Supplementary material to:

Fanou and Wang. S Afr J Sci. 2018;114(1/2), Art. # 2016-0347, 7 pages

How to cite:

Fanou EH, Wang X. Assessment of transit transport corridor efficiency of landlocked African countries using data envelopment analysis [supplementary material]. S Afr J Sci. 2018;114(1/2), Art. #2016-0347, 6 pages. http://dx.doi.org/10.17159/sajs.2018/20160347/suppl

DEA CRS, VRS and super-efficiency

The primary basic DEA model, named CRS (constant returns to scale), as proposed by Charnes et al.[1] is suitable when all DMUs are operating at an optimal scale. Another version of the basic DEA model that is in common use is that of Banker et al.[2], VRS (variable returns to scale). The CRS efficiency is decomposed into 'pure' technical efficiency (VRS efficiency) and scale efficiency. The main difference between the VRS and the CRS models is the introduction of a parameter that relaxes the constant returns to scale (CRS). The VRS version is more flexible and it measures only pure technical efficiency for each DMU. That is, for a DMU to be considered as CRS efficient, it must be both scale and purely technically efficient. For a DMU to be considered VRS efficient, it needs to be only purely technically efficient. And, if we estimate the CRS efficiency/VRS efficiency ratio, we obtain the scale efficiency (SE). Super-efficiency ranks efficient DMUs by considering the DEA VRS and CRS scores. Thus, super efficiency can be measured in either VRS or CRS terms. For inefficient DMUs, the super-efficiency score coincides with the standard score. For efficient DMUs, it indicates the maximal radial change which is feasible such that the DMU remains efficient.

Selection of input and output variables

The first and probably most difficult step in an efficiency evaluation is to decide which input and output data should be included. Obsolete and inefficient border procedures, inadequate infrastructure and absence of consistent logistics services often mean high transactions costs and long delays, principally for landlocked countries. The more costly and time consuming it is to export, the more challenging it is for local businesses to be competitive and to reach international markets. The input and output variables that we chose cover documentation requirements and procedures at customs and other regulatory agencies as well as at the port. They also cover logistical aspects, including the time and cost of inland transport between the largest business city in the landlocked country and the main port used by traders.[3,4] We would have preferred to use more variables for inputs/outputs but because of the large area covered by this study, the data collection was difficult. This study was undertaken for all the landlocked African countries using the most homogeneous and consistent data from the World Bank Group Doing Business project which provides objective measures of business regulations that can be compared across 190 economies.[5] Doing Business measures the time and cost (excluding tariffs) associated with exporting and importing by sea transport and the number of documents needed to complete the transaction.

Table 1: Data summary

(a) Inputs and output data

Corridor	Landlocked African country	Transit	Year	Time (days)	Cost (USD/TEU)	Number of documents	Exports (TEU)†
BW	Botswana	South Africa	2008	33	3312.30	6	247544
BF	Burkina Faso	Ghana	2008	45	2813.40	11	23506
BI	Burundi	Tanzania	2008	47	5515.10	9	7089
CF	Central African Republic	Cameroon	2008	57	5030.30	8	5710
TD	Chad	Cameroon	2008	78	5845.10	7	217266
ET	Ethiopia	Djibouti	2008	47	2037.00	8	80092
LS	Lesotho	South Africa	2008	44	1860.10	8	12233
MW	Malawi	Mozambique	2008	45	1623.00	11	43950
ML	Mali	Senegal	2008	44	2619.10	7	95913
NE	Niger	Cotonou	2008	59	2743.00	8	51278
RW	Rwanda	Kenya	2008	47	2975.00	8	12508
SZ	Swaziland	South Africa	2008	21	2950.50	8	84048
UG	Uganda	Kenya	2008	35	2940.00	7	86215
ZM	Zambia	South Africa	2008	53	2098.00	7	254934
ZW	Zimbabwe	South Africa	2008	52	2957.20	7	84694
BW	Botswana	South Africa	2009	31	2268.00	6	172786
BF	Burkina Faso	Ghana	2009	45	2262.00	11	39777
BI	Burundi	Tanzania	2009	47	5159.10	9	5647
CF	Central African Republic	Cameroon	2009	57	5121.00	8	4027
TD	Chad	Cameroon	2009	78	5367.00	7	131804
ET	Ethiopia	Djibouti	2009	47	2377.00	8	80908
LS	Lesotho	South Africa	2009	44	1549.00	8	31406
MW	Malawi	Mozambique	2009	45	1671.00	11	59396
ML	Mali	Senegal	2009	38	2012.00	7	89146
NE	Niger	Cotonou	2009	59	3343.00	8	31401
RW	Rwanda	Kenya	2009	42	3275.00	8	13033
SZ	Swaziland	South Africa	2009	21	2184.00	8	73964
UG	Uganda	Kenya	2009	35	3090.00	7	78381
ZM	Zambia	South Africa	2009	53	2664.00	7	215603
ZW	Zimbabwe	South Africa	2009	53	2678.00	7	113445
BW	Botswana	South Africa	2010	30	2570.00	6	234662
BF	Burkina Faso	Ghana	2010	41	2561.10	11	64407
BI	Burundi	Tanzania	2010	41	4888.60	9	5908
CF	Central African Republic	Cameroon	2010	54	6074.40	9	4491
TD	Chad	Cameroon	2010	75	5497.00	7	170525
ET	Ethiopia	Djibouti	2010	50	2230.00	8	116490
LS	Lesotho	South Africa	2010	44	1929.00	8	40063
MW	Malawi	Mozambique	2010	41	1713.00	10	53310
ML	Mali	Senegal	2010	32	2075.00	6	99813
NE	Niger	Cotonou	2010	59	3961.70	8	23931
RW	Rwanda	Kenya	2010	38	2914.50	8	11891
SZ	Swaziland	South Africa	2010	21	2986.70	8	77849
UG	Uganda	Kenya	2010	33	3190.00	7	80930
ZM	Zambia	South Africa	2010	53	2664.00	7	360013
ZW	Zimbabwe	South Africa	2010	53	3280.00	7	159962
BW	Botswana	South Africa	2011	28	2770.00	6	294096
BF	Burkina Faso	Ghana	2011	41	2412.00	10	115621
BI	Burundi	Tanzania	2011	41	4516.10	9	9892
CF	Central African Republic	Cameroon	2011	54	5491.00	9	5197
TD	Chad	Cameroon	2011	75	5902.00	7	229938
ET	Ethiopia	Djibouti	2011	45	2180.00	8	130745
LS	Lesotho	South Africa	2011	31	1680.00	8	58405
MW	Malawi	Mozambique	2011	41	1713.00	10	71264

Corridor	Landlocked African country	Transit	Year	Time (days)	Cost (USD/TEU)	Number of documents	Exports (TEU)[†]
ML	Mali	Senegal	2011	26	2202.00	6	118725
NE	Niger	Cotonou	2011	59	3734.70	8	54033
RW	Rwanda	Kenya	2011	35	2672.80	7	20867
SZ	Swaziland	South Africa	2011	18	1754.00	8	95059
UG	Uganda	Kenya	2011	33	2780.00	7	107954
ZM	Zambia	South Africa	2011	51	4364.00	7	450047
ZW	Zimbabwe	South Africa	2011	53	3852.00	7	175606
BW	Botswana	South Africa	2012	28	2945.00	6	298562
BF	Burkina Faso	Ghana	2012	41	2488.40	10	120548
BI	Burundi	Tanzania	2012	35	4347.60	9	12135
CF	Central African Republic	Cameroon	2012	54	6162.20	9	5709
TD	Chad	Cameroon	2012	75	6563.40	7	195034
ET	Ethiopia	Djibouti	2012	44	2180.00	8	144567
LS	Lesotho	South Africa	2012	31	1952.00	8	54933
MW	Malawi	Mozambique	2012	41	2494.60	10	63014
ML	Mali	Senegal	2012	26	2543.00	6	130519
NE	Niger	Cotonou	2012	59	3641.70	8	65337
RW	Rwanda	Kenya	2012	29	2608.20	7	25287
SZ	Swaziland	South Africa	2012	18	1855.00	8	94854
UG	Uganda	Kenya	2012	33	2880.00	7	117875
ZM	Zambia	South Africa	2012	51	4378.00	7	468233
ZW	Zimbabwe	South Africa	2012	53	3484.10	7	194121
BW	Botswana	South Africa	2013	27	3166.30	6	378665
BF	Burkina Faso	Ghana	2013	41	2411.20	10	132527
BI	Burundi	Tanzania	2013	32	3803.90	9	10287
CF	Central African Republic	Cameroon	2013	54	6114.70	9	2426
TD	Chad	Cameroon	2013	75	6044.70	7	224781
ET	Ethiopia	Djibouti	2013	44	2480.00	8	203847
LS	Lesotho	South Africa	2013	31	1695.00	7	46702
MW	Malawi	Mozambique	2013	34	2200.00	11	60399
ML	Mali	Senegal	2013	26	2327.10	6	130038
NE	Niger	Cotonou	2013	59	3474.00	8	66858
RW	Rwanda	Kenya	2013	29	3245.00	7	31023
SZ	Swaziland	South Africa	2013	18	1880.00	7	64943
UG	Uganda	Kenya	2013	33	3050.00	7	120387
ZM	Zambia	South Africa	2013	51	4465.00	7	529703
ZW	Zimbabwe	South Africa	2013	53	3229.50	7	175365

[†]TEU, twenty-foot equivalent unit. We converted the export value into TEU based on the data sample: 1 TEU = USD20 000. The export data were originally obtained from the UN Comtrade database in US dollars. The data from Doing Business are not comparable between DB2014 and DB2015 as a result of methodological changes.

(b) Indicators

Indicator	Interpretation/definition
Documents to export	Number of formal documents that exporters need to compile/submit. This is an indicator of bureaucratic hurdles. A larger number of documents means that exporters have to spend more time, and most likely also more money, to be able to carry out their trade activities.
Days to export	Time required (in days) to complete all procedures related to exporting, including custom clearances and unloading of cargo. Shorter procedures indicate greater ease of trade.
Cost to export	Fees (in US dollars) levied on a 20-foot container to export merchandise out of the country. It is a measure of the monetary cost of trading.

Table 2: Additional information on the results

(a) DEA super-efficiency scores in CRS terms, 2008–2013

2008			2009			2010			2011			2012			2013		
Rank	**Corridor**	**CRS**	**Rank**	**Corridor**	**CRS**	**Rank**	**Corridor**	**CRS**	**Rank**	**Corridor**	**CRS**	**Rank**	**Corridor**	**CRS**	**Rank**	**Corridor**	**CRS**
1	ZM	**1.63**	1	BW	**1.37**	1	ZM	**1.48**	1	ZM	**1.31**	1	ZM	**1.34**	1	BW	**1.35**
2	BW	**1.56**	2	ZM	**1.07**	2	BW	**1.15**	2	BW	**1.19**	2	BW	**1.16**	2	ZM	**1.20**
3	TD	0.75	3	SZ	0.63	3	SZ	0.47	3	ET	0.56	3	ET	0.62	3	ET	0.69
4	SZ	0.53	4	TD	0.61	4	TD	0.47	4	TD	0.51	4	ZW	0.52	4	ML	0.47
5	ML	0.38	5	ML	0.55	5	ZW	0.44	5	SZ	0.51	5	SZ	0.50	5	BF	0.46
6	UG	0.36	6	ZW	0.53	6	ML	0.43	6	ML	0.51	6	ML	0.50	6	ZW	0.45
7	ET	0.34	7	MW	0.44	7	ET	0.39	7	BF	0.45	7	BF	0.45	7	TD	0.42
8	ZW	0.31	8	ET	0.42	8	UG	0.31	8	ZW	0.44	8	TD	0.42	8	UG	0.33
9	MW	0.22	9	UG	0.40	9	MW	0.23	9	MW	0.39	9	UG	0.38	9	SZ	0.29
10	NE	0.17	10	LS	0.25	10	BF	0.22	10	UG	0.37	10	LS	0.26	10	LS	0.23
11	BF	0.09	11	BF	0.22	11	LS	0.15	11	LS	0.33	11	MW	0.24	11	MW	0.23
12	LS	0.06	12	NE	0.13	12	NE	0.06	12	NE	0.14	12	NE	0.17	12	NE	0.16
13	RW	0.05	13	RW	0.06	13	RW	0.04	13	RW	0.07	13	RW	0.09	13	RW	0.08
14	BI	0.02	14	BI	0.02	14	BI	0.02	14	BI	0.02	14	BI	0.03	14	BI	0.02
15	CF	0.02	15	CF	0.02	15	CF	0.01	15	CF	0.01	15	CF	0.01	15	CF	0.00

(b) DEA CRS efficiency scores for 2013

	DMU	**Score**	**Doc{I}{V}**	**Time {I}{V}**	**Cost{I}{V}**	**Exports {O}{V}**	**Benchmarks**	**{S}Doc{I}**	**{S} Time{I}**	**{S}Cost{I}**	**{S}Export{O}**
1	**BW**	**100.00%**	**0**	**1**	**0**	**1**	**12**				
2	BF	45.96%	0	0	1	1	1 (0.35)	2.5	9.39	0	0
3	BI	2.29%	0	1	0	1	1 (0.03)	0.04	0	1.17	0
4	CF	0.39%	0.61	0.39	0	1	1 (0.00) 14 (0.00)	0	0	3.21	0
5	TD	42.44%	1	0	0	1	14 (0.42)	0	10.18	670.35	0
6	ET	68.73%	0	0	1	1	1 (0.54)	2.27	15.71	0	0
7	LS	23.04%	0	0	1	1	1 (0.12)	0.87	3.81	0	0
8	MW	22.96%	0	0	1	1	1 (0.16)	1.57	3.5	0	0
9	ML	46.73%	0	0	1	1	1 (0.34)	0.74	2.88	0	0
10	NE	16.09%	0	0	1	1	1 (0.18)	0.23	4.73	0	0
11	RW	7.99%	0	0	1	1	1 (0.08)	0.07	0.11	0	0
12	SZ	28.88%	0	0	1	1	1 (0.17)	0.99	0.57	0	0
13	UG	33.00%	0	0	1	1	1 (0.32)	0.4	2.31	0	0
14	**ZM**	**100.00%**	**1**	**0**	**0**	**1**	**2**				
15	ZW	45.41%	0	0	1	1	1 (0.46)	0.4	11.56	0	0

(c) DEA VRS efficiency scores for 2013

	DMU	Score	Doc{I}{V}	Time{I}{V}	Cost{I}{V}	Exports{O}{V}	Benchmarks	{S}Doc{I}	{S}Time{I}	{S}Cost{I}	{S}Export{O}
1	**BW**	**100.00%**	**0**	**1**	**0**	**1**	**8**				
2	BF	86.07%	0	0	1	1	1 (0.26) 7 (0.74)	1.87	5.32	0	0
3	BI	71.15%	0.69	0.31	0	1	9 (0.60) 12 (0.40)	0	0	560.07	93464.42
4	CF	66.67%	1	0	0	1	1 (0.36) 9 (0.64)	0	9.64	1444.59	217909.1
5	TD	85.71%	1	0	0	1	1 (0.76) 9 (0.24)	0	37.52	2214.96	94604.52
6	ET	96.43%	0	0	1	1	1 (0.47) 7 (0.53)	1.19	13.32	0	0
7	**LS**	**100.00%**	**0**	**0**	**1**	**1**	**3**				
8	MW	81.02%	0	0.11	0.89	1	1 (0.03) 7 (0.72) 12 (0.26)	1.94	0	0	0
9	**ML**	**100.00%**	**0.76**	**0.03**	**0.21**	**1**	**7**				
10	NE	75.00%	1	0	0	1	1 (0.19) 9 (0.81)	0	18.06	114.88	111626.6
11	RW	87.06%	0.66	0.34	0	1	9 (0.91) 12 (0.09)	0	0	540.04	92888.35
12	**SZ**	**100.00%**	**0**	**1**	**0**	**1**	**3**				
13	UG	85.71%	1	0	0	1	1 (0.09) 9 (0.91)	0	2.19	207.99	33114.64
14	**ZM**	**100.00%**	**0.69**	**0**	**0.31**	**1**	**0**				
15	ZW	85.71%	1	0	0	1	1 (0.31) 9 (0.69)	0	19.11	177.39	32783.8

(d) DEA CRS super-efficiency scores for 2013

	DMU	Score	Doc{I}{V}	Time {I}{V}	Cost {I}{V}	Exports {O}{V}	Benchmarks	{S}Doc{I}	{S}Time{I}	{S}Cost{I}	{S}Export{O}
1	**BW**	**135.03%**	**0**	**1**	**0**	**1.35**	**12**				
2	BF	45.96%	0	0	1	0.46	1 (0.35)	2.5	9.39	0	0
3	BI	2.29%	0	1	0	0.02	1 (0.03)	0.04	0	1.17	0
4	CF	0.39%	0.61	0.39	0	0	1 (0.00) 14 (0.00)	0	0	3.21	0
5	TD	42.44%	1	0	0	0.42	14 (0.42)	0	10.18	670.35	0
6	ET	68.73%	0	0	1	0.69	1 (0.54)	2.27	15.71	0	0
7	LS	23.04%	0	0	1	0.23	1 (0.12)	0.87	3.81	0	0
8	MW	22.96%	0	0	1	0.23	1 (0.16)	1.57	3.5	0	0
9	ML	46.73%	0	0	1	0.47	1 (0.34)	0.74	2.88	0	0
10	NE	16.09%	0	0	1	0.16	1 (0.18)	0.23	4.73	0	0
11	RW	7.99%	0	0	1	0.08	1 (0.08)	0.07	0.11	0	0
12	SZ	28.88%	0	0	1	0.29	1 (0.17)	0.99	0.57	0	0
13	UG	33.00%	0	0	1	0.33	1 (0.32)	0.4	2.31	0	0
14	**ZM**	**119.90%**	**1**	**0**	**0**	**1.2**	**2**				
15	ZW	45.41%	0	0	1	0.45	1 (0.46)	0.4	11.56	0	0

(e) DEA VRS Super-efficiency scores for 2013

	DMU	Score	Doc{I}{V}	Time {I}{V}	Cost{I}{V}	Exports {O}{V}	Benchmarks	{S}Doc{I}	{S}Time{I}	{S}Cost{I}	{S}Export{O}
1	**BW**	**149.17%**	**0**	**1**	**0**	**1**	**8**				
2	BF	86.07%	0	0	1	0.24	1 (0.26) 7 (0.74)	1.87	5.32	0	0
3	BI	71.15%	0.69	0.31	0	0	9 (0.60) 12 (0.40)	0	0	560.07	93464.42
4	CF	66.67%	1	0	0	0	1 (0.36) 9 (0.64)	0	9.64	1444.59	217909.1
5	TD	85.71%	1	0	0	0	1 (0.76) 9 (0.24)	0	37.52	2214.96	94604.52
6	ET	96.43%	0	0	1	0.36	1 (0.47) 7 (0.53)	1.19	13.32	0	0
7	**LS**	**110.91%**	**0**	**0**	**1**	**0**	**3**				
8	MW	81.02%	0	0.11	0.89	0.11	1 (0.03) 7 (0.72) 12 (0.26)	1.94	0	0	0
9	**ML**	**107.63%**	**0.76**	**0.03**	**0.21**	**0**	**7**				
10	NE	75.00%	1	0	0	0	1 (0.19) 9 (0.81)	0	18.06	114.88	111626.6
11	RW	87.06%	0.66	0.34	0	0	9 (0.91) 12 (0.09)	0	0	540.04	92888.35
12	**SZ**	**144.44%**	**0**	**1**	**0**	**0**	**3**				
13	UG	85.71%	1	0	0	0	1 (0.09) 9 (0.91)	0	2.19	207.99	33114.64
14	**ZM**	**big**	**0.69**	**0**	**0.31**	**194552**	**0**				
15	ZW	85.71%	1	0	0	0	1 (0.31) 9 (0.69)	0	19.11	177.39	32783.8

References

1. Charnes A, Cooper WW, Rhodes E. Measuring the efficiency of decision making units. Eur J Oper Res. 1978;2(6):429–444. https://doi.org/10.1016/0377-2217(78)90138-8
2. Banker RD, Charnes A, Cooper WW. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manage Sci. 1984;30(9):1078–1092. http://dx.doi.org/10.1287/mnsc.30.9.1078
3. The World Bank. Trading across borders. In: Doing business 2013: Smarter regulations for small and medium-size enterprises. Washington DC: World Bank Group; 2013. p. 123–124. http://dx.doi.org/10.1596/978-0-8213-9615-5
4. The World Bank. Business regulations. In: Doing business in landlocked economies. Washington DC: World Bank Group; 2009.
5. The World Bank. Doing business: Measuring business regulation [homepage on the Internet]. c2014 [cited 2015 Feb 12]. Available from: http://www.doingbusiness.org/data/exploretopics/trading-across-borders