When trade saves natural resources: evidence from cereals trade in SADC

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Introduction

Africa is one of the continents most vulnerable to climate change. While global temperatures have risen by 0.2°C per decade since 1991, Africa has registered a 0.3°C increase (WMO, 2022). Beyond rising temperatures, Africa faces various related challenges, including rising sea levels, unpredictable rainfall leading to both droughts and severe storms, and increased threats from plant pests and animal diseases. As a result, the continent is expected to see a significant decline in arable land, further compromising its agricultural future. Specifically, southern Africa is highly climate vulnerable. Water scarcity is critical for food security, yet trade can help reallocate cereals from water-rich to water-scarce areas.

Indeed one often-overlooked aspect in the discussion about trade and climate change is how trade can actually help combat climate change. Indeed, when production is shifted from places that have limited environmental resources to those that are rich in them, the ecological footprint of economic activities can be lessened. For instance, international and regional trade have the potential to conserve water on both global and regional scales by exporting water-intensive goods from regions that have high water efficiency or abundant water resources to those with less availability (Fracasso 2014), yielding a much more efficient allocation of water resources around the world. SADC's own regional water policy recognizes comparative advantage in water as a basis for trade integration (SADC 2005).

This policy note reviews virtual water trade in the SADC region and tests whether trade flows reflect countries' comparative advantage in water endowment, with a focus on cereals. It first presents an overview of virtual water trade flows in the region and uses an econometric model to test the link between water endowments and the water content of trade flows. We conclude with a discussion and some policy implications.

Cereals and virtual water trade in SADC

Table 1 presents the volume shares of intra-SADC cereal exports and imports of each crop for the 12 member states considered in the study, and the aggregated share of the total value of the intra-SADC cereal trade (export and import) by crop and member state. Maize, wheat and rice are the three main cereals traded within the SADC region, accounting for 95% of the total intra- regional exports and 97% of the imports. The volume of the intra-SADC cereal trade is dominated by maize which accounted for nearly two-thirds of the total, followed by wheat and rice. The trade in millet, sorghum, rye and barley is minimal and tends to be dominated by one exporting and importing country. Three countries dominate regional trade. South Africa alone accounts for 48%, 35% and 51%, respectively, of the total intra-SADC exported volume of maize, rice and wheat. Overall, it accounts for 46% of the total intra-SADC export value. Zimbabwe's imports of maize amounted to 60% of the total intra-SADC volume imported and 46% of the total rice import. For wheat imports, Zambia and Zimbabwe account for the largest intra-SADC shares, 52% and 23%, respectively.

A couple of patterns emerge from Table 1. First, we observe situations in which the trade of a particular cereal is dominated by a main exporter and importer (about two thirds of the cross-border flow). Botswana is the main exporter of rye and Malawi the main importer, Mozambique the main exporter of barley and South Africa the main importer, and Malawi the main exporter of millet while Mozambique represents the main importer. This suggests that intra-regional trade is based on internal specialization patterns of cereal production within the region. A country that accounts for a large share of intra-regional exports of a particular cereal is generally a net exporter. Second, there are situations in which a country accounts for a large share of two-way trade within a commodity, i.e., the country is both an important exporter and importer of the same cereal (accounting for at least 8% of both export and import volume). This includes Botswana and Mozambique in sorghum, South Africa in rice and sorghum, and Zimbabwe in wheat and sorghum, and Zambia in maize. This pattern is not counterintuitive and consistent with economic theory (Armington, 1969) when the various dimensions of a market (time, location, access to market, product differentiation, etc.) are considered. For instance, cereal trade is subject to seasonality in production which implies that harvest periods can differ across countries, resulting in a country exporting earlier in the marketing year only to import the cereal later. In other words, this is expected, as countries may export in one season and import in another due to production cycles and storage limits, among other factors.

While the trade flows in cereals can reflect a pattern of specialization in production or two-way flows for the reasons discussed, the flow of virtual water from the trade in cereals is expected to reflect endowments of water. In table 2, the exports of cereals are converted into virtual water export equivalent. The virtual water traded (VWT) is computed by multiplying the specific water demand (SWD) of a crop by the amount of the crop traded (CT) from the i^{th} exporter to the j^{th} importer as expressed in equation (1):

$$VWT_{ij} = CT_{ij} \cdot SWD \qquad (1)$$

where VWT is water in billion m^3 per year, CT is in tons, and SWD is the crop's water requirement divided by the crop yield. The total VWT is the sum of all virtual water for all crops traded from the i^{th} exporter to the j^{th} importer. In computing total VWT a weighted average of the SWDs per crop is used, based on the volume traded. The crop's water requirements are taken from Hoekstra and Hung (2002).[1]

Table 2 presents the bilateral virtual water trade flows for SADC. South Africa represents the largest intra-SADC cereal exporter and accounts for the largest share of intra-SADC virtual water exports with 53.7% of the total, followed by Zambia (15.9%) and Malawi (11.8%). Zimbabwe, because of the disruptions in agricultural production during the post land reform years, is the largest virtual water importer accounting for 52% of the total. The other major importers of virtual water include Zambia (12.9%), South Africa (9.7%), Mozambique (8.4%) and Malawi (6.8%).

[1] Many factors, including technological advances, have affected the yield of various crops. Hence, the current known average yield for each crop in each country is used to compute the weighted average SWD. Thus, whether the values for crop water requirements are from Hoekstra and Hung (2002) or modified to include updated yield values, the results obtained are similar and are not sensitive to a simple change in the method of constructing the variable.

Table 1. Share of intra-SADC cereal export and import volumes and members' share of total volume, 1996-2012

	Maize		Rice		Wheat		Millet		Sorghum		Rye		Barley		Member's share of total value	
	Member's share of total volume traded															
	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import
Botswana	0.4	1.1	10.6	3.7	3.8	0.1	1.5	1.0	33.7	12.5	88.0	0.0	0.9	0.0	2.7	1.2
Lesotho	10.6	0.3	2.8	0.0	0.9	1.2	2.4	0.5	5.2	0.0	0.0	0.0	0.0	0.0	7.6	0.5
Madagascar	0.6	1.4	0.1	2.6	0.0	3.2	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.9
Malawi	11.8	6.2	14.0	1.7	2.8	4.8	65.9	2.3	3.9	4.7	0.0	97.3	0.0	0.0	11.3	5.5
Mauritius	0.2	0.4	3.1	0.1	0.0	0.0	0.2	7.5	0.0	0.0	0.0	0.7	0.0	0.2	0.5	0.4
Mozambique	3.8	11.8	14.0	5.8	8.6	4.7	5.4	66.2	13.0	7.9	0.0	1.4	93.5	0.2	6.2	10.3
Namibia	0.6	1.1	3.2	0.1	0.3	0.0	1.4	0.1	1.0	1.3	8.7	0.1	2.9	0.0	0.8	0.7
South Africa	48.4	3.0	35.2	10.2	51.1	1.1	9.5	2.8	17.1	14.4	1.6	0.6	2.7	78.6	46.0	3.2
Swaziland	1.7	1.4	5.8	0.0	0.1	5.2	5.1	1.0	0.1	0.0	1.6	0.0	0.0	0.0	1.8	2.2
Tanzania	5.2	3.4	2.6	0.9	14.3	4.5	3.6	0.5	0.7	21.7	0.0	0.0	0.0	0.0	6.6	3.8
Zambia	13.6	8.2	5.6	13.3	2.8	51.9	0.5	7.2	8.6	6.6	0.0	0.0	0.0	0.0	10.3	19.3
Zimbabwe	3.1	59.6	2.9	46.4	15.3	23.2	3.7	10.1	16.8	30.5	0.0	0.0	0.0	0.0	5.8	48.6
Cereal's share of total volume																
Export	66.6		9.0		19.7		2.4		1.9		0.0		0.3		100.0	100.0
Import		65.8		6.4		24.7		1.4		1.6		0.0		0.1	100.0	100.0

Source: Authors computation based on UN COMTRADE data.

Table 2. Virtual water trade shares from intra-SADC trade in cereals, 1996-2012

Virtual water exports from cereal trade	Virtual water imports from cereal trade														Share in intra-SADC virtual water exports
	Angola	DRC	Botswana	Lesotho	Madagascar	Malawi	Mauritius	Mozambique	Namibia	South Africa	Swaziland	Tanzania	Zambia	Zimbabwe	
Botswana	1,3	0,0	-	0.0	0.0	0.0	0.1	0.7	0.0	77.8	0.0	1.4	2.0	16.6	4.9
Lesotho	0,0	0,0	0.0	-	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	1.5
Madagascar	0,5	0,0	0.0	0.0	-	0.0	98.1	1.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1
Malawi	0,1	0,7	0.0	0.0	0.0	-	0.0	9.5	0.0	13.1	0.0	2.4	7.0	67.2	11.8
Mauritius	0,0	0,0	0.0	0.0	98.3	0.0	-	0.1	0.0	0.7	0.0	0.0	0.9	0.0	0.1
Mozambique	2,8	0,0	0.2	0.0	0.0	51.2	0.0	-	0.0	5.9	1.3	2.8	1.9	33.9	4.4
Namibia	90,4	1,2	0.4	0.0	0.0	0.0	0.0	0.2	-	7.1	0.0	0.0	0.7	0.0	0.4
South Africa	3,1	1,8	0.1	0.0	0.6	3.4	0.2	12.3	0.0	-	0.0	2.0	17.8	58.8	53.7
Swaziland	0,0	0,0	0.0	3.2	0.0	0.0	0.0	28.7	6.1	61.9	-	0.0	0.1	0.0	0.8
Tanzania	0,0	26,4	0.0	0.0	0.2	26.8	0.0	0.4	0.0	2.1	0.0	-	39.7	4.4	4.5
Zambia	0,3	6,3	2.2	0.2	0.1	6.1	0.0	0.6	1.4	11.3	2.1	6.8	-	62.7	15.9
Zimbabwe	3,4	3,6	3.1	0.1	0.0	31.0	0.0	16.8	0.0	7.3	0.4	5.2	29.1	-	2.0
Share of intra-SADC virtual water imports	2,3	3,3	0.5	0.1	0.4	6.8	0.2	8.4	0.3	9.7	0.4	2.7	12.9	52.0	100.0

Source: Authors own computation using UN COMTRADE data

Table 3 illustrates the total renewable water resources available per capita in SADC countries, along with the annual water withdrawal rates measured in cubic meters. While this data offers some perspective on the water available for agricultural production, it does not automatically indicate that market conditions are favorable for cereal exports. On a broader scale, Madagascar, Mozambique, Tanzania, Zambia, and South Africa present higher total water availability. On a per capita basis, Namibia and Botswana are relatively endowed. A comparison between table 2 and Table 3 (between water resources and net virtual water trade) is not straightforward and does not show a clear link based solely on the information shown here, highlighting the need for deeper analysis. For instance, trade flows between Madagascar and Mauritius are highly influenced by their (neighboring) highland or remoteness status, thus the necessity to account for multilateral resistance in a gravity framework (Anderson and van Wincoop, 2003).

Table 3. Water resources in selected countries of the SADC region, 2012

	Total renewable water resources per capita, cubic meters	Total annual water withdrawal per capita, cubic meters	Total renewable water resources in billion cubic meters
Swaziland	2 145.0	962.1	2.57
Zimbabwe	893.3	333.5	13.27
South Africa	869.0	271.7	52.21
Namibia	7 844.0	147.1	19.61
Zambia	5 698.0	147.0	104.8
Tanzania	1 758.0	144.7	105.4
Botswana	5 962.0	107.3	0.27
Malawi	1 088.0	99.9	1.90
Mozambique	8 870.0	46.1	217.10
Mauritius	2 190.0	-	3.40
Lesotho	1 363.0	21.8	2.90
Madagascar	15 080.0	-	337.00

Source: FAO AQUASTAT

Does virtual water trade flows reflects countries comparative advantages?

We performed a gravity model estimation including the main determinants of trade in cereals. The gravity model has become the workhorse model for explaining bilateral trade flows with strong micro-foundations (Head and Mayer, 2014). With virtual water trade measured by the weighted average of the SWDs per crop as dependent variable, we include, in addition to traditional gravity explanatory variables (GDP, distance, etc.) a water abundance index capturing countries endowments[2]. The index is measured as the amount of water per capita available from rainfall and ground and surface water sources and reflects an opportunity to produce and export or produce for local consumption, reducing import demand.

In the analysis, there is evidence, from the available data, that trade in cereals does reflect virtual trade in water. Water endowments do matter for trade, alongside other factors whose combination with

[2] A full description of the gravity model can be found in Matchaya, Garcia and Traore (2023). The model was estimated using panel data from 1996 to 2014 with the Poisson Pseudo- Maximum Likelihood (PPML) estimator while controlling for the importer-year and exporter-year fixed effects to resolve the problem of multilateral resistance terms (Head and Mayer, 2014) and the bias introduced by the log-linearization operation (Santos and Tenreyro, 2010).

water endowments constitute each country’s comparative advantage. The abundance of water resources in a country influences trade for a product that is water dependent, in line with the factor abundance models of trade theory. The effects of water variables on virtual water trade are significant over this study period. The water abundance index of the exporter has a positive and significant coefficient in the econometric analysis. The results suggest that a 1% increase in the index results in a 0.19% increase in virtual water trade (exports) by that country. Water abundant areas are more likely to trade (export) water-intensive products.

Conclusion

The central question in this Note has been to understand, among other things, whether in SADC the abundance of water resources in a country influences trade for a product that is water intensive. In practice, cereal trade is already helping transfer water from wetter to drier countries. There appears to be an efficient use of comparative advantages regarding water endowments. Therefore, further trade integration in the SADC region could reduce the overexploitation of water resources in the region as water scarce areas can rely on trade with water-abundant countries. Thus, not only does trade contribute to food security, but it also contributes to better and more efficient use of natural resources. Deeper regional integration, reduced border delays, and investment in transport infrastructure can amplify water-saving benefits, improving both food and water security.

Two limitations are worth mentioning for this study. First, while countries’ exports reflect their comparative advantage in water endowments, there is no evidence that users are operating at the technology frontier and that there are no leakages. Second, on the data side, while the results presented are statistically sound, they should be interpreted while bearing in mind that agricultural trade data in developing countries often suffer quality issues and are generally incomplete due to the presence of informal cross-border trade flows (Bouët, Cissé and Traoré, 2020). Thus, inefficient irrigation, incomplete trade data, and informal cross-border flows may reduce the potential benefits of virtual water trade. Policies should address these gaps.

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