Measuring efficiency of Tunisian schools in the presence of quasi-fixed inputs: A bootstrap data envelopment analysis approach

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Appendix B and Appendix C
to
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Abstract: The objective of this paper is to measure the efficiency of high schools in Tunisia. We use a statistical Data Envelopment Analysis (DEA)-bootstrap approach with quasi-fixed inputs to estimate the precision of our measure. To do so, we developed a statistical model serving as the foundation of the Data Generation Process (DGP). The DGP is constructed such that we can implement both smooth homogeneous and heterogeneous bootstrap methods. Bootstrap simulations were used to estimate and correct the bias, and to construct confidence intervals for the efficiency measures. The simulation results show that the efficiency measures are subject to sampling variations. The adjusted measure reveals that high schools with residence services would have to give up less than 12.1 percent of their resources on average to be efficient.

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Appendix B

Simulation results for the homogenous and heterogeneous bootstrap

DMU	$\hat{\theta}_j$	Homogenous bootstrap				Heterogeneous bootstrap			
		$\widehat{Bias_B}\left(\hat{\theta}_j\right)$	$\hat{\hat{\theta}}_j$	95 % conf. int.		$\widehat{Bias_B}\left(\hat{\theta}_j\right)$	$\hat{\hat{\theta}}_j$	95 % conf. int.	
L116	1	-0.00016	1	1	1	-0.14804	1	1	1.343666
L117	0.834441	0.128114	0.706328	0.668883	0.838665	0.163885	0.670557	0.668883	0.684991
L1115	0.932966	0.016421	0.932966	0.865932	1.020763	-0.07241	0.932966	0.865932	1.183798
L1235	0.782581	0.183027	0.599554	0.565162	0.690202	0.197646	0.584935	0.565162	0.675467
L1543	1	-0.02927	1	1	1.131736	-0.1299	1	1	1.284386
L1461	0.817183	0.115815	0.817183	0.634365	0.830658	0.127568	0.689614	0.634365	0.822096
L1462	0.798161	0.127139	0.671023	0.596323	0.801716	0.151903	0.646259	0.596323	0.829994
L1464	0.897658	0.051329	0.897658	0.795316	0.984905	0.087066	0.810592	0.795316	0.897861
L1466	0.9265	0.010917	0.9265	0.853	1.043014	0.008642	0.9265	0.853	1.069146
L1467	0.725834	0.219912	0.505922	0.451668	0.63271	0.172803	0.725834	0.451668	0.741052
L2171	0.837941	0.105866	0.837941	0.675882	0.857883	0.056817	0.837941	0.675882	0.97882
L2172	1	0	1	1	1	-0.13521	1	1	1.307084
L2173	0.946722	0.008841	0.946722	0.893444	1.091655	-0.0008	0.946722	0.893444	1.105945
L2174	1	-0.01818	1	1	1.110573	-0.06976	1	1	1.236468
L2176	1	-0.02204	1	1	1.115469	-0.09882	1	1	1.257492
L2177	0.873208	0.076906	0.873208	0.746416	0.954552	0.039835	0.873208	0.746416	1.006322
L2178	1	0	1	1	1	-0.13295	1	1	1.30788
L3184	0.787594	0.144895	0.642699	0.575188	0.777733	0.179632	0.607962	0.575188	0.746628
L3186	0.845195	0.083321	0.845195	0.69039	0.877581	0.114717	0.730478	0.69039	0.85906
L3187	1	-0.01326	1	1	1.088979	-0.03525	1	1	1.152939
L3188	0.959631	-0.01189	0.959631	0.919263	1.115269	-0.05046	0.959631	0.919263	1.178287
L3189	1	0	1	1	1	-0.01225	1	1	1.108589
L3190	0.832805	0.099377	0.832805	0.665611	0.883586	0.110996	0.832805	0.665611	0.883659
L3191	1	-0.01971	1	1	1.113345	-0.0146	1	1	1.113221
L3192	0.795047	0.132055	0.662992	0.590093	0.784237	0.132	0.795047	0.590093	0.817587
L3193	1	0	1	1	1	-0.02554	1	1	1.158629
L3194	0.874363	0.077185	0.874363	0.748727	0.912247	0.079187	0.874363	0.748727	0.935885
L3295	0.891439	0.061034	0.891439	0.782878	0.940636	-0.01875	0.891439	0.782878	1.126538
L3296	1	-0.01374	1	1	1.10935	-0.06737	1	1	1.20687
L3297	0.899345	0.036551	0.899345	0.79869	0.965799	0.016696	0.899345	0.79869	1.077839
L3299	1	0	1	1	1	-0.15872	1	1	1.354908
L32100	0.899071	0.053817	0.899071	0.798141	1.001234	0.029339	0.899071	0.798141	1.029609
L32101	0.853951	0.095369	0.853951	0.707902	0.888063	0.068821	0.853951	0.707902	0.959757
L32102	0.882123	0.053955	0.882123	0.764245	0.948302	0.041213	0.882123	0.764245	0.998464
L32103	0.897146	0.051019	0.897146	0.794291	0.981489	0.003034	0.897146	0.794291	1.06934
L32104	0.912722	0.050775	0.912722	0.825444	0.97227	-0.04727	0.912722	0.825444	1.14511
L32105	1	0	1	1	1	-0.02476	1	1	1.139201
L32106	1	0	1	1	1	-0.1357	1	1	1.305786
L42108	0.949955	-0.00439	0.949955	0.89991	1.073025	-0.04024	0.949955	0.89991	1.130657
L42109	1	0	1	1	1	-0.03766	1	1	1.155832
L42110	1	1.11E-16	1	1	1	-0.01768	1	1	1.112494
L42111	0.852001	0.091437	0.852001	0.704003	0.895201	0.096439	0.852001	0.704003	0.915675
L42112	0.872323	0.071874	0.872323	0.744645	0.921798	0.098071	0.774252	0.744645	0.887366
L42114	0.976285	-0.01918	0.976285	0.95257	1.117378	-0.01362	0.976285	0.95257	1.124218

L42115	1	1.11E-16	1	1	1	-0.07181	1	1	1.24378
L42117	0.944843	0.01209	0.944843	0.889686	1.051605	0.015558	0.944843	0.889686	1.074103
L42118	1	0	1	1	1	-0.00285	1	1	1.022435
L42119	1	-2.2E-16	1	1	1	-0.0021	1	1	1
L41120	0.856296	0.085777	0.856296	0.712592	0.901349	0.033947	0.856296	0.712592	0.99501
L41121	0.86558	0.078586	0.86558	0.73116	0.889087	0.012263	0.86558	0.73116	1.028179
L41122	0.832825	0.131282	0.701543	0.665649	0.830777	0.146976	0.685848	0.665649	0.777868
L41123	0.913382	0.041343	0.913382	0.826764	0.992786	0.079696	0.833686	0.826764	0.882848
L41124	0.853976	0.089051	0.853976	0.707953	0.911232	0.08485	0.853976	0.707953	0.917221
L41125	1	-0.02173	1	1	1.139288	-0.069	1	1	1.230956
L41126	0.895857	0.013897	0.895857	0.79207	0.99405	0.045764	0.895857	0.791714	0.997109
L41127	0.95482	0.00056	0.95482	0.90964	1.08643	0.011205	0.95482	0.90964	1.082387
L41128	0.851231	0.08762	0.851231	0.702462	0.886799	0.128367	0.722864	0.702462	0.835776
L41129	1	-0.01347	1	1	1.099598	-0.00435	1	1	1.04404
L41130	0.862208	0.092073	0.862208	0.724416	0.929008	0.002999	0.862208	0.724416	1.051566
L41131	0.952568	0.006062	0.952568	0.905136	1.0572	0.035981	0.952568	0.905136	0.99346
L41132	0.853083	0.082902	0.853083	0.706167	0.930083	0.063614	0.853083	0.706167	0.957034
L43133	0.820019	0.11391	0.820019	0.640039	0.844511	0.054522	0.820019	0.640039	0.952574
L43134	0.748963	0.197363	0.551601	0.497927	0.63988	0.201483	0.54748	0.497927	0.675446
L43137	1	0	1	1	1	-0.14978	1	1	1.329479
L43139	0.960045	-0.00908	0.960045	0.920089	1.091019	-0.06319	0.960045	0.920089	1.18995
L43140	1	0	1	1	1	-0.03145	1	1	1.128128
L43141	0.940789	0.015024	0.940789	0.881578	1.016737	0.042219	0.940789	0.881578	0.996612
L43142	0.946769	-0.01573	0.946769	0.893538	1.062109	0.009409	0.946769	0.893538	1.053565
L43143	0.998128	-0.0433	0.998128	0.996257	1.177121	-0.10207	0.998128	0.996257	1.286972
L43144	0.9894	-0.03369	0.9894	0.9788	1.146242	-0.05767	0.9894	0.9788	1.206833
L43145	1	1.11E-16	1	1	1	-0.07027	1	1	1.206042
L51146	0.996937	-0.02963	0.996937	0.993874	1.148646	-0.10796	0.996937	0.993874	1.273153
L51147	1	0	1	1	1	-0.12798	1	1	1.323852
L51149	1	-0.01171	1	1	1.097904	-0.07882	1	1	1.243697
L51150	0.862228	0.072972	0.862228	0.724456	0.988855	0.095087	0.862228	0.724456	0.933052
L51151	1	-0.01353	1	1	1.081456	-0.06674	1	1	1.219654
L51152	0.888831	0.060087	0.888831	0.777662	0.950096	0.081473	0.888831	0.777662	0.935871
L51153	0.863885	0.091258	0.863885	0.727771	0.894677	0.014408	0.863885	0.727771	1.025236
L51154	0.853551	0.092737	0.853551	0.707103	0.885254	0.091362	0.853551	0.707103	0.926345
L51155	0.960813	-0.00271	0.960813	0.921626	1.08735	-0.02343	0.960813	0.921626	1.144923
L51156	0.944876	0.017678	0.944876	0.889752	1.051828	-0.04219	0.944876	0.889752	1.149372
L51158	1	0	1	1	1	-0.04127	1	1	1.153791
L51159	0.86721	0.060399	0.86721	0.73442	0.956963	0.082846	0.86721	0.73442	0.906738
L51160	0.897529	0.061967	0.897529	0.795059	0.945139	-0.00911	0.897529	0.795059	1.068134
L51161	1	-0.00052	1	1	1	-0.02962	1	1	1.144421
L52162	1	0	1	1	1	-0.11561	1	1	1.315734
L52163	1	-0.00036	1	1	1	-0.15647	1	1	1.358305
L52164	0.959961	0.011002	0.959961	0.919922	1.071877	-0.0663	0.959961	0.919922	1.201937
L52165	0.9289	0.036368	0.9289	0.857801	1.014041	0.043858	0.9289	0.857801	0.997834
L52168	0.90945	0.03411	0.90945	0.818899	0.994021	-0.02151	0.90945	0.818899	1.082143
L52171	0.841527	0.099041	0.841527	0.683055	0.868302	0.008154	0.841527	0.683055	0.999154
L52173	1	-0.03121	1	1	1.134805	-0.08787	1	1	1.229067
L53178	1	-0.00339	1	1	1.031279	-0.10336	1	1	1.270511
L53179	1	-0.00031	1	1	1	-0.04816	1	1	1.192427
L61180	1	-0.0014	1	1	1.007019	-0.1154	1	1	1.305022

L61181	0.958822	0.012847	0.958822	0.917644	1.058931	0.005677	0.958822	0.917644	1.066825
L61183	1	0	1	1	1	-0.05837	1	1	1.209743
L61185	1	0	1	1	1	-0.05379	1	1	1.191629
L61186	1	-0.02375	1	1	1.112945	-0.0708	1	1	1.233287
L61188	1	-0.02715	1	1	1.15569	-0.06169	1	1	1.210277
L62192	0.71656	0.224969	0.491591	0.43312	0.621845	0.236194	0.480366	0.43312	0.600619
L62194	0.969579	-0.01803	0.969579	0.939159	1.094519	-0.09587	0.969579	0.939159	1.25093
L62196	1	-0.03119	1	1	1.122497	-0.02334	1	1	1.121271
L62197	0.866701	0.092698	0.774002	0.733401	0.884873	0.122572	0.744128	0.733401	0.815875
L62198	1	0	1	1	1	-2.4E-05	1	1	1
L63200	1	2.22E-16	1	1	1	-0.19066	1	1	1.344703
L63202	1	-0.03343	1	1	1.157248	-0.08471	1	1	1.249582
L63204	0.844859	0.109009	0.844859	0.689717	0.884667	0.126752	0.718107	0.689717	0.837266
L63205	0.87231	0.06071	0.87231	0.744619	0.946501	0.085778	0.87231	0.744619	0.916305
L63207	1	-0.01479	1	1	1.083705	-0.15547	1	1	1.322578
L63209	1	-0.02868	1	1	1.13666	-0.12081	1	1	1.319331
L63211	0.885024	0.078585	0.885024	0.770048	0.945586	-0.09775	0.885024	0.770048	1.179267
L63214	1	0	1	1	1	-0.03984	1	1	1.18797
L64218	0.885837	0.048317	0.885837	0.771675	0.945144	0.03027	0.885837	0.771675	1.031744
L64222	0.979332	-0.0304	0.979332	0.958665	1.148407	-0.08702	0.979332	0.958665	1.243011
L64224	1	-0.01875	1	1	1.15109	-0.05754	1	1	1.227455
L64225	0.884319	0.068442	0.884319	0.768638	0.938418	0.085264	0.799055	0.768638	0.898475
L64226	1	-0.01296	1	1	1.098866	-0.09212	1	1	1.232456
L64227	1	0	1	1	1	-0.05023	1	1	1.20329
L71228	0.885749	0.065232	0.885749	0.771498	0.942203	-0.03197	0.885749	0.771498	1.109356
L71233	1	0	1	1	1	-0.20262	1	1	1.415269
L71235	1	-0.00063	1	1	1	-0.06387	1	1	1.197651
L71239	1	0	1	1	1	-0.03743	1	1	1.15733
L71244	0.902299	0.038957	0.902299	0.804598	0.999329	-0.01962	0.902299	0.804598	1.086384
L71247	0.874242	0.059856	0.874242	0.748484	0.941405	0.031579	0.874242	0.748484	1.022365
L71248	1	-0.00219	1	1	1.003486	-0.02728	1	1	1.122541
L71249	1	-0.0209	1	1	1.137025	-0.03827	1	1	1.151131
L71250	1	0	1	1	1	-0.09892	1	1	1.226384
L71251	0.879983	0.091062	0.788921	0.759965	0.891392	0.07978	0.879983	0.759965	0.918727
L71252	0.969126	-0.01268	0.969126	0.938251	1.088648	-0.06622	0.969126	0.938251	1.213764
L71253	0.881071	0.050213	0.881071	0.762143	0.967714	0.076297	0.881071	0.762143	0.934639
L71254	1	0	1	1	1	-0.01383	1	1	1.105265
L82255	0.845153	0.101496	0.845153	0.690305	0.89128	0.032679	0.845153	0.690305	0.982857
L82258	1	0	1	1	1	-0.11936	1	1	1.296553
L82259	1	0	1	1	1	-0.05427	1	1	1.201684
L82260	0.844793	0.104632	0.844793	0.689585	0.868675	0.078202	0.844793	0.689585	0.917601
L82261	1	-0.00923	1	1	1.083296	-0.00698	1	1	1.050014
L82262	0.833589	0.076556	0.833589	0.667178	0.882027	0.059208	0.833589	0.667178	0.956378
L82264	0.944978	0.019501	0.944978	0.889956	1.057542	-0.06434	0.944978	0.889956	1.186506
L82265	1	-0.0306	1	1	1.136488	-0.14404	1	1	1.323067
L82266	0.928364	0.024585	0.928364	0.856728	1.044385	0.032856	0.928364	0.856728	1.016827
L82267	1	0	1	1	1	-0.02637	1	1	1.18455
L81270	0.928845	-0.00156	0.928845	0.85769	1.051628	0.029	0.928845	0.85769	1.044035
L81272	0.882195	0.038696	0.882195	0.764391	0.976923	0.064928	0.882195	0.764391	0.981944
L81274	1	-0.01531	1	1	1.118024	-0.13536	1	1	1.323247
L81275	0.916343	0.050265	0.916343	0.832685	0.965921	0.070153	0.84619	0.832685	0.926983

L81276	1	0	1	1	1	-0.01447	1	1	1.105228
L81277	1	0	1	1	1	-0.05921	1	1	1.188097
L81278	0.928114	0.028897	0.928114	0.856229	1.023039	-0.0327	0.928114	0.856229	1.156353
L81279	0.940764	0.005959	0.940764	0.881528	1.041606	0.003755	0.940764	0.881528	1.07341
L81281	0.90537	0.023301	0.90537	0.81074	1.025448	0.04923	0.90537	0.81074	0.990897
L81283	0.954754	0.001455	0.954754	0.909509	1.076845	-0.0885	0.954754	0.909509	1.23086
L81284	0.943689	0.020325	0.943689	0.887379	1.049603	0.014589	0.943689	0.887379	1.066389
L84303	1	0	1	1	1	-0.04702	1	1	1.176919
L84304	1	-0.00289	1	1	1.00407	-0.11017	1	1	1.288631
L84305	0.857299	0.109842	0.747458	0.714598	0.876166	-0.02105	0.857299	0.714598	1.064143
L84312	1	-0.0005	1	1	1	-0.14166	1	1	1.337383
L84313	0.893922	0.062511	0.893922	0.787845	0.929357	0.048825	0.893922	0.787845	0.982255
L84317	1	0	1	1	1	-0.13421	1	1	1.306127
L91319	1	0	1	1	1	-0.14053	1	1	1.347794
L91320	1	0	1	1	1	-0.1828	1	1	1.365956
L91322	1	-0.00071	1	1	1	-0.17205	1	1	1.33639
L91325	1	0	1	1	1	-0.122	1	1	1.295006
L91328	1	0	1	1	1	-0.11695	1	1	1.279062
L91329	1	0	1	1	1	-0.19876	1	1	1.402448
L91330	1	-0.00029	1	1	1	-0.11541	1	1	1.295339

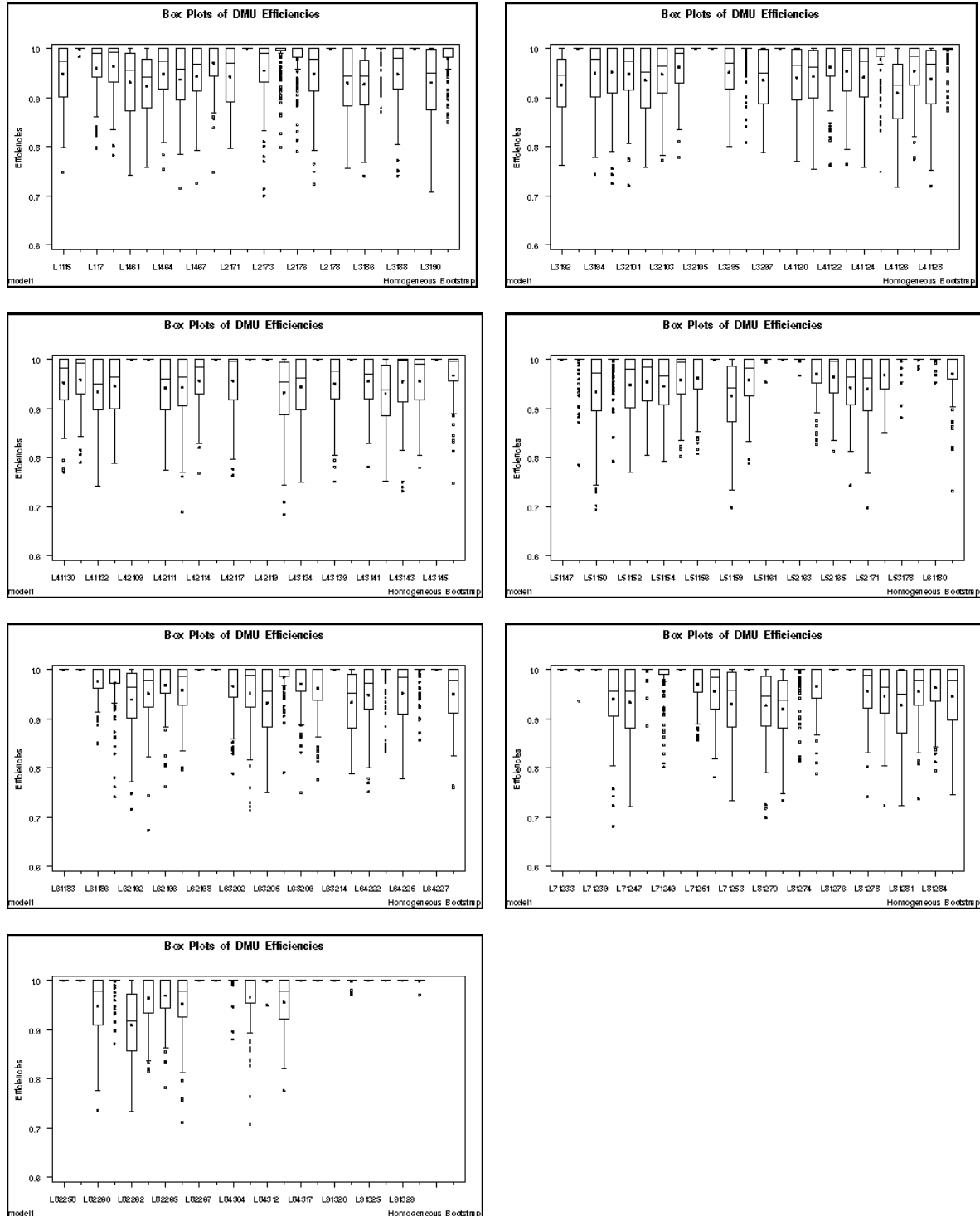# Appendix C

Box plot of the efficiency scores

Figure C.1: Homogenous bootstrap

Figure C.2: Heterogeneous bootstrap

Box Plots of DMU Efficiencies

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