

RELATIONAL MODELING ON MORTALITY RATES: INTERNATIONAL TESTS AND HEDGING

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Importance of the Research Question

- ▣ Modeling the changes/dynamics of mortality rates is critical to life insurers, social benefits programs, and the society.
 - Ignoring possible mortality rate changes can lead to significant under-pricing and under-reserving.
 - Under-estimating improvements in mortality rates can jeopardize the programs' solvency and continuity
 - Mortality rates affects the growth prospects of many industries

Importance of the Research Question (*cont.*)

- ▣ Internal hedge may not be reached by immunization strategies.
- ▣ Hedging via capital markets and longevity instruments would face the basis risk.
- ▣ A proper approach to solve these two questions is important to the literatures.

Related Literatures

- ▣ Mortality rate modeling:
 - Explanatory models: Stallard (2006)
 - Factor models:
 - ▣ Lee and Carter (1992)
 - ▣ Renshaw and Haberman (2003); Hyndman and Ullah (2007)
 - Curve Fitting Methods:
 - ▣ McNown and Rogers (1989); Cairns, Blake, and Dowd (2006a); Blackburn and Sherris (2011)
 - Financial Engineering Approaches:
 - ▣ Dahl (2004); Cairns, Blake, and Dowd (2006b)
 - ▣ Biffis (2005); Luciano and Vigna (2005)

Relational Modeling

- ▣ It starts from a mortality rate curve that contains information on how the mortality rates of different ages relate to each other.
 - These relations may result from biological reasons (e.g., new-born babies have higher mortality rates; mortality rates increase with ages for adults) or social reasons (e.g., the speed driving by young adults leads to higher mortality rates).
 - Factor models did not capture such information.

Relational Modeling (*cont.*)

- ▣ The second step of relational modeling specifies a relation between two curves.
 - The relations might emerge across genders, sub-groups of populations, geographic areas, and time.
 - For instance, mortality rates on the curve of a later year can be regarded as a transformation of those on the curve of an earlier year.

Rationale: mortality rate curves move slowly with small changes and shift stably in terms of shape, which may result from biological constraints and/or the rigidity of social changes (e.g., health care systems, living habits, medical technology improvements, and medicine inventions).

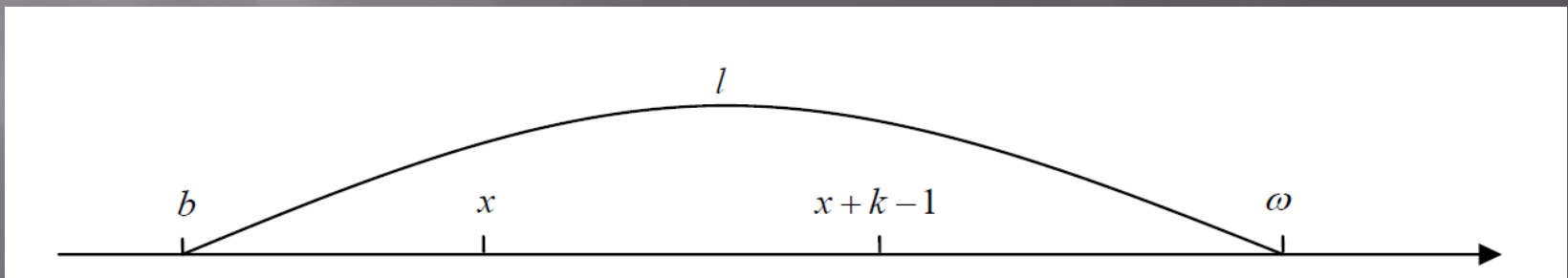
Our Contributions

- ▣ Conduct global tests on the fitting and forecasting capabilities of a relational model relative to two well-known, different types of models.

Linear Hazard Transform

- Assume that there is a linear relation (plus an error term) between the forces of mortality (i.e., hazard rates) of two mortality rate curves from years A and B , where $B = A + a$. One mathematical representation of such a relation is:

$$\mu^B(x+k-1) = (1 + \alpha_{b,l}^{A,B}) \times \mu^A(x+k-1) + \beta_{b,l}^{A,B} + \varepsilon_{b,l}^{A,B}(k-1), \quad k = 1, 2, \dots, \omega - x$$



Linear Hazard Transform (*cont.*)

$$p_{x+k-1}^B = e^{-\int_{k-1}^k [(1+\alpha_{b,l}^{A,B})\mu^A(x+t) + \beta_{b,l}^{A,B} + \varepsilon_{b,l}^{A,B}(t)] dt} = [p_{x+k-1}^A]^{1+\alpha_{b,l}^{A,B}} \times e^{-\beta_{b,l}^{A,B}} \times e^{-\int_{k-1}^k \varepsilon_{b,l}^{A,B}(t) dt}$$

$$(-\ln p_{x+k-1}^B) = (1 + \alpha_{b,l}^{A,B}) \times (-\ln p_{x+k-1}^A) + \beta_{b,l}^{A,B} + \int_{k-1}^k \varepsilon_{b,l}^{A,B}(t) dt$$

$$\text{Min}_{\alpha_{b,l}^{A,B}, \beta_{b,l}^{A,B}} \sum_{k=1}^l \left[\int_{k-1}^k \varepsilon_{b,l}^{A,B}(t) dt \right]^2$$

$$\alpha_{b,l}^{A,B} \text{ and } \beta_{b,l}^{A,B}$$

Global Time-Series Tests

□ Target Models:

- Lee-Carter:

$$\log q_x^A = a_x + b_x \kappa_A + \varepsilon_x^A$$

- CBD

$$\text{logit } q_x^A = k_1^A + k_2^A (x - \bar{x}) + \varepsilon_x^A$$

□ Error Measurements

- RMSE:

$$\text{RMSE} = \frac{1}{T} \sum_{B=A+1}^{A+T} \sqrt{\frac{1}{l+1} \sum_{x=b}^{b+l} (q_x^B - \hat{q}_x^B)^2}$$

- MAE:

$$\text{MAE} = \frac{1}{T(l+1)} \sum_{B=A+1}^{A+T} \sum_{x=b}^l |q_x^B - \hat{q}_x^B|$$

Statistical Tests – Data

Geographical Region (Number of Countries)	Country	Sampling Period
Asia-Pacific (3)	Australia	1950-2010
	New Zealand	1950-2008
	Japan	1950-2009
Europe (18)	Austria; Sweden	1950-2010
	Belgium; Bulgaria; Czech Republic; Denmark; Finland; France; Hungary; Ireland; Netherlands; Norway; Portugal; Slovakia; Spain; Switzerland; United Kingdom	1950-2009
	Italy	1950-2008
North America (2)	Canada; United States	1950-2007

Table 2: Descriptive Statistics on the Fitting Improvement Ratios of the LHT Model with respect to the Lee-Carter and CBD Models across 23 Countries

(a) Performance Relative to Lee-Carter of Male Populations

	No. of Samples	Mean (%)	Median (%)	S.D. (%)	Min. (%)	Max. (%)
Improvement Ratio in RMSE	23	14.49	11.92	18.19	-13.20	49.96
Improvement Ratio in MAE	23	9.53	9.27	20.75	-26.06	49.14

(b) Performance Relative to CBD of Male Populations

	No. of Samples	Mean (%)	Median (%)	S.D. (%)	Min. (%)	Max. (%)
Improvement Ratio in RMSE	23	19.84	17.71	20.15	-8.92	60.57
Improvement Ratio in MAE	23	15.28	14.22	22.08	-20.33	60.17

(c) Performance Relative to Lee-Carter of Female Populations

	No. of Samples	Mean (%)	Median (%)	S.D. (%)	Min. (%)	Max. (%)
Improvement Ratio in RMSE	23	11.21	12.09	20.06	-16.83	72.52
Improvement Ratio in MAE	23	5.43	1.84	21.93	-22.46	70.40

(d) Performance Relative to CBD of Female Populations

	No. of Samples	Mean (%)	Median (%)	S.D. (%)	Min. (%)	Max. (%)
Improvement Ratio in RMSE	23	54.82	61.93	20.05	12.24	83.03
Improvement Ratio in MAE	23	52.00	56.85	19.85	11.15	82.21

Results of In-Sample Fitting on Males'

RMSE						MAE				
Country Name	LHT	LC	Improvement Related to LC (%)	CBD	Improvement Related to CBD (%)	LHT	LC	Improvement Related to LC (%)	CBD	Improvement Related to CBD (%)
Euro										
Austria	0.0039	0.0036	-8.04%	0.0049	19.85%	0.0024	0.0022	-9.50%	0.0028	15.96%
Belgium	0.0035	0.0040	11.92%	0.0046	24.33%	0.0021	0.0024	14.22%	0.0026	20.34%
Bulgaria	0.0064	0.0067	4.91%	0.0068	6.46%	0.0035	0.0038	9.27%	0.0037	5.04%
Czech Republic	0.0048	0.0048	0.41%	0.0047	-2.64%	0.0028	0.0028	-2.69%	0.0027	-3.75%
Denmark	0.0041	0.0051	19.70%	0.0038	-7.56%	0.0024	0.0027	10.81%	0.0022	-11.46%
Finland	0.0060	0.0055	-9.33%	0.0055	-8.92%	0.0036	0.0030	-19.27%	0.0030	-20.33%
France	0.0024	0.0025	4.84%	0.0060	60.57%	0.0013	0.0014	4.91%	0.0034	60.17%
Hungary	0.0050	0.0090	44.88%	0.0056	11.13%	0.0029	0.0054	46.61%	0.0032	10.29%
Ireland	0.0059	0.0057	-2.56%	0.0071	17.71%	0.0036	0.0034	-3.47%	0.0041	14.22%
Italy	0.0025	0.0031	20.69%	0.0030	18.12%	0.0015	0.0018	19.37%	0.0018	20.33%
Netherlands	0.0023	0.0042	47.04%	0.0036	38.14%	0.0014	0.0024	41.09%	0.0021	31.85%
Norway	0.0029	0.0031	5.64%	0.0032	9.10%	0.0018	0.0018	-5.31%	0.0018	-2.65%
Portugal	0.0040	0.0039	-1.82%	0.0056	27.95%	0.0025	0.0022	-12.04%	0.0033	24.89%
Slovakia	0.0069	0.0087	20.39%	0.0065	-6.74%	0.0041	0.0048	14.35%	0.0036	-12.73%
Spain	0.0024	0.0026	10.26%	0.0041	42.10%	0.0014	0.0015	3.05%	0.0023	37.86%
Sweden	0.0029	0.0033	12.20%	0.0034	12.80%	0.0018	0.0017	-2.52%	0.0018	2.29%
Switzerland	0.0036	0.0036	-1.24%	0.0041	11.48%	0.0022	0.0019	-15.67%	0.0022	-0.81%
United Kingdom	0.0020	0.0030	32.55%	0.0041	50.61%	0.0012	0.0018	33.44%	0.0025	52.25%
Average	0.0040	0.0046	13.52%	0.0048	17.54%	0.0024	0.0026	9.70%	0.0027	13.58%
North America										
Canada	0.0023	0.0030	24.04%	0.0025	9.44%	0.0014	0.0017	18.46%	0.0015	5.73%
United States	0.0012	0.0020	40.89%	0.0025	51.62%	0.0008	0.0013	38.78%	0.0015	48.66%
Average	0.0017	0.0025	30.85%	0.0025	30.40%	0.0011	0.0015	27.08%	0.0015	27.36%
Asia-Pacific										
Australia	0.0026	0.0032	19.03%	0.0038	31.90%	0.0016	0.0019	12.30%	0.0022	25.18%
Japan	0.0020	0.0040	49.96%	0.0036	44.64%	0.0012	0.0024	49.14%	0.0021	42.32%
New Zealand	0.0061	0.0053	-13.20%	0.0057	-5.67%	0.0037	0.0030	-26.06%	0.0033	-14.11%
Average	0.0035	0.0042	15.12%	0.0044	18.99%	0.0022	0.0024	8.69%	0.0025	12.91%

Results of In-Sample Fitting on Females'

RMSE						MAE				
Country Name	LHT	LC	Improvement Related to LC (%)	CBD	Improvement Related to CBD (%)	LHT	LC	Improvement Related to LC (%)	CBD	Improvement Related to CBD (%)
Euro										
Austria	0.0026	0.0025	-2.80%	0.0071	63.52%	0.0015	0.0014	-7.07%	0.0039	61.53%
Belgium	0.0023	0.0022	-3.84%	0.0065	64.74%	0.0013	0.0012	-7.69%	0.0035	62.77%
Bulgaria	0.0051	0.0060	16.33%	0.0067	24.28%	0.0027	0.0032	16.96%	0.0036	26.82%
Czech Republic	0.0033	0.0028	-16.83%	0.0045	27.59%	0.0018	0.0015	-22.46%	0.0026	29.22%
Denmark	0.0029	0.0034	14.93%	0.0055	47.90%	0.0017	0.0020	14.89%	0.0030	41.18%
Finland	0.0041	0.0039	-6.41%	0.0062	33.45%	0.0024	0.0021	-11.89%	0.0034	29.71%
France	0.0014	0.0020	30.79%	0.0083	83.03%	0.0008	0.0011	28.53%	0.0045	82.21%
Hungary	0.0035	0.0034	-4.32%	0.0062	43.44%	0.0020	0.0019	-7.40%	0.0036	44.07%
Ireland	0.0045	0.0041	-8.34%	0.0062	27.60%	0.0027	0.0023	-16.26%	0.0037	26.15%
Italy	0.0016	0.0020	16.90%	0.0054	69.51%	0.0010	0.0010	7.54%	0.0030	68.30%
Netherlands	0.0015	0.0017	12.09%	0.0059	74.40%	0.0009	0.0009	0.27%	0.0032	70.48%
Norway	0.0020	0.0023	15.48%	0.0055	64.75%	0.0013	0.0013	2.90%	0.0029	56.85%
Portugal	0.0027	0.0031	12.42%	0.0063	56.33%	0.0017	0.0018	1.84%	0.0037	53.65%
Slovakia	0.0050	0.0045	-11.07%	0.0057	12.24%	0.0028	0.0024	-16.14%	0.0032	11.15%
Spain	0.0017	0.0025	34.30%	0.0065	74.08%	0.0010	0.0014	29.41%	0.0036	72.12%
Sweden	0.0021	0.0021	-1.68%	0.0059	64.11%	0.0013	0.0012	-10.31%	0.0031	59.09%
Switzerland	0.0027	0.0028	3.40%	0.0070	61.74%	0.0016	0.0015	-8.31%	0.0036	55.96%
United Kingdom	0.0013	0.0018	27.10%	0.0034	60.27%	0.0007	0.0011	31.72%	0.0019	60.74%
Average	0.0028	0.0030	5.59%	0.0060	53.77%	0.0016	0.0016	0.51%	0.0033	51.23%
North America										
Canada	0.0015	0.0018	15.11%	0.0039	61.93%	0.0009	0.0010	6.84%	0.0021	56.75%
United States	0.0008	0.0014	41.34%	0.0042	80.05%	0.0005	0.0008	39.03%	0.0023	77.39%
Average	0.0012	0.0016	26.78%	0.0041	71.24%	0.0007	0.0009	21.72%	0.0022	67.45%
Asai-Parcific										
Australia	0.0016	0.0018	10.33%	0.0045	64.16%	0.0010	0.0010	2.73%	0.0025	59.29%
Japan	0.0014	0.0050	72.52%	0.0060	77.08%	0.0008	0.0028	70.40%	0.0033	75.16%
New Zealand	0.0041	0.0038	-9.89%	0.0055	24.73%	0.0026	0.0021	-20.67%	0.0030	15.39%
Average	0.0024	0.0035	32.62%	0.0053	55.48%	0.0015	0.0020	26.00%	0.0029	50.15%

Table 5: Descriptive Statistics on the Forecasting Improvement Ratios of the LHT Model with respect to the Lee-Carter and CBD Models across 23 Countries

(e) Performance Relative to Lee-Carter of Male Populations

	No. of Samples	Mean (%)	Median (%)	S.D. (%)	Min. (%)	Max. (%)
Improvement Ratio in RMSE	23	9.38	23.42	48.33	-162.08	57.45
Improvement Ratio in MAE	23	15.02	29.33	46.33	-151.96	58.16

(f) Performance Relative to CBD of Male Populations

	No. of Samples	Mean (%)	Median (%)	S.D. (%)	Min. (%)	Max. (%)
Improvement Ratio in RMSE	23	41.34	50.84	32.87	-58.97	76.66
Improvement Ratio in MAE	23	36.31	45.58	31.62	-62.17	68.88

(g) Performance Relative to Lee-Carter of Female Populations

	No. of Samples	Mean (%)	Median (%)	S.D. (%)	Min. (%)	Max. (%)
Improvement Ratio in RMSE	23	28.06	42.83	39.77	-117.76	71.58
Improvement Ratio in MAE	23	33.11	44.52	36.21	-100.25	74.30

(h) Performance Relative to CBD of Female Populations

	No. of Samples	Mean (%)	Median (%)	S.D. (%)	Min. (%)	Max. (%)
Improvement Ratio in RMSE	23	65.63	74.52	21.15	6.25	85.37
Improvement Ratio in MAE	23	58.96	65.02	20.96	-4.54	81.49

Results of Forecasting on Males'

RMSE						MAE				
Country Name	LHT	LC	Improvement Related to LC (%)	CBD	Improvement Related to CBD (%)	LHT	LC	Improvement Related to LC (%)	CBD	Improvement Related to CBD (%)
Euro										
Austria	0.0044	0.0071	37.75%	0.0125	64.74%	0.0025	0.0049	49.68%	0.0066	62.40%
Belgium	0.0051	0.0066	22.88%	0.0137	63.01%	0.0031	0.0044	29.33%	0.0074	57.78%
Bulgaria	0.0111	0.0081	-36.86%	0.0113	1.88%	0.0059	0.0046	-29.51%	0.0056	-5.83%
Czech Republic	0.0065	0.0107	39.01%	0.0105	37.71%	0.0035	0.0074	52.02%	0.0065	45.58%
Denmark	0.0048	0.0064	25.01%	0.0099	51.44%	0.0033	0.0046	27.64%	0.0059	44.23%
Finland	0.0071	0.0077	8.12%	0.0145	51.09%	0.0048	0.0052	7.89%	0.0080	39.66%
France	0.0051	0.0082	37.69%	0.0153	66.59%	0.0032	0.0057	44.38%	0.0077	58.71%
Hungary	0.0095	0.0178	46.79%	0.0083	-13.80%	0.0055	0.0106	48.00%	0.0048	-13.89%
Ireland	0.0195	0.0074	-162.08%	0.0123	-58.97%	0.0123	0.0049	-151.96%	0.0076	-62.17%
Italy	0.0048	0.0085	43.72%	0.0097	50.84%	0.0031	0.0056	43.94%	0.0060	47.95%
Netherlands	0.0070	0.0056	-24.99%	0.0124	43.56%	0.0049	0.0042	-16.74%	0.0077	36.58%
Norway	0.0094	0.0053	-78.10%	0.0119	20.94%	0.0064	0.0038	-68.05%	0.0067	3.97%
Portugal	0.0054	0.0084	35.88%	0.0154	64.88%	0.0037	0.0058	36.82%	0.0083	55.65%
Slovakia	0.0082	0.0141	41.98%	0.0072	-12.79%	0.0051	0.0077	33.23%	0.0048	-6.56%
Spain	0.0077	0.0080	4.04%	0.0119	35.58%	0.0049	0.0057	14.31%	0.0069	29.84%
Sweden	0.0031	0.0074	57.45%	0.0116	72.98%	0.0021	0.0051	58.16%	0.0064	66.44%
Switzerland	0.0042	0.0077	45.50%	0.0118	64.60%	0.0028	0.0052	46.93%	0.0065	57.40%
United Kingdom	0.0063	0.0077	17.71%	0.0128	50.53%	0.0042	0.0054	21.97%	0.0080	46.82%
Average	0.0072	0.0085	15.37%	0.0118	39.38%	0.0045	0.0056	19.26%	0.0067	32.96%
North America										
Canada	0.0062	0.0049	-25.65%	0.0113	45.20%	0.0042	0.0036	-18.02%	0.0067	37.59%
United States	0.0039	0.0050	22.27%	0.0131	70.14%	0.0028	0.0037	25.52%	0.0072	61.43%
Average	0.0050	0.0050	-1.38%	0.0122	58.62%	0.0035	0.0037	4.29%	0.0070	49.93%
Asai-Pacific										
Australia	0.0030	0.0046	35.49%	0.0128	76.66%	0.0022	0.0034	35.47%	0.0072	68.88%
Japan	0.0037	0.0048	23.42%	0.0107	65.31%	0.0025	0.0039	36.42%	0.0062	60.22%
New Zealand	0.0072	0.0071	-1.39%	0.0117	38.74%	0.0039	0.0048	18.09%	0.0068	42.37%
Average	0.0046	0.0055	16.16%	0.0117	60.57%	0.0029	0.0040	28.90%	0.0067	57.27%

Results of Forecasting on Females'

RMSE						MAE				
Country Name	LHT	LC	Improvement Related to LC (%)	CBD	Improvement Related to CBD (%)	LHT	LC	Improvement Related to LC (%)	CBD	Improvement Related to CBD (%)
Euro										
Austria	0.0025	0.0051	49.99%	0.0148	82.82%	0.0016	0.0034	51.60%	0.0068	75.94%
Belgium	0.0028	0.0049	42.83%	0.0146	81.03%	0.0017	0.0031	44.39%	0.0067	74.31%
Bulgaria	0.0091	0.0080	-14.03%	0.0136	33.27%	0.0049	0.0040	-21.93%	0.0071	31.26%
Czech Republic	0.0042	0.0081	47.60%	0.0137	68.95%	0.0026	0.0053	50.32%	0.0070	62.98%
Denmark	0.0030	0.0096	68.98%	0.0083	63.97%	0.0021	0.0060	64.66%	0.0046	54.04%
Finland	0.0041	0.0056	27.29%	0.0167	75.55%	0.0027	0.0036	23.94%	0.0078	65.02%
France	0.0033	0.0038	13.86%	0.0140	76.65%	0.0018	0.0025	30.43%	0.0062	71.58%
Hungary	0.0090	0.0078	-14.62%	0.0135	33.59%	0.0048	0.0048	-0.17%	0.0068	28.86%
Ireland	0.0122	0.0056	-117.76%	0.0130	6.25%	0.0073	0.0036	-100.25%	0.0070	-4.54%
Italy	0.0026	0.0056	53.20%	0.0118	77.77%	0.0015	0.0036	57.74%	0.0056	72.70%
Netherlands	0.0041	0.0076	46.37%	0.0148	72.51%	0.0025	0.0049	48.14%	0.0070	63.61%
Norway	0.0032	0.0057	43.92%	0.0120	73.46%	0.0020	0.0037	45.92%	0.0055	63.73%
Portugal	0.0039	0.0059	32.81%	0.0155	74.52%	0.0025	0.0039	34.10%	0.0076	66.70%
Slovakia	0.0054	0.0070	23.15%	0.0109	50.83%	0.0029	0.0043	32.14%	0.0056	47.98%
Spain	0.0038	0.0037	-2.92%	0.0152	75.09%	0.0024	0.0026	6.55%	0.0071	66.05%
Sweden	0.0021	0.0075	71.58%	0.0114	81.26%	0.0012	0.0048	74.30%	0.0054	76.95%
Switzerland	0.0024	0.0046	47.27%	0.0122	80.19%	0.0014	0.0030	52.37%	0.0054	73.23%
United Kingdom	0.0041	0.0076	45.99%	0.0113	63.69%	0.0027	0.0049	44.52%	0.0061	55.53%
Average	0.0045	0.0063	27.94%	0.0132	65.52%	0.0027	0.0040	32.08%	0.0064	57.59%
North America										
Canda	0.0037	0.0050	27.25%	0.0095	61.53%	0.0023	0.0033	31.31%	0.0047	51.32%
United States	0.0017	0.0054	69.12%	0.0098	83.09%	0.0011	0.0036	69.74%	0.0050	78.28%
Average	0.0027	0.0052	48.85%	0.0097	72.47%	0.0017	0.0034	51.30%	0.0048	65.26%
Asai-Parcific										
Australia	0.0018	0.0043	57.43%	0.0117	84.34%	0.0013	0.0029	55.88%	0.0055	77.03%
Japan	0.0016	0.0023	32.43%	0.0108	85.37%	0.0010	0.0019	50.44%	0.0052	81.49%
New Zealand	0.0071	0.0067	-6.32%	0.0093	23.74%	0.0036	0.0042	15.48%	0.0046	21.96%
Average	0.0035	0.0044	21.13%	0.0106	66.98%	0.0019	0.0030	35.74%	0.0051	61.96%

Fitting and Forecasting Results on Global Indexes

Fitting		RMSE			MAE		
Country Name	LHT	LC	CBD	LHT	LC	CBD	
Male	0.0011	0.0017	0.0020	0.0007	0.0010	0.0012	
Improvement related of LC or CBD (%)		33.47	43.90		29.41	40.17	
Female	0.0007	0.0012	0.0053	0.0004	0.0007	0.0029	
Improvement related of LC or CBD (%)		36.40	85.91		31.88	84.85	

Forecasting		RMSE			MAE		
Country Name	LHT	LC	CBD	LHT	LC	CBD	
Male	0.0030	0.0074	0.0125	0.0022	0.0054	0.0074	
Improvement related of LC or CBD (%)		59.60	76.19		59.22	70.36	
Female	0.0013	0.0052	0.0125	0.0008	0.0036	0.0060	
Improvement related of LC or CBD (%)		75.06	89.67		76.32	85.82	

Fitting and Forecasting Results on Regional Indexes

Asia Pacific

Fitting		RMSE			MAE		
Country Name	LHT	LC	CBD	LHT	LC	CBD	
Male	0.0025	0.0026	0.0029	0.0015	0.0015	0.0017	
Improvement related of LC or CBD (%)		6.24	16.19		-2.67	9.54	
Female	0.0016	0.0019	0.0049	0.0010	0.0011	0.0027	
Improvement related of LC or CBD (%)		16.73	67.25		7.70	63.06	

Forecasting		RMSE			MAE		
Country Name	LHT	LC	CBD	LHT	LC	CBD	
Male	0.0032	0.0062	0.0123	0.0021	0.0046	0.0072	
Improvement related of LC or CBD (%)		47.89	73.76		53.41	70.38	
Female	0.0017	0.0050	0.0107	0.0010	0.0035	0.0053	
Improvement related of LC or CBD (%)		65.58	83.89		69.92	80.16	

North America

Fitting		RMSE			MAE		
Country Name	LHT	LC	CBD	LHT	LC	CBD	
Male	0.0014	0.0023	0.0023	0.0009	0.0013	0.0014	
Improvement related of LC or CBD (%)		37.66	37.89		34.42	35.49	
Female	0.0009	0.0014	0.0040	0.0006	0.0008	0.0022	
Improvement related of LC or CBD (%)		33.31	76.34		27.81	73.09	

Forecasting		RMSE			MAE		
Country Name	LHT	LC	CBD	LHT	LC	CBD	
Male	0.0049	0.0049	0.0124	0.0035	0.0036	0.0071	
Improvement related of LC or CBD (%)		0.44	60.42		5.19	51.04	
Female	0.0023	0.0052	0.0097	0.0015	0.0035	0.0048	
Improvement related of LC or CBD (%)		54.84	75.79		55.60	68.25	

Euro

Fitting		RMSE			MAE		
Country Name	LHT	LC	CBD	LHT	LC	CBD	
Male	0.0014	0.0021	0.0024	0.0008	0.0012	0.0014	
Improvement related of LC or CBD (%)		35.85	43.59		31.87	43.43	
Female	0.0010	0.0013	0.0054	0.0006	0.0007	0.0030	
Improvement related of LC or CBD (%)		20.38	80.72		21.31	80.75	

Forecasting		RMSE			MAE		
Country Name	LHT	LC	CBD	LHT	LC	CBD	
Male	0.0030	0.0090	0.0131	0.0022	0.0063	0.0076	
Improvement related of LC or CBD (%)		66.28	76.90		65.16	70.93	
Female	0.0017	0.0064	0.0137	0.0011	0.0043	0.0066	
Improvement related of LC or CBD (%)		73.29	87.63		75.07	83.82	

Thank you very much!