

# HALIL METE SONER

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## ACADEMIC EXPERIENCE

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- 2009–present ETH Zürich Zürich  
*Professor of Mathematics*  
*Chair of Department of Mathematics, August 2017-present*
- 2007–2009 Sabancı University Istanbul, Turkey  
*Işık İnelbağ Professor*
- 2000–2007 Koç University Istanbul, Turkey  
*Dean, Professor of Mathematics and Finance*
- 1998–2000 Princeton University Princeton, NJ  
*Paul M. Whythes '55 Professor of Finance and Engineering*
  - Department of Operations Research and Financial Engineering.
  - Program in Applied and Computational Mathematics.
  - Bendheim Center for Finance.
- 1986–1998 Carnegie Mellon University Pittsburgh, PA  
*Professor of Mathematics*
  - Prof., 1992, Associate Prof., 1990, Assistant Prof., 1986.
- 1985–1986 Institute for Math. and App. Minneapolis, MN  
*Research Associate*

## EDUCATION

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- 1981–1985 Brown University Providence, RI
  - Ph.D., Applied Mathematics, 1986.
  - M.Sc., Applied Mathematics, 1983.
- 1977–1981 Bogazici University Istanbul, Turkey
  - B.Sc., Mathematics and Electrical Engineering.

## AWARDS AND HONORS

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- SIAM Fellow, Class of 2015.
- Alexander von Humbolt Foundation Research Award, 2014.
- European Research Council Advanced Grant: Dec. 2008 - Nov. 2013.
- Twice Invited Speaker in European Mathematical Congress: July 2008, Amsterdam and July 2016, Berlin.
- Plenary Speaker, SIAM Conf. on Control and Its App., July 2015, Paris.
- Plenary Speaker, INFORMS, June 2015, Istanbul .
- Plenary Speaker, SIAM Meeting on Financial Engineering, and Topical Speaker, SIAM Annual Meeting, June 2006, Boston, MA.

## SERVICE TO ACADEMIC COMMUNITY

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- During 2011-2016, Soner has been the Executive Secretary of the *Bachelier Finance Society*.
- Soner served as the Vice-Chair to the Department of Mathematics during 08.2015-08.2017.

- Currently Soner is an associate editor for
  - SIAM Journal of Mathematical Finance,
  - Mathematics and Financial Economics,
  - Interfaces and Free Boundaries,
  - ESAIM: Control, Optimisation and Calculus of Variations.
- In the past he has served in the editorial boards of: Journal of European Mathematical Society, Annals of Applied Probability, SIAM Journal on Control and Optimization, SIAM Journal on Mathematical Analysis, Applied Mathematics and Optimization, Mathematical Methods in Operations Research.
- He has organized many workshops and several large conferences.
- He has given many invited lectures and the list can be found in Soner's web page.

## RESEARCH PROJECTS

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Since 1986, Soner's research has been supported by

- European Research Council (ERC),
- Swiss National Fund (SNSF),
- National Science Foundation of USA (NSF),
- Air Force Office of Research (USA),
- Turkish Foundation of Science and Technology (TUBITAK),
- ETH Foundation.

## GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS AT ETH

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Graduate students at ETH (since 2009) and their current positions are,

- Mr. Vincenzo Ignazio, continuing,
- Mr. Matti Kiiski, continuing,
- Mr. Max Reppen, continuing,
- Dr. Sebastian Hermann, (ETH, 2016), University of Michigan,
- Dr. Mario Sikic, (ETH, 2015), University of Zurich,
- Dr. Albert Altarovici, (ETH, 2015), Palantir, California, USA,
- Dr. Mirjana Vukelja, (ETH, 2014), UBS, Zurich,
- Prof. Erdinç Akyildirim, (Swiss Finance Institute, 2013), Akdeniz University, Antalya, Turkey,
- Dr. Selim Gökay (ETH, 2011) Deutsche Bank, Berlin, Germany.

Postdoctoral Fellows at ETH (since 2009) and their current positions are,

- Dr. Chen Yang, (April 2016, continuing),
- Dr. Matteo Burzoni, (October 2014, continuing),
- Dr. Ariel Neufeld, (April 2015, continuing),
- Dr. Ibrahim Ekren, (September 2014, September 2017), University of Michigan.
- Dr. Ludovic Moreau, (October 2012-October 2014), Ernst & Young, Paris.
- Prof. Anja Richter, (January 2013-August 2013), Baruch College, New York, USA.
- Dr. Marcus Wunsch, (January 2013-August 2013), UBS, Zurich,
- Prof. Yan Dolinsky, (February 2010-September 2012), Hebrew University, Jerusalem, Israel.
- Prof. Marcel Nutz, (October 2010-September 2011), Columbia University, New York, USA.
- Dr. Gilles-Edouard Espinosa, (September 2010-February 2011), ENPC (Cermics), Paris,
- Prof. Idris Kharroubi, (January 2010-June 2010), Ceremade, University of Paris IX, Dauphine,
- Prof. Alexandre Roch, (September 2009-July 2010), ESG UQAM, Montreal, Canada.

## SONER'S RESEARCH HIGHLIGHTS SINCE 2013

Since 2013, Soner's research has focused on the following topics:

- Quasi-sure analysis and second order backward stochastic differential equations,
- Robust or Model-Independent Hedging,
- Impact of Transaction Costs on Investment Decisions.

In the each of the following sections we briefly describe his contributions to these problems since 2013.

### 1. QUASI-SURE ANALYSIS

In joint work with Professors Nizar Touzi (Ecole Polytechnique, Paris) and Jianfeng Zhang (USC, California), Soner developed a theory for non-dominated backward stochastic differential equations (BSDE). In the Markovian case, these equations provide a stochastic representation for fully nonlinear parabolic partial differential equations and therefore are called second order BSDEs. Since it is well known that BSDE's are connected to semilinear partial differential equations (i.e., with linear dependence on the Hessian), 2BSDE's are an extension of the classical theory of BSDEs. The 2BSDE theory has its roots in an earlier paper of Soner and Touzi joint with Cheridito and Victoir [5] and in [14].

In [15] it is observed that 2BSDE's can be constructed as the essential-supremum of a family of BSDE's. However, the driving noise of these BSDEs have their own volatility processes. Therefore, the natural probability measures under which these BSDE's are defined are mutually orthogonal to each other. On the technical side, this structure requires interesting new constructions for the stochastic integrals and stochastic processes in general. In fact, even the definition of the essential supremum is not clear and a construction using stochastic analysis and dynamic programming is provided in these papers.

### 2. ROBUST HEDGING

In joint work with a postdoctoral fellow Yan Dolinsky (currently in Hebrew University in Jerusalem), Soner proved several convex duality results in this context. In particular, [6] gives the first convex duality result for the Martingale Optimal Transport (MOT) in continuous time. This proof is based on a novel discretization technique. Indeed, one can easily obtain discrete time approximations of a stochastic processes. Then, for these discrete structures, the MOT duality follow rather directly from standard mini-max theorems and the Fenchel-Moreau theorem. However, the convergence of the resulting discrete problems to the original ones is not clear. The main difficulty is the hard adaptability constraints that the hedges need to satisfy. [6] provides an approximation technique which allows for convergence results. Later, in [8] Dolinsky & Soner extended this duality to great generality by considering general càdlàg processes with values in  $\mathbb{R}^d$  and with many marginals. The main technical step was the extension of the discretization technique.

Again in joint work with Dolinsky, Soner considered robust hedging in financial markets with frictions. [7, 9] provide financial insight for the impact of trading costs. In particular, [9] shows that in a financial market with non-trivial transactions costs, the minimal super-replication cost is the same for any probabilistic model with full support. Moreover, this common value is the model-independent cost. In other words, one can not use the probabilistic model for the financial market when super-replication is desired.

An abstract formulation of hedging problems and their connections to the classical optimal transport is proved by Ekren and Soner in a recent manuscript [10].

### 3. HEDGING WITH FRICTIONS

In joint work with Touzi and Possamai [12, 13], Soner developed a new method for the asymptotic analysis of problems with small proportional transaction costs. This is a novel systematic approach and generalizes all earlier results on Markovian models. This method is then extended to models with fixed transaction cost in a joint with Altarovici and Muhle-Karbe [1] and with mixed costs in [2]. [11] considers the problems with market impact and [4] applies the technique to problems with loss constraints.

A pure tracking problem is considered by Bank, Soner and Voss in [3].

### REFERENCES

- [1] A. Altarovici, J. Muhle-Karbe, and H. M. Soner. Asymptotics for fixed transaction costs. *Finance and Stochastics*, 19(2):363–414, 2015.
- [2] A. Altarovici, M. Reppen, and H. M. Soner. Optimal consumption and investment with fixed and proportional transaction costs. *SIAM Journal on Control and Optimization*, 25(5):1673–1710, 2017.
- [3] P. Bank, H. M. Soner, and M. Voss. Hedging with temporary price impact. *Mathematics and Financial Economics*, 11(2):215–239, 2017.
- [4] B. Bouchard, L. Moreau, and H. M. Soner. Hedging under an expected loss constraint with small transaction costs. *SIAM Journal on Mathematical Finance*, 7(1):508–551, 2016.
- [5] P. Cheridito, H. M. Soner, N. Touzi, and N. Victoir. Second-order backward stochastic differential equations and fully nonlinear parabolic pdes. *Communications on Pure and Applied Mathematics*, 60(7):1081–1110, 2007.
- [6] Y. Dolinsky and H. M. Soner. Martingale optimal transport and robust hedging in continuous time. *Probability Theory and Related Fields*, 160(1-2):391–427, 2014.
- [7] Y. Dolinsky and H. M. Soner. Robust hedging with proportional transaction costs. *Finance and Stochastics*, 18(2):327–347, 2014.
- [8] Y. Dolinsky and H. M. Soner. Martingale optimal transport in the skorokhod space. *Stochastic Processes and their Applications*, 125(10):3893–3931, 2015.
- [9] Y. Dolinsky and H. M. Soner. Convex duality with transaction costs. *Mathematics of Operations Research*, 42(2):448–471, 2017.
- [10] I. Ekren and H. M. Soner. Constrained optimal transport. *Archive for Rational Mechanics and Analysis*, 227(3):929–965, 2018.
- [11] L. Moreau, J. Muhle-Karbe, and H. M. Soner. Trading with small price impact. *Mathematical Finance*, 27(2):350–400, 2017.
- [12] D. Possamai, H. M. Soner, and N. Touzi. Homogenization and asymptotics for small transaction costs: the multidimensional case. *Communications in Partial Differential Equations*, 40(11):2005–2046, 2015.
- [13] H. M. Soner and N. Touzi. Homogenization and asymptotics for small transaction costs. *SIAM Journal on Control and Optimization*, 51(4):2893–2921, 2013.
- [14] H. M. Soner, N. Touzi, and J. Zhang. Wellposedness of second order backward sdes. *Probability Theory and Related Fields*, 153(1-2):149–190, 2012.
- [15] H. M. Soner, N. Touzi, J. Zhang, et al. Dual formulation of second order target problems. *The Annals of Applied Probability*, 23(1):308–347, 2013.

## SONER'S RESEARCH OUTPUT SINCE 2013

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Complete list of publications can be found at the web site

<https://people.math.ethz.ch/~hmsoner/publications.html>

### PREPRINTS

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1. [Viability and arbitrage under Knightian uncertainty](#), (with Matteo Burzoni and Frank Riedel), arXiv:1707.03335v1, (2017).
2. [Dividends with random profitability rate](#), (with Max Reppen and Jean-Charles Rochet), arXiv:1706.01813v1, (2017).
3. [Conditional Davis prices](#), (with Kasper Larsen and Gordan Zitkovic), arXiv:1702.02087v1, (2017).

### PAPERS IN REFEREED JOURNALS

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#### 2018:

4. [Constrained optimal transport](#), (with Ibrahim Ekren), arXiv:1610.02940v1, Archive for Rational Mechanics, 3, 929—965, (2018).

#### 2017:

5. [A primer on portfolio choice with small transaction costs](#), (with Johannes Muhle-Karbe and Max Reppen), arXiv:1612.01302v1, Annual Review of Financial Economics, 9, 301—331, (2017).
6. [Optimal consumption and investment with fixed and proportional transaction costs](#), (with Albert Altarovici and Max Reppen), arXiv:1610.03958, SIAM J. Control and Optimization, 55,1673–1710, (2017).
7. [Convex duality with transaction costs](#), (with Yan Dolinsky), arXiv:1502.01735, Mathematics of Operations Research, 42/2,448–471, (2017).
8. [Trading with small impact](#), (with L. Moreau and J. Muhle-Karbe), arXiv:1402.5304, Mathematical Finance, 27/2,350–400, (2017).
9. [Hedging with temporary price impact](#), (with Peter Bank and Moritz Voss), arXiv:1510.03223v1, Mathematics and Financial Economics, 11, 215–229, (2017).

#### 2016:

8. [Utility maximization in an illiquid market in continuous time](#), (with M. Vukelja), Mathematical Methods in Operations Research, 84/2, 285–321, (2016).
9. [Hedging under an expected loss constraint with small transaction costs](#), (with B. Bouchard and L. Moreau), SIAM Journal on Math. Fin., 7/1, 508–551, (2016).
10. [Facelifting in utility maximization](#), (with K. Larsen and G. Zitkovic), Finance and Stochastics, 20(1), 99-121, (2016).

#### 2015:

11. [Homogenization and asymptotics for small transaction costs - the multi-dimensional case](#), (with D. Possamaï and N. Touzi), Communications in PDEs, 40(11), 2005-2046, (2015).
12. [Martingale optimal transport in the Skorokhod space](#), (with Y. Dolinsky), Stochastic processes and their Applications, 125(10), 3893-3931, (2015).
13. [Asymptotics with fixed transaction costs](#), (with A. Altarovici and J. Muhle-Karbe), Finance

and Stochastics, 19(2), 363-414, (2015).

**2014:**

14. [Robust hedging with proportional transaction costs](#), (with Y. Dolinsky), Finance and Stochastics, 18 (2), 327–347, (2014).
15. [Approximating stochastic volatility by recombining trees](#), (with E. Akyildirim and Y. Dolinsky), Annals of Applied Probability, 24/5, 2176–2205, (2014).
16. [Optimal dividend policy with random interest rates](#), (with E. Akyildirim, I.E. Guney and J.C. Rochet), Journal on Mathematical Economics, 24/5, 2176–2205, (2014).
17. [Martingale optimal transport and robust hedging in continuous time](#), (with Y. Dolinsky), Probability Theory and Related Fields, 160 (1–2), 391–427, (2014).
18. [Hedging in an Illiquid Binomial Market](#), (with S. Gökay), Nonlinear Analysis. Real World Applications, 16, 1–16, (2014).

**2013:**

19. [Homogenization and asymptotics for small transaction costs](#), (with N. Touzi), SIAM Journal on Control and Optimization, 51/4, 2893–2921, (2013).
20. [Resilient price impact of trading and the cost of illiquidity](#), (with A.F. Roch), International Journal on Theoretical and Applied Finance, 16/6, (2013).
21. [Utility maximization in an illiquid market](#), (with M. Vukelja), Stochastics - special issue in memory of M. Taksar, 85/4, 692–706, (2013).
22. [Dual Formulation of Second Order Target Problems](#), (with N. Touzi and J. Zhang), Annals of Applied Probability, 23/1, 308–347, (2013).
23. [Vortex density models for superconductivity and superfluidity](#), (with S. Baldo, R.L. Jerrard, G. Orlandi), Communications in Mathematical Physics, 318/1, 131–171, (2013).
24. [Duality and Convergence for Binomial Markets with Friction](#), (with Y. Dolinsky), Finance and Stochastics, 17 (3), 447–475, (2013).

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## SELECTED INVITED PLENARY PRESENTATIONS

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- July 2017, Invited Speaker, Congress on Free Boundaries, Shanghai.
- July 2017, Invited Speaker, Indham Wrokshop on Control, Rome.
- July 2016, Invited Speaker, European Mathematical Congress, Berlin.
- July 2015, Plenary Speaker, SIAM Con. on Control and Its App., Paris.
- June 2015, Plenary Speaker, INFORMS App. Prob. Conf., Istanbul.
- March 2014, Invited Talk, 11th German Probability and Statistics Days, Ulm.
- April 2013, Nomura Seminar Oxford.

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## INVITED PRESENTATIONS

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**2018:**

- January 2018, Talks on martingale optimal transport, Singapore.

**2017:**

- September 2017, Turkish Math. Society Talk, Istanbul.
- September 2017, Workshop on robust methods in finance, Leeds.

- September 2017, Workshop on martingale optimal transport, Oxford.
- July 2017, Invited Speaker, Congress on Free Boundaries, Shanghai.
- July 2017, Invited Speaker, Indham Wrokshop on Control in honor of Cannarsa, Rome.
- June 2017, Workshop in honor of Karatzas, Santorini.
- March 2017, Workshop on finance, Trier.
- March 2017, Workshop, Oberwolfach.
- January 2017, Koc University Seminar, Istanbul.

#### **2016:**

- July 2016, Invited Speaker, European Mathematical Congress, Berlin.
- June 2016, Byrne Workshop on Stochastic Analysis in Finance and Insurance, Michigan.
- April 8, 2016, Finance Seminar, University of Zurich.
- March 29, 2016, Workshop on Stochastic Systems, Rio De Janerio, Brasil.
- January 2016, Series of Finance talks, National University of Singapore.

#### **2015 :**

- October 15, 2015, Invited Colloquium talk, London Math Finance Talks.
- September 17, 2015, Invited workshop talk, ITS workshop on robust techniques in Zurich.
- July 2015, Pleanary Speaker, SIAM Con. on Control and Its App., Paris.
- June 2015, Pleanary Speaker, INFORMS App. Prob. Conf., Istanbul.
- May 19, 2015, Invited workshop talk, Bielefeld workshop on mathematical economics.
- March 19, 2015, Invited workshop talk, Kaiserslautern workshop on quantitative finance.
- March 9, 2015, workshop on martingale optimal transport, Hausdorf Institute, Bonn.
- January 27, 2015, Invited seminar, University of Bonn.

#### **2014:**

- February 5, 2014, Invited Conference Talk in the German Probability Conference, Ulm.
- March 24, 25, 2014. ETH Conference on Robust techniques, organizer.
- April, 7-9, 2014. ETH-Imperial Conference, co-organizer.
- May 5-9, Invited seminar during the Oberwolfach meeting on Mathematical Finance.
- June 17, 2014. Invited seminar, AMS-Israeli Mathematical Society meeting, Tel-Aviv.
- July 2, 2014. Invited seminar during the workshop onn nonlinear analysis, in Cyprus.
- October 21, 2014, Mathematics Colloquium, University of Michigan.
- October 23, 2014, Statistics seminar Columbia University, NewYork.
- November 20, 2014, Mathematical Finance seminar, Humbolt University, Berlin.
- November 25, 2014, Seminar Max-Planck Institute, Leipzig, Germany.

#### **2013:**

- Januray 2013, Several talks in the National University of Singapore, Singapore..

- March 5, 2013, Workshop at the Imperial College, London, UK.
- March 7, 2013, Workshop talk during the ETH-Imperial workshop, London, UK.
- April 1-5, 2013, Series of talks, University of Pittsburgh, Pittsburgh, PA, USA.
- April 29, 2013, Seminar talk "Robust Hedging" in Oxford University, Oxford, UK.
- June 4, 2013, Conference talk "Robust Hedging", Dublin, Ireland.
- June 26, 2013, Conference talk "Robust Hedging", Moscow, Russia.
- September, 2013, Series of talks "Model free hedging", Paris, France.
- September 17, 2013, Seminar talk "Trading with small transaction costs" in University of Paris, Dauphine, Paris, Paris, France.
- October, 30, 2013, Colloquium "Mathematics in Finance" in Istanbul Stock Exchange, Istanbul, Turkey.
- October 27, 2013, Conference talk "Robust Hedging" in Fields Institute, Toronto, Canada