

COMPLETE MONOTONICITY OF THE LOGARITHMIC MEAN

FENG QI AND SHOU-XIN CHEN

Abstract. In the paper, the logarithmic mean is proved to be completely monotonic and an open problem about the logarithmically complete monotonicity of the extended mean values is posed. As two remarks, some errors appeared in [7, 21, 34] are corrected.

Mathematics subject classification (2000): 26A48, 26A51.

Key words and phrases: Completely monotonic function, logarithmically completely monotonic function, logarithmic mean, Stolarsky's mean values, extended mean values.

REFERENCES

- [1] M. ABRAMOWITZ AND I. A. STEGUN (EDS), *Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables*, National Bureau of Standards, Applied Mathematics Series **55**, 9th printing, Washington, 1972.
- [2] R. D. ATANASSOV AND U. V. TSOUKROVSKI, *Some properties of a class of logarithmically completely monotonic functions*, C. R. Acad. Bulgare Sci. **41** (1988), no. 2, 21–23.
- [3] C. BERG, *Integral representation of some functions related to the gamma function*, Mediterr. J. Math. **1** (2004), no. 4, 433–439.
- [4] P. S. BULLEN, *Handbook of Means and Their Inequalities*, Mathematics and its Applications, Volume 560, Kluwer Academic Publishers, Dordrecht/Boston/London, 2003.
- [5] CH.-P. CHEN AND F. QI, *An alternative proof of monotonicity for the extended mean values*, Austral. J. Math. Anal. Appl. **1** (2004), no. 2, Art. 11; Available online at URL: <http://ajmaa.org/cgi-bin/paper.pl?string=v1n2/V1I2P11.tex>.
- [6] CH.-P. CHEN AND F. QI, *Logarithmically completely monotonic ratios of mean values and an application*, Glob. J. Math. Math. Sci. **1** (2005), no. 1, 71–76. RGMIA Res. Rep. Coll. **8** (2005), no. 1, Art. 18, 147–152; Available online at URL: <http://rgmia.vu.edu.au/v8n1.html>.
- [7] J.-CH. KUANG, *Chángyòng Bùděngshì (Applied Inequalities)*, 2nd ed., Hunan Education Press, Changsha City, Hunan Province, China, 1993. (Chinese)
- [8] E. B. LEACH AND M. C. SHOLANDER, *Extended mean values*, Amer. Math. Monthly **85** (1978), 84–90.
- [9] E. B. LEACH AND M. C. SHOLANDER, *Extended mean values II*, J. Math. Anal. Appl. **92** (1983), 207–223.
- [10] Z. PÁLES, *Inequalities for differences of powers*, J. Math. Anal. Appl. **131** (1988), 271–281.
- [11] F. QI, *A note on Schur-convexity of extended mean values*, Rocky Mountain J. Math. **35** (2005), no. 5, 1787–1793.
- [12] F. QI, *Certain logarithmically N -alternating monotonic functions involving gamma and q -gamma functions*, Nonlinear Funct. Anal. Appl. **13** (2008), no. 1, in press. RGMIA Res. Rep. Coll. **8** (2005), no. 3, Art. 5, 413–422; Available online at URL: <http://rgmia.vu.edu.au/v8n3.html>.
- [13] F. QI, *Generalized abstracted mean values*, J. Inequal. Pure Appl. Math. **1** (2000), no. 1, Art. 4; Available online at URL: <http://jipam.vu.edu.au/article.php?sid=97>. RGMIA Res. Rep. Coll. **2** (1999), no. 5, Art. 4, 633–642; Available online at URL: <http://rgmia.vu.edu.au/v2n5.html>.
- [14] F. QI, *Generalized weighted mean values with two parameters*, R. Soc. Lond. Proc. Ser. A Math. Phys. Eng. Sci. **454** (1998), no. 1978, 2723–2732.
- [15] F. QI, *Logarithmic convexity of extended mean values*, Proc. Amer. Math. Soc. **130** (2002), no. 6, 1787–1796.
- [16] F. QI, *Logarithmic convexity of the extended mean values*, RGMIA Res. Rep. Coll. **2** (1999), no. 5, Art. 5, 643–652; Available online at URL: <http://rgmia.vu.edu.au/v2n5.html>.

- [17] F. QI, *Schur-convexity of the extended mean values*, RGMIA Res. Rep. Coll. **4** (2001), no. 4, Art. 4, 529–533; Available online at URL: <http://rgmia.vu.edu.au/v4n4.html>.
- [18] F. QI, *The extended mean values: definition, properties, monotonicities, comparison, convexities, generalizations, and applications*, Cubo Mat. Educ. **5** (2003), no. 3, 63–90. RGMIA Res. Rep. Coll. **5** (2002), no. 1, Art. 5, 57–80; Available online at URL: <http://rgmia.vu.edu.au/v5n1.html>.
- [19] F. QI AND CH.-P. CHEN, *A complete monotonicity property of the gamma function*, J. Math. Anal. Appl. **296** (2004), no. 2, 603–607.
- [20] F. QI AND CH.-P. CHEN, *Monotonicity and inequalities for ratio of the generalized logarithmic means*, RGMIA Res. Rep. Coll. **6** (2003), no. 2, Art. 18, 333–339; Available online at URL: <http://rgmia.vu.edu.au/v6n2.html>.
- [21] F. QI, SH.-X. CHEN AND CH.-P. CHEN, *Monotonicity of ratio between the generalized logarithmic means*, Math. Inequal. Appl. **10** (2007), no. 3, 559–564.
- [22] F. QI AND B.-N. GUO, *Complete monotonicities of functions involving the gamma and digamma functions*, RGMIA Res. Rep. Coll. **7** (2004), no. 1, Art. 8, 63–72; Available online at URL: <http://rgmia.vu.edu.au/v7n1.html>.
- [23] F. QI AND B.-N. GUO, *On Steffensen pairs*, J. Math. Anal. Appl. **271** (2002), no. 2, 534–541. RGMIA Res. Rep. Coll. **3** (2000), no. 3, Art. 10, 425–430; Available online at URL: <http://rgmia.vu.edu.au/v3n3.html>.
- [24] F. QI, B.-N. GUO, AND CH.-P. CHEN, *Some completely monotonic functions involving the gamma and polygamma functions*, RGMIA Res. Rep. Coll. **7** (2004), no. 1, Art. 5, 31–36; Available online at URL: <http://rgmia.vu.edu.au/v7n1.html>.
- [25] F. QI, B.-N. GUO, AND CH.-P. CHEN, *Some completely monotonic functions involving the gamma and polygamma functions*, J. Austral. Math. Soc. **80** (2006), 81–88.
- [26] F. QI AND Q.-M. LUO, *A simple proof of monotonicity for extended mean values*, J. Math. Anal. Appl. **224** (1998), no. 2, 356–359.
- [27] F. QI, J. SÁNDOR, S. S. DRAGOMIR, AND A. SOFO, *Notes on the Schur-convexity of the extended mean values*, Taiwanese J. Math. **9** (2005), no. 3, 411–420. RGMIA Res. Rep. Coll. **5** (2002), no. 1, Art. 3, 19–27; Available online at URL: <http://rgmia.vu.edu.au/v5n1.html>.
- [28] F. QI AND S.-L. XU, *The function $(b^x - a^x)/x$: Inequalities and properties*, Proc. Amer. Math. Soc. **126** (1998), no. 11, 3355–3359.
- [29] F. QI, S.-L. XU, AND L. DEBNATH, *A new proof of monotonicity for extended mean values*, Internat. J. Math. Math. Sci. **22** (1999), no. 2, 415–420.
- [30] F. QI AND SH.-Q. ZHANG, *Note on monotonicity of generalized weighted mean values*, R. Soc. Lond. Proc. Ser. A Math. Phys. Eng. Sci. **455** (1999), no. 1989, 3259–3260.
- [31] J. A. SAMPAIO MARTINS, *Inequalities of Rado-Popoviciu type*, In: Marques de Sá, Eduardo (ed.) et al. Mathematical studies. Homage to Professor Doctor Luís de Albuquerque. Coimbra: Universidade de Coimbra, Faculdade de Ciências e Tecnologia, Departamento de Matemática, (1994), 169–175.
- [32] H.-N. SHI, SH.-H. WU, AND F. QI, *An alternative note on the Schur-convexity of the extended mean values*, Math. Inequal. Appl. **9** (2006), no. 2, 219–224.
- [33] K. B. STOLARSKY, *Generalizations of the logarithmic mean*, Mag. Math. **48** (1975), 87–92.
- [34] M.-J. WANG AND B. HU, *A poof of monotonicity of H. Alzer's function and some properties*, Shùxué de Shìjiàn yǔ Rènshí (Mathematics in Theory and Practice) **36** (2006), no. 10, 243–246. (Chinese)
- [35] D. V. WIDDER, *The Laplace Transform*, Princeton University Press, Princeton, 1946.
- [36] A. WITKOWSKI, *Convexity of weighted extended mean values*, RGMIA Res. Rep. Coll. **7** (2004), no. 2, Art. 10; Available online at URL: <http://rgmia.vu.edu.au/v7n2.html>.
- [37] A. WITKOWSKI, *Weighted extended mean values*, Colloq. Math. **100** (2004), no. 1, 111–117. RGMIA Res. Rep. Coll. **7** (2004), no. 1, Art. 6; Available online at URL: <http://rgmia.vu.edu.au/v7n1.html>.
- [38] S.-L. ZHANG, CH.-P. CHEN AND F. QI, *Another proof of monotonicity for the extended mean values*, Tamkang J. Math. **37** (2006), no. 3, 207–209.