6.3	6.8	8.1
Materials handling equipment	14.0	19.0	18.3	16.7
Photo and service industry machinery	11.0	10.0	13.1	13.9
Other ind. engines and services mach.	30.5	32.8	31.0	30.8
B. China only				
Total, in billion USD	1.0	4.2	10.3	13.7
Growth rate, in percent		332.4	142.2	33.4
Industrial and services machinery	*Shares, percent of industrial and services machinery*			
Industrial engines	5.2	3.4	3.2	3.7
Food and tobacco machinery	3.4	3.6	3.5	4.4
Metalworking machine tools	6.6	8.4	5.9	5.6
Textile and sewing machines	7.3	2.7	2.4	2.7
Wood, glass and plastic machinery	10.3	8.9	7.3	7.2
Pulp and paper machinery	3.9	3.1	2.3	2.3
Measuring, testing, control instruments	6.6	4.0	5.2	8.0
Materials handling equipment	15.9	20.9	20.8	18.0
Photo, service industry machinery	17.5	15.7	24.9	23.2
Other ind. engines and services mach.	23.2	29.3	24.6	25.0

Note: Author's calculations using data from the UN Comtrade Database.

TABLE 6 Sub-Saharan African countries' capital goods imports: concentration index and the share of the top capital goods imports, 2002–2005 and 2014–2017.

	2002–2005			2014–2017		
Country	Concentration index	Item description	Share, %	Concentration index	Item description	Share, %
Angola	0.250	Floating or submersible platforms	37.5	0.080	Floating or submersible platforms	26.3
Benin	0.041	Telephonic or telegraphic switching apparatus	15.1	0.045	Instruments, for demonstrational purposes	17.2
Botswana	0.082	Transmission apparatus	24.8	0.046	Line telephony or telegraphy systems	13.9
Burkina Faso	0.020	Telephonic or telegraphic switching apparatus	7.2	0.025	Transmission apparatus	10.1
Burundi	0.033	Transmission apparatus	12.0	0.077	Line telephony or telegraphy systems	20.0
Cabo Verde	0.019	Engines	5.9	0.049	Transmission apparatus	15.8
Cameroon	0.019	Transmission apparatus	10.1	0.039	Line telephony or telegraphy systems	16.3
Central African Rep.	0.029	Transmission apparatus	9.2	0.042	Line telephony or telegraphy systems	12.9
Chad	0.022	Electric generating sets	7.9	0.022	Boring and sinking machinery	7.6
Comoros	0.039	Transmission apparatus	9.9	0.031	Furniture; metal, other than for office use	12.1
Congo	0.013	Transmission apparatus	6.6	0.214	Floating cranes, floating docks	45.8
Côte d'Ivoire	0.019	Transmission apparatus	9.6	0.014	Line telephony or telegraphy systems	6.8
Dem. Rep. of the Congo	0.045	Transmission apparatus	15.7	0.018	Line telephony or telegraphy systems	8.5
Equatorial Guinea	0.077	Floating or submersible platforms	15.5	0.148	Floating or submersible platforms	37.6
Eritrea	0.021	Machines and mechanical appliances; n.e.s.	6.7	0.032	Electric generating sets	10.8
Ethiopia	0.015	Telephonic or telegraphic switching apparatus	5.9	0.018	Line telephony or telegraphy systems	10.0
Eswatini	0.033	Line telephony or telegraphy systems	9.7	0.050	Line telephony or telegraphy systems	17.5

(Continues)

TABLE 6 (Continued)

Country	2002–2005			2014–2017		
	Concentration index	Item description	Share, %	Concentration index	Item description	Share, %
Gabon	0.017	Transmission apparatus	6.9	0.033	Floating or submersible platforms	13.2
Gambia	0.033	Transmission apparatus	9.6	0.031	Transmission apparatus	10.6
Ghana	0.020	Transmission apparatus	9.3	0.017	Transmission apparatus	6.6
Guinea	0.019	Electric generating sets	7.6	0.028	Line telephony or telegraphy systems	12.2
Guinea-Bissau	0.028	Instruments and apparatus for telecommunications	7.8	0.063	Line telephony or telegraphy systems	17.2
Kenya	0.020	Transmission apparatus	10.0	0.014	Line telephony or telegraphy systems	6.2
Country		2002–2005			2014–2017	
	Concentration index	Item description	Share, %	Concentration index	Item description	Share, %
Lesotho	0.062	Textile machinery; n.e. s.	14.8	0.136	Line telephony or telegraphy systems	35.4
Liberia	0.316	Floating or submersible platforms	55.8	0.466	Floating cranes, floating docks	68.1
Madagascar	0.014	Transmission apparatus	7.4	0.018	Transmission apparatus	7.3
Malawi	0.040	Transmission apparatus	13.6	0.040	Transmission apparatus	16.0
Mali	0.023	Transmission apparatus	8.8	0.043	Line telephony or telegraphy systems	13.5
Mauritania	0.018	Transmission apparatus	6.2	0.017	Engines	5.9
Mauritius	0.168	Transmission apparatus	40.5	0.059	Transmission apparatus	21.7
Mozambique	0.044	Electroplating machines	16.1	0.023	Line telephony or telegraphy systems	11.0
Namibia	0.025	Transmission apparatus	10.8	0.020	Mechanical shovels, excavators	7.9
Niger	0.031	Telephonic or telegraphic switching apparatus	12.0	0.031	Line telephony or telegraphy systems	13.5
Nigeria	0.032	Transmission apparatus	14.1	0.029	Transmission apparatus	11.9
Rwanda	0.026	Transmission apparatus	11.8	0.094	Transmission apparatus	28.8

TABLE 6 (Continued)

	2002–2005			2014–2017		
Country	**Concentration index**	**Item description**	**Share, %**	**Concentration index**	**Item description**	**Share, %**
Sao Tome and Principe	0.036	Regulating or controlling instruments and apparatus	13.8	0.101	Transmission apparatus	27.3
Senegal	0.014	Transmission apparatus	6.7	0.027	Transmission apparatus	13.1
Seychelles	0.048	Cans of iron or steel	16.6	0.049	Transmission apparatus	18.6
Sierra Leone	0.014	Transmission apparatus	6.6	0.019	Mechanical shovels, excavators	6.2
Somalia	0.118	Telephonic or telegraphic switching apparatus	22.9	0.049	Line telephony or telegraphy systems	17.7
South Africa	0.026	Transmission apparatus	13.3	0.026	Transmission apparatus	12.7
South Sudan	-			0.056	Line telephony or telegraphy systems	19.4
Sudan	-			0.014	Line telephony or telegraphy systems	4.5
Togo	0.026	Transmission apparatus	13.6	0.159	Transmission apparatus	38.6
Uganda	0.052	Transmission apparatus	19.5	0.065	Line telephony or telegraphy systems	17.2
United Rep. of Tanzania	0.018	Transmission apparatus	9.6	0.034	Line telephony or telegraphy systems	14.9
Zambia	0.043	Telephonic or telegraphic switching apparatus	16.3	0.032	Transmission apparatus	14.3
Zimbabwe	0.024	Transmission apparatus	9.5	0.063	Line telephony or telegraphy systems	19.9

Note: Author's calculations using data from the UN Comtrade Database.

Analysing each country's top equipment and machinery import shows that transmission apparatus for radio, television etc. reception is the top capital good import for 27 of the 46 countries in the 2002–2005 period (Table 6). This item is replaced by telecommunications equipment in 2014–2017, where it is the top import in 21 SSA countries. To have a sense of the diversity of the type of capital goods imported by each country, Table 6 also provides the concentration index across all 627 six-digit HS codes classified as finished capital goods. The composition of Liberia's capital goods imports is the least diverse in the first and last periods with a concentration index of 0.316 and 0.466, respectively. Floating and submersible platforms make up 56% of Liberia's capital goods imports in the first period. A related item, floating cranes and docks, comprised 68% of the country's capital goods imports in the last period. Such observations are consistent with Liberia's flag of convenience status in the world of shipping (The Economist, 2019).

For most countries, the concentration index did not change dramatically between the two periods. Besides Liberia, notable exceptions to this are Angola which experienced an increase in the diversity of the types of capital goods imported, whereas the composition of Congo's and Togo's capital goods imports became less diverse. Although floating and submersible platforms continue to dominate Angola's capital goods imports, consistent with both the petroleum industry's dominance in the country's economy and oil production mostly coming from offshore fields [U.S. Energy Information Administration (EIA), 2021a], the item's share declined from 38 to 26%. Close to half of Congo's capital goods imports are floating cranes and docks in the last period (transmission equipment is the country's top import in the first period with only a 7% share), whereas Togo continues to import transmission equipment with the item's share increasing from 14 to 39%. The former observation is due to Congo's mostly offshore oil production and the launch of a series of bidding for petroleum exploration licences starting in 2015 (U.S. EIA, 2021b), whereas the latter observation is in line with Togo's dense media landscape (Reporters Without Borders, 2021). The latest available data (2012) show that Togo has 11 radio and two TV stations per million inhabitants, whereas Nigeria only has less than one of each per million inhabitants (International Research and Exchange, 2012).

Table 7 provides the top industrial machinery import of each country. These provide rough estimates of the extent and composition of production capacity augmentation in SSA countries that potentially can be linked to specific industries. For example, 15% of Lesotho's capital equipment imports in 2002–2005 are textile machinery. This is in line with the observation that the country is one of few countries in the region identified to have benefited from the Multifiber Agreement (Lawrence, 2005).[18] In the last period, nine SSA countries' top industrial and services machinery imports are machinery used in the beverage industry with shares ranging from 1% (Uganda) to 9% (Gabon).

The main takeaways from this section are as follows: The relative importance of capital goods in SSA countries' imports is comparable to those of low-income non-SSA countries. There is a movement away from traditional sources (e.g. France), China is now the top source of capital goods for more than half of the 48 SSA countries studied. Telecommunications equipment is the largest category of imports for most SSA countries. Focusing on sector-specific equipment and machinery imports, data show the continued dominance of the oil and mining sectors in the region. Moreover, the trade data also provided a snapshot of possible economic stasis or transformation among the SSA countries. Of particular interest are equipment and machinery that can be matched to a specific industry producing items that undergo some processing (non-primary products). Using various concordances, this direct matching is possible for 83 of the 627 six-digit HS codes classified as capital goods which make up about 6%–7% of SSA countries' total capital goods imports. These equipment and machinery can be matched to over a thousand six-digit HS non-primary items comprising about 20% of SSA countries' exports per year. Section 3.4 will focus on these capital goods imports and subsequent exports of items using such equipment and machinery. Prior to investigating whether capital stock augmentation through imports contributes to increased exports, it is necessary to first describe available capital stock data essential to this investigation.

3.3 | Capital stock data

Capital stock data are available from Feenstra et al.'s (2015) Penn World Table (PWT, version 10.0). This study uses the machinery component (which includes computers, communication equipment and other machinery) of the net capital stock data in the PWT.[19] For the purposes of this study, it is important to make a distinction between domestic- and foreign-sourced equipment and machinery. PWT does not make this distinction. Eaton and Kortum (2001) provide some guidance on apportioning existing capital stock into domestic and foreign shares. They find that a large proportion of equipment in five

[18]Besides Lesotho, Lawrence (2005) also identifies Kenya and South Africa to have benefited from the Multifiber Agreement, which started in 1972.

[19]The current cost net capital stock of machinery and (non-transport) equipment (N_c_Mach) from PWT version 10.0's capital detail data file is used. Depreciation rates are calculated as capital consumption (D_c_Mach) divided by N_c_Mach.

TABLE 7 Sub-Saharan African countries' top industrial and services machinery imports and their share, 2002–2005 and 2014–2017.

Country	2002–2005 Item description	Share, %	2014–1017 Item description	Share, %
Angola	Aluminium; casks, drums, cans, boxes and the like	0.6	Furniture; metal, not for office use	2.8
Benin	Pumps and liquid elevators; n.e.s.	1.1	Furniture; metal, not for office use	5.6
Botswana	Machines; for making bags, and related items, paper or paperboard	0.7	Furniture; metal, not for office use	1.6
Burkina Faso	Machinery; for packaging beverages	2.8	Machinery; for packaging beverages	2.6
Burundi	Machinery; for packaging beverages	3.4	Machinery; for packaging beverages	4.1
Cabo Verde	Machinery; for filtering or purifying water	5.1	Aluminium; casks, drums, cans, boxes and the like	4.5
Cameroon	Machinery; for packaging beverages	3.0	Furniture; metal, not for office use	1.2
Central African Rep.	Signalling apparatus	5.0	Machinery; for filtering or purifying water	5.8
Chad	Pumps and liquid elevators; n.e.s.	2.6	Pumps; centrifugal, n.e.s.	2.8
Comoros	Cranes; self-propelled, on tyres, n.e.s.	1.1	Furniture; metal, not for office use	12.1
Congo	Pumps and liquid elevators; n.e.s.	2.0	Pumps; centrifugal, n.e.s.	1.2
Côte d'Ivoire	Cans, of iron or steel	3.6	Fork-lift and other works trucks	1.8
Dem. Rep. of the Congo	Machinery; for packaging beverages	2.7	Furniture; metal, not for office use	1.5
Equatorial Guinea	Pumps and compressors	14.0	Cranes; portal or pedestal jib cranes	1.7
Eritrea	Machinery; for packaging beverages	2.8	Machines; for working non-metals	1.6
Eswatini	Compressors; used in refrigerating equip.	8.2	Compressors; used in refrigerating equip.	4.1
Ethiopia	Machinery; industrial, for bakery and similar products	1.0	Machinery; industrial, for sugar manufacture	2.1
Gabon	Pumps and compressors	4.8	Machinery; for filtering or purifying liquids, n.e.s.	8.7
Gambia	Furniture; metal, not for office use	1.5	Furniture; metal, not for office use	7.3
Ghana	Fork-lift and other works trucks	1.6	Furniture; metal, not for office use	2.5
Guinea	Reservoirs, tanks, vats and similar containers	2.6	Furniture; metal, not for office use	2.5
Guinea-Bissau	Pumps	2.0	Pumps; centrifugal, n.e.s.	1.3
Kenya	Machinery; for packaging beverages	2.4	Meters	1.8
Lesotho	Textile machinery; n.e.s.	14.8	Machinery; for filtering or purifying water	3.0
Liberia	Cranes; tower cranes	1.6	Elevators and conveyors; continuous action, n.e.s.	1.4
Madagascar	Sewing machines; not household or automatic unit type	2.3	Furniture; metal, not for office use	2.2

(Continues)

TABLE 7 (Continued)

Country	2002–2005 Item description	Share, %	2014–1017 Item description	Share, %
Malawi	Pumps; centrifugal, n.e.s.	1.7	Meters	3.6
Mali	Pumps and liquid elevators; n.e.s.	1.5	Machinery; industrial, for bakery and similar products	1.6
Mauritania	Pumps and liquid elevators; n.e.s.	1.7	Machinery; industrial, for bakery and similar products	2.6
Mauritius	Knitting machines	1.7	Furniture; metal, not for office use	2.3
Mozambique	Machines; for working non-metals	3.5	Furniture; metal, not for office use	2.6
Namibia	Machinery; for packaging beverages	4.1	Furniture; metal, not for office use	2.0
Niger	Machinery; for packaging beverages	1.3	Pumps; centrifugal, n.e.s.	2.9
Nigeria	Floating structures	1.9	Pumps; centrifugal, n.e.s.	2.2
Rwanda	Machines; for mixing, and related processes	1.5	Machinery; for filtering or purifying water	1.4
Sao Tome and Principe	Moulds; for rubber or plastics, injection or compression types	6.7	Machine tools; for working metal	2.3
Senegal	Machinery; for packing or wrapping	1.9	Furniture; metal, not for office use	4.5
Seychelles	Cans, of iron or steel	16.6	Floating structures	3.4
Sierra Leone	Fans; n.e.s.	2.3	Elevators and conveyors	3.5
Somalia	Pumps and liquid elevators; n.e.s.	1.1	Furniture; metal, not for office use	6.7
Country	2002–2005 Item description	Share, %	2014–2017 Item description	Share, %
South Africa	Compressors; used in refrigerating equip.	1.2	Fork-lift and other works trucks	1.0
South Sudan		-	Machinery; for filtering or purifying liquids, n.e.s.	2.3
Sudan		-	Pumps; centrifugal, n.e.s.	2.1
Togo	Machinery; for packing or wrapping	2.4	Cranes; transporter, gantry and bridge cranes	7.2
Uganda	Machinery; for packaging beverages	0.9	Machinery; for packaging beverages	1.0
United Rep. of Tanzania	Machinery; for packaging beverages	2.2	Furniture; metal, not for office use	2.5
Zambia	Machinery; for liquefying air or gas	1.9	Machinery; for packaging beverages	1.7
Zimbabwe	Textile machinery; spinning machines	1.7	Pumps; centrifugal, n.e.s.	1.7

Note: Author's calculations using data from the UN Comtrade Database.

SSA countries included in their study are foreign sourced with a range of 0.60 to 0.993. The median share of 0.73 is used to estimate foreign-sourced capital stock at the start of the analysis period in 2002 (*Kfs*).[20] This initial foreign-sourced capital stock is allowed to depreciate over time using the depreciation rates calculated from the PWT. The initial foreign-sourced net capital stock is augmented by imported

[20]As robustness check of the results, the minimum and maximum foreign source shares in Eaton and Kortum's study are also used.

equipment and machinery over time. Capital stock sourced domestically (*Kd*) is assumed to be 0.27 of the capital stock data from PWT. Although both domestic- and initial foreign-sourced net capital stock are available only at the aggregate level, it is important to control for both *Kd* and *Kfs* to properly evaluate the effect of augmenting local production capacity via capital goods imports (*Kimports*). *Kimports* is tracked starting in 2002, summed in each subsequent period and allowed to depreciate over time. This approach should not be overly problematic because *Kfs* is included in the regressions below. Since imported equipment and machinery augment production capacity, non-primary exports are expected to be positively associated with these imports.

3.4 | Import–export regression model

To investigate the import–export link, only non-primary exports are considered. These items are identified using the UN Comtrade's concordance between the 2002 six-digit HS codes (5224 codes) and BEC classification schemes. All six-digit HS codes classified as primary goods (578 codes) are excluded from the analysis. For example, BEC 111 are primary food and beverage items mainly used for household consumption, so all six-digit HS codes with this BEC classification are excluded from the analysis.

Imported capital equipment and machinery with broad uses potentially augment the production capacity of all firms. As a first step, exports of all non-primary goods are linked to imports of all capital goods with broad uses (general purpose) and specifically on imports of electricity-generating and telecommunications equipment. Access to electricity is necessary for processing raw materials, and access to telecommunication services lowers coordination costs along the production value chains. Next, imported equipment and machinery with specific uses are matched with the non-primary items these imports are used for. For example, imports of machinery for the manufacture of cocoa and chocolate (HS 843820) are matched with the total exports of all six-digit HS codes that fall under cocoa and cocoa preparations (HS 18) excluding those that are primary items. The specific use of 83 equipment and machinery imports (i.e. 83 six-digit HS codes) can be matched to the production of specific items. Appendix B provides the correspondence between capital goods imports and the subsequent exports of non-primary products using the capital goods.

Because data from the SSA countries are more limited, to identify subsequent exports, their trade partners' imports are used instead (mirror exports[21]). Since a majority of SSA countries are classified as low income, the exports of their low-income peers are also considered in the trade gravity regressions below. Data used in the regressions are from the UN Comtrade, PWT and Mario Larch's Regional Trade Agreements Database from Egger and Larch (2008).

Section 2.2 contains the theoretical framework for studying the relationship between imports of capital goods and subsequent exports of items using these capital goods. Certainly, besides imported capital goods, other factors are important determinants of countries' export capacity. This is where the trade gravity equation becomes relevant. In its basic form, the trade gravity model includes exporters' gross and per capita output (supply side controls), importers' gross and per capita income (demand side controls) and the distance between a trading pair. Besides these basic controls, additional controls that impede (e.g. tariffs) or enhance (e.g. common language) trade flows are also included in trade gravity regressions. The model has reliably explained observed bilateral total trade flows, thus its popularity. The empirical approach taken in this paper relies heavily on Yotov et al.'s (2016) detailed guide on the proper estimation of the structural gravity model described in detail below.

It is important to highlight that the regressand in the trade gravity regressions is the exports of all SSA and non-SSA low income to all export market destinations over time.[22] Separate regressions are performed at various levels of aggregation: total non-primary exports and by broad product groups. Each regression uses a panel data set with three dimensions: year, exporter, and importer.

[21]For brevity, mirror exports are referred to as exports below.

[22]Due to data availability, exports from only 64 rather than 73 countries (48 SSA countries and 25 low-income peers) are included in the regressions.

Yotov et al. (2016) provide several recommendations in the estimation of trade gravity equations relevant to this study. First, use panel data in 3-, 4- or 5-year intervals instead of consecutive years 'to allow for adjustment in bilateral trade flows in response to trade policy or other changes in trade costs'. (Yotov et al., 2016: 24). Second, include both exporter-time and importer-time fixed effects to control for unobservable outward (exporter) and inward (importer) multilateral resistance trade effects and other country characteristics that vary over time. This means that it is not necessary to include time-varying exporter (importer) characteristics such as gross and per capita output (income), their effects on trade flows are subsumed in the exporter-time (importer-time) fixed effects. Third, include pair fixed effects 'to account for the endogeneity of trade policy variables … and the effects of all time-invariant bilateral trade costs …' (Yotov et al., 2016: 25). The trade flow effects of non-time varying determinants between a pair of countries such as sharing a common border or language are covered by the pair fixed effects. Lastly, use the Poisson PPML estimator as it can handle both heteroskedasticity (inherent in trade data) and zero trade flows.[23]

As a preliminary step, all of Yotov et al.'s (2016) suggested best practices are implemented using bilateral panel trade data at 3-year intervals. Total bilateral non-primary export data are regressed against a series of exporter-year, importer-year and pair fixed effects and a dummy variable indicating whether a trading pair has a regional trade agreement (RTA) in place.[24] Contrary to theoretical predictions, the RTA dummy is not statistically significant at conventional levels (results not shown to conserve space). To make sense of this result, the three sets of fixed effects are excluded from the regressions. In this specification, the RTA dummy now has the expected positive coefficient. Together, these results suggest that although, on average, SSA countries and their low-income peers export more non-primary products to countries they have RTAs with, once one controls for observed and unobserved heterogeneity for each country over time (e.g. economic size and trade costs captured by the country-year fixed effects) and between each trading pair (e.g. common language captured by the pair fixed effects), RTAs have not boosted bilateral trade as expected. That is, there is no evidence that these agreements have led to more non-primary merchandise trade between SSA and non-SSA low-income countries and trading partners they have RTAs with. This result differs from studies such as that of Yotov et al. (2016), which did not limit their analysis to the exports of low-income countries nor to exports of only non-primary products.

Note that including exporter-year fixed effects precludes the inclusion of exporter characteristics that vary across time such as capital stock augmentation through imports as regressor. Because of the paper's main objective, exporter-year fixed effects are excluded in the regressions (as these are perfectly correlated with factors that vary across time for each exporter). Instead, the export regressions include exporter fixed effects along with exporter characteristics that vary across time such as exporters' equipment and machinery investments over time. To properly evaluate the effect of capital goods imports (*Kimports* is tracked starting in 2002, summed in each subsequent period and allowed to depreciate over time), it is also important to control for domestic-sourced net capital stock in each period (*Kd*, already accounts for depreciation) and foreign-sourced net capital stock at the start of the analysis period in 2002 (*Kfs* is allowed to depreciate over time). Because the output is a function of capital stock, all three regressors (*Kimports*, *Kd* and *Kfs*) are included in place of exporter output in the trade gravity equation.

The following trade gravity equation is estimated using the PPML estimator:

[23]In a series of papers, Santos Silva and Tenreyro (2006, 2010, 2011) make a convincing case that in the presence of heteroskedasticity, the PPML estimator is preferred (over the log-linear specification estimated using ordinary least squares, for example). The PPML has the added advantage of dealing with zero trade observations in a natural way. Santos Silva and Tenreyro emphasise that the PPML estimator is appropriate even if the regressand is not Poisson. All that is necessary for consistency is for the conditional mean to be correctly specified. Santos Silva and Tenreyro (2006) show that the first-order conditions for estimating multiplicative models, such as the trade gravity equation, is equivalent to the first-order conditions of the PPML estimator typically used with count data. This coincidence (equivalence of first-order conditions) has made the PPML the preferred estimator for estimating trade gravity models.

[24]Correia et al.'s (2020) PPMLHDFE Stata package is used in all estimations.

$$\exp_{ij,t} = \alpha_i + \gamma_{j,t} + \delta_{ij} + \theta\,\mathrm{RTA}_{ij,t} + \beta_1 \ln(Lag\, Kd_{i,t}) + \beta_2 \ln(Lag\, Kfs_{i,t}) + \beta_3 \ln(Lag\, Kimports_{i,t}) + \epsilon_{ij,t}, \quad (1)$$

where $exp_{ij,t}$ is country i exports to country j in period t measured in levels. α_i and $\gamma_{j,t}$ are the exporter fixed effects and importer-year fixed effects, respectively. δ_{ij} are country pair i and j fixed effects. $RTA_{ij,t}$ is a qualitative indicator equal to 1 if country i and country j have an RTA in place at period t.[25] The three capital stock variables are measured with a lag of one period as these are capital stocks available for deployment at the start of period t. Both $Kd_{i,t}$ and $Kfs_{i,t}$ are only available at the aggregate level. As explained in section 3.3, *Kd* is assumed to be 0.27 of the capital stock data from PWT.

Equation (1) is estimated in two ways: First, $exp_{ij,t}$ is taken as the sum of all non-primary product exports of country i to country j in period t. This is matched with $Kimports_{i,t}$ measured three ways: all general-purpose equipment and machinery, electric and electricity-generating equipment only and telecommunications equipment only. Second, $exp_{ij,t}$ is calculated as the sum of select non-primary product exports matched to relevant $Kimports_{i,t}$. For example, country *i*'s bilateral exports of select manufactured items (e.g. textiles and textile articles) to country *j* at period *t* are matched with its net stock of industry-specific equipment and machinery imports used in the production of these items. Throughout, the natural log of the net capital stock is used,[26] so the coefficient estimates are import–export elasticities, that is, the export response for a 1% increase in the net stock of imported equipment and machinery. Altogether 15 broad types of industry-specific equipment and machinery consisting of 83 six-digit HS items are matched with 1535 six-digit HS non-primary items summed over 33 two-digit HS codes (see Appendix B for details). Exports linked to industry-specific equipment and machinery imports comprise about 20% of non-primary product exports each year.

For reference, descriptive statistics and pairwise correlations of the variables are provided in Tables A1 and A2, respectively. The estimation sample consists of an unbalanced panel of as many as 64 exporters and as many as 181 of their trading partners with data at 3-year intervals (2005, 2008, 2011, 2014 and 2017).[27] This is the working sample, but note that sample sizes vary across estimations depending on the presence of singletons or when there is no within-pair variation over time (e.g. $exp_{ij,t}$ is 0 for all period t for a specific country i and country j pair). Average bilateral non-primary product exports are about \$53.9 million per year, whereas the annual average net stock of imported general-purpose equipment and machinery (imported since 2002) is \$2.41 billion. Table A2 shows that *Kd* and *Kfs* have a high positive correlation (0.91).[28] The pairwise correlations between *Kd* and *Kimports* range from 0.47 to 0.53, whereas those for *Kfs* and *Kimports* range from 0.34 to 0.38.

3.5 | Analysis of results

Table 8 contains elasticity estimates of regressing the exports of all non-primary products against various measures of the net stock of imported capital goods since 2002 aggregated in three ways: column (1) includes all imported general-purpose capital goods, column (2) includes electric and electric generating equipment and column (3) includes telecommunications equipment. Throughout, statistical significance is established at the 5% level. Controlling for the net stock of domestic-sourced capital goods and the initial net stock of foreign-sourced capital goods, the estimates show a positive correlation between

[25] As mentioned in section 2.2, since the export data involve over a thousand six-digit HS non-primary items, it is impractical to quantify all the intermediate inputs used in the production of each item. Leaving out imported intermediate inputs is not overly problematic as the presence of trade agreements opens up or widens access to imported intermediate inputs. In other words, the RTA dummy partly accounts for access to imported intermediate inputs which mitigates any potential bias in the estimated coefficients.

[26] To keep observations with zero *Kimports* values, log (1 + *Kimports*) is used in the regressions.

[27] Working backwards from 2017 provides adequate data coverage and time to track capital goods imports since 2002.

[28] Not surprising as both are calculated from a common base (PWT's capital stock data) with a 0.27 share for *Kd* and 0.73 for *Kfs*.

the net stock of imported equipment and machinery and subsequent exports of non-primary products. The elasticity estimates range from 0.77 to 1.24. Thus, there is evidence that augmenting the net stock of electricity-generating and telecommunications equipment via imports is associated with increased export capacity. Electricity is needed to process raw materials, whereas telecommunication services lower the cost of coordinating activities along the production value chains. Not surprisingly, the elasticity estimates are larger for all general-purpose capital goods (Column (1)) as this additionally includes computers, business machinery and other general-purpose capital goods besides those that generate electricity and provide telecommunication services.

When statistically significant, *Kd* and *Kfs* have negative and positive signs, respectively. These suggest that the initial net stock of foreign-sourced capital goods augments export capacity, whereas the net stock of domestic-sourced capital goods curtails exports. Domestically sourced equipment and machinery might have expanded production capacity to mainly supply domestic markets and thus are negatively correlated with export capacity. As in the preliminary regressions, the RTA dummy is statistically insignificant. This result is consistent with UNCTAD's (2019: 30) observation that 'the liberalization of tariffs … has been slower than scheduled' and a large proportion of intraregional tariffs in the various RTAs in the region have yet to be reduced to zero. For example, 90% of the tariff lines in the Economic Community of West African States (ECOWAS) need to be reduced to zero (UNCTAD, 2019), the highest among the RTAs in the region. The result is also consistent with the notion that firms in the region have not been able to take advantage of the benefits of preferential market access through RTA membership perhaps due to limited production capacity or high trade costs.

Table 9 contains the estimates for the 15 broad types of industry-specific equipment and machinery. There is some evidence in favour of the study's main hypothesis that the net stock of industry-specific imported equipment and machinery augments production capacity and this is partly reflected in increased exports of items using these imported equipment and machinery. The natural log of *Kimports* is statistically significant with a positive coefficient in nine of the 15 regressions. The elasticity estimates range from 0.10 [Column (6), preparations of vegetables, fruits and nuts] to 1.10 [Column (9), articles of plastics, rubber, woods and cork]. *Kimports* is statistically significant in

TABLE 8 Trade gravity regressions using the PPML estimator.

Variables	(1) General purpose	(2) Electric and electric gen. equip.	(3) Telecom equip.
Log exporter *Kimports*	1.2433***	0.7653***	0.9324***
	(0.134)	(0.095)	(0.140)
Log exporter *Kd*	−0.2408**	−0.0325	−0.2186**
	(0.103)	(0.097)	(0.110)
Log exporter *Kfs*	1.4970	2.9245***	1.8032*
	(0.990)	(0.919)	(0.995)
RTA dummy	−0.0635	−0.0937	−0.0845
	(0.081)	(0.096)	(0.082)
Constant	−24.7600*	−35.8765***	−21.5709
	(13.423)	(12.271)	(13.457)
Observations	39,822	39,822	39,822
Exporter Fixed Effects	Yes	Yes	Yes
Importer-Year FE	Yes	Yes	Yes
Pair FE	Yes	Yes	Yes
Pseudo R-squared	0.983	0.983	0.982

Note: Estimates use data for 2005, 2008, 2011, 2014 and 2017. Standard errors are clustered by country pairs in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

TABLE 9 Trade gravity regressions using the PPML estimator, by type of equipment and machinery imports.

Variables	(1) type = 1	(2) type = 2	(3) type = 3	(4) type = 4	(5) type = 5
Log exporter *Kimports*	0.1596***	0.0699	0.0394	0.2624**	0.0595
	(0.058)	(0.093)	(0.031)	(0.130)	(0.092)
Log exporter *Kd*	0.5401**	0.0323	0.3233	0.4675***	−0.0874
	(0.220)	(0.157)	(0.239)	(0.165)	(0.131)
Log exporter *Kfs*	−1.8237	2.1704	1.9619	−1.5825	4.7172**
	(2.519)	(4.021)	(2.597)	(3.448)	(1.862)
RTA dummy	−0.1486	−0.2780	0.1710	0.7210***	−0.3089***
	(0.225)	(0.171)	(0.199)	(0.245)	(0.113)
Constant	38.6857	−13.9588	−11.7668	26.9612	−53.2145*
	(43.788)	(55.143)	(29.686)	(45.340)	(27.588)
Observations	9,207	7,157	8,529	6,383	8,565
Exporter Fixed Effects	Yes	Yes	Yes	Yes	Yes
Importer-Year FE	Yes	Yes	Yes	Yes	Yes
Pair FE	Yes	Yes	Yes	Yes	Yes
Pseudo *R*-squared	0.993	0.973	0.901	0.974	0.980

Variables	(6) type = 6	(7) type = 7	(8) type = 8	(9) type = 9	(10) type = 10
Log exporter *Kimports*	0.0992**	0.7820***	0.0724	1.0955***	1.0010***
	(0.040)	(0.208)	(0.084)	(0.128)	(0.122)
Log exporter *Kd*	0.3283*	−0.0623	0.8240*	0.0409	0.3085*
	(0.197)	(0.215)	(0.431)	(0.092)	(0.177)
Log exporter *Kfs*	−0.3271	1.7646	4.5430	−4.5551***	9.1566***
	(1.554)	(1.815)	(4.468)	(1.673)	(1.675)
RTA dummy	0.4250***	0.0990	0.7162*	−0.1844*	−0.1339
	(0.121)	(0.207)	(0.388)	(0.106)	(0.182)
Constant	14.1245	−15.5061	−60.0091	64.4616***	−138.9972***
	(18.584)	(19.818)	(58.975)	(24.042)	(23.904)
Observations	10,359	11,260	4,740	26,546	16,080
Exporter Fixed Effects	Yes	Yes	Yes	Yes	Yes
ImporterYear FE	Yes	Yes	Yes	Yes	Yes
Pair FE	Yes	Yes	Yes	Yes	Yes
Pseudo *R*-squared	0.974	0.971	0.961	0.984	0.991

Variables	(11) type = 11	(12) type = 12	(13) type = 13	(14) type = 14	(15) type = 15
Log exporter *Kimports*	0.4530***	1.0365***	0.3804***	0.0440	−0.0874***
	(0.148)	(0.178)	(0.086)	(0.061)	(0.031)
Log exporter *Kd*	−0.3786	−0.1254	−0.0570	−0.7467***	−1.1183***
	(0.327)	(0.343)	(0.140)	(0.203)	(0.379)
Log exporter *Kfs*	1.3983	−7.7932**	4.4609***	7.0233***	9.1607**
	(2.523)	(3.158)	(1.491)	(1.834)	(3.940)

(Continues)

TABLE 9 (Continued)

Variables	(11) type = 11	(12) type = 12	(13) type = 13	(14) type = 14	(15) type = 15
RTA dummy	0.1885	−0.2339	−0.1861	−0.1645	−0.0538
	(0.174)	(0.249)	(0.117)	(0.168)	(0.238)
Constant	−6.3387	99.8531**	−48.7633**	−78.4982***	−98.8291*
	(36.361)	(39.890)	(19.424)	(25.628)	(54.023)
Observations	15,261	17,812	28,015	15,029	12,821
Exporter Fixed Effects	Yes	Yes	Yes	Yes	Yes
Importer-Year FE	Yes	Yes	Yes	Yes	Yes
Pair FE	Yes	Yes	Yes	Yes	Yes
Pseudo R-squared	0.989	0.963	0.991	0.994	0.967

Note: Estimates use data for 2005, 2008, 2011, 2014, and 2017. Standard errors are clustered by country pairs in parentheses. See Appendix B for the list of capital goods (equipment and machinery) imports included in each type. Column (1): animal or vegetable fats and oils and related items; (2) preparations of meat, fish and other related items; (3) sugar and sugar confectionary; (4) cocoa and cocoa preparations; (5) preparations of cereals, flour, starch or milk; (6) preparations of vegetables, fruits and nuts; (7) beverages, spirits and vinegar; (8) tobacco and manufactured tobacco substitutes; (9) plastics, rubber, wood and cork and articles thereof; (10) articles of leather, fur skins and related products; (11) pulp, paper and paperboard, and related items; (12) printed books, newspapers and related products; (13) textiles and textile articles; (14) footwear; (15) glass and glassware.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

most non-food related products such as articles of plastics, rubber, wood and cork (type = 9) and textile and textile articles (type = 13). It is important to note though that a statistically insignificant coefficient estimate for *Kimports* does not rule out an increase in production capacity. It is possible that the observed statistically insignificant export response is due either to domestic demand absorbing all additional output or a lack of foreign demand precluding exports. Thus, this paper is only able to provide lower bound estimates of the production capacity-building effects of the net stock of imported equipment and machinery.

Not surprisingly, because both *Kd* and *Kfs* are measured at the aggregate level, and RTAs apply broadly rather than to specific goods, the coefficient estimates for these factors are statistically significant in very few regressions with mixed signs. *Kd* augments export capacity only in animal or vegetable fats and oils (type = 1) and cocoa and cocoa preparations (type = 4). *Kfs* is statistically significant with a positive coefficient in a third of the 15 regressions. For example, the net initial stock of (aggregate) foreign-sourced equipment and machinery is associated with increased exports of textile and textile articles (type = 13). Exports of cocoa and cocoa preparations (type = 4) and preparations of vegetables, fruits and nuts (type = 6) are higher among countries with RTAs.

As robustness checks, Equation (1) is re-estimated using panel data at 4-year intervals, and then, it is also re-estimated by assuming *Kd* is equal to 0.007 and 0.40 to account for the range of values identified in Eaton and Kortum's (2001) study. For the most part, the results for these two sets of robustness checks are comparable to those in Tables 8 and 9. Because China is now the main source of capital goods for the SSA countries and their low-income peers, Equation (1) is also re-estimated using capital goods imported only from China. Recall that a good portion of the SSA countries' capital goods imports from China are telecommunications equipment. PPML regression shows that a 1% increase in *Kimports* (telecom equipment) from China increases non-primary exports only by 0.07% (much lower than the 0.93 elasticity estimate from all source countries). The export elasticity effect of *Kimports* (electric and electric generating equipment) from China is close to half of the estimated effect from all sources (0.33 vs 0.76). Among the 15 broad types of industry-specific equipment and machinery imported from China, only those used in the production of articles of plastics, rubber, woods and cork (elasticity estimate of 0.33) and printed books, newspapers and related products (elasticity estimate of 0.23) are positively associated with subsequent non-primary exports.

Lastly, Equation (1) is also re-estimated using the SSA sub-sample only. Total bilateral non-primary products exports continue to be positively correlated with the three measures of the net stock of imported general-purpose equipment and machinery, but the elasticity estimates are much smaller in magnitude at about 0.12 to 0.14 (compared to 0.77–1.24 for the full sample). The results for industry-specific *Kimports* are qualitatively similar to those using the full sample (elasticity estimates range from 0.15 to 1.84) with three exceptions. The coefficient for *Kimports* is no longer statistically significant in cocoa and cocoa preparations (type = 4), articles of leather, fur skins, and related products (type = 10) and textiles and textile articles (type = 13). These suggest that results for these three product groups for the full sample are primarily due to variations in *Kimports* between SSA countries as a group and their low-income peers as a group.[29] Among SSA countries, variations in *Kimports* in these three equipment and machinery types are insufficient to explain variations in exports of non-primary products using these three types of capital goods.[30]

4 | DISCUSSION AND CONCLUDING REMARKS

As argued in the introductory section, the large electricity and telecommunication infrastructure deficits or lack of technology readiness by the SSA countries can partly be ameliorated by the sourcing of capital goods abroad. Because imported capital equipment and machinery augment a country's physical capital stock, they could generate new employment and production opportunities and lead to a diversification of a country's economic base. Moreover, technology embodied in these imports could boost firm productivity, thereby increasing its capacity to export. Due to data limitations, an indirect approach is used to ascertain the potential economic diversification or improved productivity effects of such imports. The paper's central idea is that these effects could be gleaned indirectly from increased export capacity. In particular, SSA countries' exports of non-primary products are expected to be positively associated with their capital equipment and machinery imports.

PPML regressions show that aggregate export capacity in non-primary products is positively associated with the net stock of imported equipment used in generating electricity and providing telecommunication services. A similar export capacity augmentation effect is found among the net stock of selected imported equipment and machinery, mostly those used in the production of non-food, non-primary products such as plastics, rubber, wood and cork articles; pulp, paper and paperboard and related items. Although primary products still account for 54% of the SSA region's exports in 2014–2017, this is more than 10 percentage points lower compared to more than a decade ago. Moreover, slightly more SSA countries (a margin of four countries) experienced an increase in the share of non-primary product exports with nine (six) countries experiencing more than a 20-percentage point rise (drop) in the share of non-primary product exports. The increased share of non-primary products in the SSA region's exports together with the regression results is indicative of some form of economic restructuring (albeit limited) happening in the region.

Rodrik (2016) argues that industrialization as a path to sustained economic growth will be harder for African countries due to tougher global competition. Participation in regional and global value chains (which RTAs facilitate) could make it easier for SSA countries to industrialise. Since there is little to no evidence that RTAs are associated with increased non-primary product exports, if SSA countries are to eventually develop regional value chains and participate in global value chains, policies that encourage capital stock augmentation through imports might be a necessary first step. Lowering barriers is especially critical in industries with strong backward linkages to the SSA region's natural endowments (e.g. articles of plastics, rubber, wood and cork) and forward linkages to producers and consumers not only in the African continent but also worldwide (e.g. beverages, spirits and vinegar).

[29]UNCTAD (2019) estimates that 75% of the world's production of cocoa beans originate in Africa, which implies a distinct difference between SSA and their low-income peers when it comes to the processing of cocoa beans for export. On the other hand, only 5% of the world's cotton production originate in Africa and both India and Pakistan (two low-income peers) are major producers of cotton.

[30]Results for all robustness checks are available in Appendix S1: Supporting Information (online appendix).

It is reassuring to observe that duty rates for the 83 industry-specific capital goods included in this study are low, on average, in the 30 SSA countries with tariff data. Average Most Favored Nation (MFN) duty rates range from 0 to 11.4% in 2005[31] (The World Bank, 2021b). In fact, these equipment and machinery enter duty free in nine countries, mostly countries in the eastern (e.g. Kenya and Tanzania) and southern (e.g. Lesotho and Namibia) parts of the African continent. However, reported bound duty rates are much higher than the MFN duty rates in some countries.[32] For example, MFN duty rates for all 83 items are 0 in both Lesotho and Namibia, but the average bound duty rate in Lesotho is 60%, whereas in Namibia, it is only 2.9% in 2005. Thus, there is potential for a more restrictive tariff regime in Lesotho but not in Namibia. Moreover, for a majority of the 30 SSA countries with tariff data, the maximum MFN duty in 2005 is 20%. Given the paper's findings, one good strategy for expanding export capacity in manufactures is to further lower or completely remove tariff barriers to capital goods imports. At the time of writing, for 17 SSA countries with tariff data in 2017, the maximum MFN duty rate is 10%.

Tackling non-tariff barriers on equipment and machinery imports is also necessary. UNCTAD (2015) estimates an 11.3% ad valorem equivalent (AVE) for technical barriers to trade (TBTs) on Africa's machinery imports compared to a 4.1% AVE on Asia's machinery imports. TBTs on machinery include requirements such as product registration, testing and inspection. Since these requirements can potentially obstruct the development of industrial capacity in the region, a detailed assessment of their impacts is necessary. As of the end of 2021, for the 83 equipment and machinery studied in this research, 13 SSA countries have notified the World Trade Organization (WTO) of at least one TBT measure, with a median of six TBT measures in place (WTO, 2022). Kenya and South Africa have the largest number of TBT measures in place at 56 and 51, respectively. Requirements that unnecessarily run up compliance costs without commensurate benefits must be eliminated.

This research focused on the export size effect of capital goods imports. A possible extension is to investigate the export diversification effect of such imports. The literature provides some ways to measure diversification. One approach is to identify the emergence of new products (extensive margin) beyond the export effect on existing products (intensive margin) (e.g. Hummels & Klenow, 2005). Another approach is to use the entire set of product exports when calculating diversification indices (e.g. Agosin et al., 2012).

Another extension is to delve into the possible differential export effects of different types of RTAs (e.g. free trade agreements [FTAs] and custom unions), depth of RTA coverage, or the length of time RTAs have been in force. This would be especially relevant given the proliferation of RTAs among SSA countries[33] and the recent signing of the agreement for an African Continental Free Trade Area (AfCFTA), which came into force on 30 May 2019. UNCTAD (2019: 5) expects AfCFTA to contribute to the region's transformation agenda by 'achieving greater scale economies and—perhaps more fundamentally—harnessing complementarities' among countries in the continent thereby increasing intra-region trade. Such complementarities also create opportunities for diversification and the development of value chains in the region, which could, ultimately, lead to participation in global value chains. However, trade expansion and diversification are not possible if African countries' production capacities remain limited and not augmented.

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[31]This is the year with the most available tariff data for the SSA countries and the 83 equipment and machinery analysed in the paper.

[32]Imports are charged Most Favored Nation (MFN) duty rates if they originate from WTO member countries while bound duty rates are the maximum tariff rates countries commit as part of their WTO membership obligations.

[33]According to the WTO's (2021) RTA Database, the SSA region has several customs union in place: Common Market for Eastern and Southern Africa (COMESA, in force since 1994), Economic Community of West African States (ECOWAS, in force since 1995), Economic and Monetary Community of Central Africa (CEMAC, in force since 1999), East African Community (EAC, in force since 2000), West African Economic and Monetary Union (WAEMU, in force since 2000) and Southern African Customs Union (SACU, in force since 2004). The Southern African Development Community (SADC, in force since 2000) is an FTA.

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CONFLICT OF INTEREST STATEMENT

There is no conflict of interest.

DATA AVAILABILITY STATEMENT

The trade data underlying this article were provided by the United Nations Comtrade under permission (subscription). Data will be shared on request to the corresponding author with the permission of the United Nations Comtrade. The capital stock and RTA data underlying this article are available in Penn World Tables version 10.0, at http://www.ggdc.net/pwt and Mario Larch's Regional Trade Agreements Database, at https://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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APPENDIX A: COUNTRY COVERAGE

The top 32 capital goods exporters included in the analysis are as follows: Austria, Belgium, Brazil, Canada, China, Hong Kong, Czech Republic, Denmark, Finland, France, Germany, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Malaysia, Mexico, Netherlands, Philippines, Poland, Republic of Korea, Singapore, Spain, Sweden, Switzerland, Thailand, United States, United Kingdom and Viet Nam.

The following Sub-Saharan African countries are included in the analysis: Angola, Benin, Botswana**, Burkina Faso, Burundi, Cabo Verde*, Cameroon, Central African Republic, Chad, Comoros, Republic of Congo, Côte d'Ivoire, Democratic Republic of the Congo#, Equatorial Guinea, Eritrea#, Eswatini*, Ethiopia, Gabon**, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius**, Mozambique, Namibia*, Niger, Nigeria, Rwanda, São Tomé and Principe, Senegal, Seychelles**, Sierra Leone, Somalia#, South Africa*, South Sudan (starting 2012)#, Sudan (starting 2012)#, Tanzania, Togo, Uganda, Zambia and Zimbabwe. In 2002, these countries were classified as low income by the World Bank except those marked with one asterisk (which were classified as lower middle-income countries) and two asterisks (upper middle-income countries). Countries with # are excluded from the regressions due to missing capital stock data from the Penn World Table.

The comparison group includes the following 25 low-income countries as classified by the World Bank in 2002: Afghanistan#, Azerbaijan, Bangladesh, Bhutan, Cambodia, Georgia, Haiti, India, Indonesia, Dem. Rep. of Korea#, Kyrgyz Republic, Laos, Moldova, Mongolia, Myanmar, Nepal, Nicaragua, Pakistan, Papua New Guinea#, Solomon Islands#, Tajikistan, Timor-Leste#, Uzbekistan, Viet Nam and the Republic of Yemen. Countries with # are excluded from the regressions due to missing capital stock data from the Penn World Table.

TABLE A1 Descriptive statistics.

Variable	Mean	Std. dev.	Min	Max
exp[a]	53.9	653.0	0	46,100.0
Kimports (general purpose)[a]	2410.0	8380.0	0	87,000.0
Kimports (electric and electric generating equip.)[a]	470.0	1340.0	0	9320.0
Kimports (telecom equip.)[a]	1280.0	4490.0	0	48,600.0
Kd[b]	10,100.0	61,400.0	0.1611	731,000.0
Kfs[b]	2042.1	15,100.0	0.0321	209,000.0
FTA	0.1325	-	0	1

Note: Unbalanced panel consisting of as many as 64 exporters and as many as 181 trade partners for 2005, 2008, 2011, 2014 and 2017. $n = 57{,}635$. This is the working sample for the trade gravity regressions.
[a]Million US dollars.
[b]Thousand 2011 US dollars.

TABLE A2 Pairwise correlations.

	(1)	(2)	(3)	(4)	(5)	(6)
exp (1)	1.00					
Log Kimports (general purpose) (2)	0.12	1.00				
Log Kimports (electric and electric generating equip.) (3)	0.12	0.97	1.00			
Log Kimports (telecom equip.) (4)	0.12	1.00	0.96	1.00		
Log Kd (5)	0.13	0.49	0.53	0.47	1.00	
Log Kfs (6)	0.11	0.36	0.38	0.34	0.91	1.00

Note: See notes in Table A1.

APPENDIX B: CORRESPONDENCE BETWEEN CAPITAL GOODS (MACHINERY) IMPORTS AND SUBSEQUENT PRODUCT EXPORTS USING THESE CAPITAL GOODS

Type	Equipment HS codes	Description	Export HS codes[b]	Description
1	847920	Machinery; for the extraction or preparation of animal or fixed vegetable fats or oils	15	Animal or vegetable fats and oils, and related items
2	843850	Machinery; industrial, for the preparation of meat or poultry	16	Preparations of meat, fish, and other related items
3	843830	Machinery; industrial, for sugar manufacture	17	Sugars and sugar confectionery
4	843820	Machinery; industrial, for the manufacture of confectionery, cocoa or chocolate	18	Cocoa and cocoa preparations
5	841720	Ovens; non-electric, bakery ovens, including biscuit ovens	19	Preparations of cereals, flour, starch or milk; bakers' wares
5	842111	Centrifuges; cream separators	19	
5	843810	Machinery; industrial, for bakery and for the manufacture of macaroni, spaghetti or similar products	19	
6	843860	Machinery; industrial, for the preparation of fruits, nuts or vegetables	20	Preparations of vegetables, fruits, nuts or other parts of plants
7	842121	Machinery; for filtering or purifying water	22	Beverages, spirits, and vinegar
7	842122	Machinery; for filtering or purifying beverages other than water	22	
7	843510	Presses, crushers and similar machinery; used in the manufacture of wine, cider, fruit juices or similar beverages	22	
7	843840	Machinery; industrial, brewery machinery	22	
8	847810	Machinery; for preparing or making up tobacco, n.e.s. in this chapter	24	Tobacco and manufactured tobacco substitutes
9	847751	Machinery; for moulding or retreading pneumatic tyres or for moulding or otherwise forming inner tubes	39–40; 44–45	Plastics, rubber, wood and cork and articles thereof
9	847759	Machinery; for moulding or forming, other than for moulding or retreading pneumatic tyres or for moulding or otherwise forming inner tubes	39–40; 44–45	
9	847710	Machinery; injection moulding, for rubber or plastics	39–40; 44–45	
9	847720	Machinery; extruding, for rubber or plastics	39–40; 44–45	
9	847730	Machinery; blow moulding, for rubber or plastics	39–40; 44–45	

APPENDIX (Continued)

Type	Equipment HS codes	Description	Export HS codes[b]	Description
9	847740	Machinery; vacuum moulding and other thermoforming machines for rubber or plastics	39–40; 44–45	
9	847780	Machinery; for working rubber or plastics n.e.s. in heading no. 8477	39–40; 44–45	
9	848071	Moulds; for rubber or plastics, injection or compression types	39–40; 44–45	
9	848079	Moulds; for rubber or plastics, other than injection or compression types	39–40; 44–45	
9	846510	Machine tools; which can carry out different types of machining operations without tool change between such operations, for working wood, cork, bone, hard rubber, hard plastics	39–40; 44–45	
9	846591	Machine tools; sawing machines, for working wood, cork, bone, hard rubber, hard plastics or similar hard materials	39–40; 44–45	
9	846592	Machine tools; planing, milling or moulding (by cutting) machines, for working wood, cork, bone, hard rubber, hard plastics or similar hard materials	39–40; 44–45	
9	846593	Machine tools; grinding, sanding or polishing machines, for working wood, cork, bone, hard rubber, hard plastics or similar hard materials	39–40; 44–45	
Type	Equipment HS codes	Description	Export HS codes[b]	Description
9	846594	Machine tools; bending or assembling machines, for working wood, cork, bone, hard rubber, hard plastics or similar hard materials	39–40; 44–45	
9	846595	Machine tools; drilling or morticing machines, for working wood, cork, bone, hard rubber, hard plastics or similar hard materials	39–40; 44–45	
9	846596	Machine tools; splitting, slicing or paring machines, for working wood, cork, bone, hard rubber, hard plastics or similar hard materials	39–40; 44–45	
9	847930	Machinery and mechanical appliances; presses for the manufacture of particle or fibre building board of wood or other ligneous materials and other machinery for treating wood or cork	39–40; 44–45	
10	845310	Machinery; for preparing, tanning or working hides, skins or leather, other than sewing machines	42–43	Articles of leather, fur skins, and related products
10	845380	Machinery; for making or repairing articles of hides, skins or leather, other than sewing machines	42–43	
11	843910	Machinery; for making pulp of fibrous cellulosic material	47–48	Pulp, paper and paperboard, and related products
11	843920	Machinery; for making paper or paperboard	47–48	
11	843930	Machinery; for finishing paper or paperboard	47–48	
11	844110	Machines; cutting, of all kinds, for making up paper pulp, paper or paperboard	47–48	

(Continues)

APPENDIX (Continued)

Type	Equipment HS codes	Description	Export HS codes[b]	Description
11	844120	Machines; for making bags, sacks or envelopes of paper pulp, paper or paperboard	47–48	
11	844130	Machines; for making cartons, boxes, cases, tubes, drums or similar containers (other than by moulding), of paper pulp, paper or paperboard	47–48	
11	844140	Machines; for moulding articles, in paper pulp, paper or paperboard	47–48	
11	844180	Machinery; n.e.s. in heading no. 8441, for making up paper pulp, paper or paperboard	47–48	
12	844010	Book-binding machinery; including book-sewing machines	49	Printed books, newspapers, related products
12	844210	Machinery; phototype-setting and composing, excluding machine tools of heading no. 8456 to 8465	49	
12	844220	Machinery; apparatus and equipment, for type-setting or composing by processes other than photo-type, with or without founding device	49	
12	844230	Machinery; apparatus and equipment, for preparing or making printing blocks, plates, cylinders or other printing components	49	
12	844311	Printing machinery; offset, reel fed	49	
12	844312	Printing machinery; offset, sheet fed, office type (sheet size not exceeding 22 × 36 cm)	49	
12	844319	Printing machinery; offset, (excluding reel or sheet fed)	49	
12	844321	Printing machinery; letterpress, reel fed, excluding flexographic printing	49	
12	844329	Printing machinery; letterpress, other than reel fed, excluding flexographic printing	49	
12	844330	Printing machinery; flexographic	49	
12	844340	Printing machinery; gravure	49	
Type	Equipment HS codes	Description	Export HS codes[b]	Description
12	844360	Printing machinery; machines for uses ancillary to printing	49	
12	900610	Cameras, photographic (excluding cinematographic); of a kind used for preparing printing plates or cylinders	49	
13	844400	Textile machinery; for extruding, drawing, texturing or cutting man-made textile materials	50–63	Textile and textile articles
13	844511	Textile machinery; carding machines for preparing textile fibres	50–63	
13	844512	Textile machinery; combing machines for preparing textile fibres	50–63	
13	844513	Textile machinery; drawing or roving machines for preparing textile fibres	50–63	
13	844519	Textile machinery; n.e.s. in heading no. 8445, for preparing textile fibres	50–63	

APPENDIX (Continued)

Type	Equipment HS codes	Description	Export HS codes[b]	Description
13	844520	Textile machinery; spinning machines	50–63	
13	844530	Textile machinery; doubling or twisting machines	50–63	
13	844540	Textile machinery; winding (including weft-winding) or reeling machines	50–63	
13	844590	Textile machinery; involved in textile fibre or textile yarn preparation and n.e.s. in heading no. 8445	50–63	
13	844610	Weaving machines (looms); for weaving fabrics of a width of 30 cm or less	50–63	
13	844621	Weaving machines (looms); for weaving fabrics of a width exceeding 30 cm, shuttle type, power looms	50–63	
13	844629	Weaving machines (looms); for weaving fabrics of a width exceeding 30 cm, shuttle type, other than power looms	50–63	
13	844630	Weaving machines (looms); for weaving fabrics of a width exceeding 30 cm, shuttleless type	50–63	
13	844711	Knitting machines; circular, with cylinder diameter not exceeding 165 mm	50–63	
13	844712	Knitting machines; circular, with cylinder diameter exceeding 165 mm	50–63	
13	844720	Knitting machines; flat, stitch-bonding machines	50–63	
13	844790	Machines; for making gimped yarn, tulle, lace, embroidery, trimmings, braid or net and machines for tufting	50–63	
13	844900	Machinery; for manufacture or finishing felt or non-wovens in the piece or in shapes, including machinery for making felt hats, blocks for making hats	50–63	
13	845129	Drying machines; of a dry linen capacity exceeding 10 kg	50–63	
13	845130	Ironing machines and presses (including fusing presses)	50–63	
13	845140	Machines; for washing, bleaching or dyeing	50–63	
13	845150	Machines; for reeling, unreeling, folding, cutting or pinking textile fabrics	50–63	
13	845180	Machinery; for wringing, dressing, finishing, coating or impregnating textile yarns, fabrics or made-up textile articles; for applying paste to base fabric used in the manufacture of floor coverings	50–63	
13	845221	Sewing machines; (not household type), automatic units	50–63	
Type	Equipment HS codes	Description	Export HS codes[b]	Description
13	845229	Sewing machines; not household or automatic unit type	50–63	
14	845320	Machinery; for making or repairing footwear, other than sewing machines	64	Footwear
15	847510	Machines; for assembling electric or electronic lamps, tubes, valves or flashbulbs, in glass envelopes	70	Glass and glassware

(Continues)

APPENDIX (Continued)

Type	Equipment HS codes	Description	Export HS codes[b]	Description
15	847521	Machines; for manufacturing or hot working glass or glassware, for making optical fibres and preforms thereof	70	
15	847529	Machines; for manufacturing or hot working glass or glassware, not for making optical fibres and preforms thereof	70	
15	848050	Moulds; for glass	70	

[a] Correspondence developed by the author using the US Bureau of Census' concordance between Harmonized System (HS) and end-use codes. See text and footnote 16 for details.
[b] Include only non-primary goods as determined using the United Nations' concordance between HS 2002 and BEC. See text for details.