Macroeconomic Dynamics, **16** (Supplement 1), 2012, 5–17. Printed in the United States of America.
doi:10.1017/S1365100511000472

ARTICLES

TRIBUTE TO KAZUO NISHIMURA

JEAN-MICHEL GRANDMONT
ICEF, University Ca' Foscari
and
CREST-GRECSTA

It is a great honor and a great pleasure for me to pay tribute to the accomplishments of Kazuo Nishimura on the occasion of this special issue. He is a great scientist, whose contributions I deeply admire and respect, and he is a good friend.

I remember vividly the first time I met Kazuo (well, "met" may not be exactly the right word, as you are going to see shortly). That was in October 1983 at the Institute for Mathematics and Its Applications of the University of Minnesota, Minneapolis, where I had been kindly invited by Hugo Sonnenschein to give a lecture on my paper "On Endogenous Competitive Business Cycles" at the Workshop on "Price Adjustment, Quantity Adjustment and Business Cycles" he had organized there. While going to the lecture room, shortly after my flight from France landed in the airport, I saw this young Japanese guy crossing suddenly my way to hand me a paper, with the words "This is for you !" only to turn around and disappear immediately. Hugo Sonnenschein told me that he was Kazuo Nishimura, who I knew already at that time had made significant contributions to business cycle theory. Indeed, I was aware of his path-breaking paper with Jess Benhabib in *JET* (1979c) introducing the Hopf bifurcation in the analysis of dynamic economic systems. I think that the paper he handed me then was a version of another important contribution of his, written also with Jess Benhabib, on "Competitive Equilibrium Cycles," and published later in *JET* (1985).

Kazuo Nishimura is a great economic theorist who has devoted his scientific life in this field to the analysis of multiple equilibria and business cycles in economic models. Actually it is striking to see that his concern with multiplicity of economic equilibria started quite early in his academic life. After an M.A. in agriculture economics at the University of Tokyo in 1972, he went on to work on a Ph.D. in economic theory under the supervision of the great general equilibrium theorist at the University of Rochester, Lionel McKenzie. It may be noticed that the title of his 1977 Ph.D. dissertation was "On the Problems of Uniqueness." The titles of his first published papers are indeed telling: "A Further Remark on the Number of Equilibria of an Economy" (1978a); "On the Uniqueness Theorems by Arrow and Hahn" (1979b). In fact, even his first published paper on economic dynamics,

This short text was meant to celebrate the accomplishments of Kazuo Nishimura on the occasion of his 65th birthday at the conference organized in his honor at GREQAM, Marseille, June 9–11, 2011 and was written down for the corresponding special issue of *Macroeconomic Dynamics*. Address correspondence to: Jean-Michel Grandmont, CREST, 15 boulevard Gabriel Peri, 92245 Malakoff, France; e-mail: Jean-Michel.Grandmont@ensae.fr.

© 2012 Cambridge University Press 1365-1005/12

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

co-authored with Jess Benhabib, dealt with the "Uniqueness of Steady States in an Economy with Heterogeneous Capital Goods" (1979a). This concern with multiplicity may even have had some personal impact. After having been assistant professor (1977–1978) and then associate professor (1978–1987) at the Tokyo Metropolitan University, he was full-time professor at the Institute of Economic Research in Kyoto University since 1987, while having all this time his home address in Tokyo. . . .

Kazuo Nishimura made very early in his academic career, jointly with Jess Benhabib, seminal contributions to the theory of endogenous deterministic cycles. In their *JET* paper (1979c), they showed that optimal growth with two or more capital goods may give rise in continuous time to optimal limit cycles through the Hopf bifurcation. In their *JET* paper (1985), they gave sufficient conditions generating robust periodic cycles based on relative capital intensities in two-sector neoclassical models of production with infinitely long-lived agents. These seminal contributions have been reprinted several times in volumes collecting major contributions on economic dynamics.

Kazuo Nishimura made also significant contributions along this line with Makoto Yano by showing the possibility of ergodic chaos in optimal growth models with low discount rates [*Economic Theory* (1994a), with Gerhard Sorger]. In their joint paper in *Econometrica* (1995c), they showed the possibility of ergodic chaos in discrete-time two-sector optimal growth models with a Leontief production technology and arbitrarily low discount rates. Pursuing along this line of research, they exhibited in their joint paper in *JET* (1996b) a least upper bound of discount factors that are compatible with optimal period-three cycles in a standard model of economic growth. At about the same time, Kazuo Nishimura and Gerhard Sorger published a nice survey of the conditions ensuring the existence of optimal cycles and chaos in neoclassical growth models in continuous as well as in discrete time [*SNDE* (1996c)]. More recently, Kazuo Nishimura showed the existence of chaotic equilibrium dynamics in multisector endogenous growth models with positive external effects among sectors [*JET* (2001c), with Michele Boldrin, Tadashi Shigoka, and Makoto Yano]. These contributions are important in analyzing the conditions underlying the emergence of "complex" deterministic trajectories in multisector optimal growth models, in particular in discrete time, where the length of the period is short.

Kazuo Nishimura pursued his important contributions on this issue by analyzing the conditions implying the occurrence of "global" bifurcations and complex deterministic equilibrium trajectories in dynamic economic models [see, e.g., *JET* (2001d), with Tapan Mitra; *IJET* (2009b), with Paolo Mattana and Tadashi Shigoka].

These (selected) contributions concerned the occurrence of complex deterministic (chaotic) economic dynamics. Kazuo Nishimura also made important contributions to the study of the occurrence of stationary random sunspots equilibrium dynamics, which emerge when there is local or global indeterminacy. In the early 1990s, it was known that such indeterminacy did occur in dynamic economic

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

models involving significant increasing returns to scale and significant market imperfections (externalities), in fact too significant to be "realistic." In an important contribution with Jess Benhabib [*JET* (1998a),]Kazuo Nishimura proved that indeterminacy and the associated sunspot equilibria can easily arise in multisector dynamic economic models with constant returns production technologies and very small market imperfections (externalities). Other significant contributions along this line are his joint papers with Jess Benhabib and Qinglai Meng in *Econometrica* (2000c), and with Alain Venditti in *JET* (2002d). A quite recent, interesting contribution that studies bifurcations and sunspots in continuous-time dynamic economic models with constant returns to scale, small externalities, and variable capacity utilization can be found in his joint paper with Jess Benhabib and Tadashi Shigoka in *IJET* (2008d).

Kazuo Nishimura made quite interesting applications of these techniques to the analysis of the conditions implying indeterminacy and endogenous (sunspot) business cycles in international trade, in particular by considering two-country models with sector-specific externalities. It is worth quoting here his joint contributions with Koji Shimomura [*JEDC* (2002c); *JET* (2002e); *Economic Theory* (2006l)] and with Alain Venditti and Makoto Yano [*IJET* 2010b).

Kazuo Nishimura also made significant contributions to the dynamic analysis of economic models in the presence of stochastic shocks to the fundamentals. In particular, in his joint work with Jess Benhabib [*IER* (1989c)], he showed the possible occurrence of stochastic equilibrium oscillations, in some cases along cyclic sets. Also important here are his joint contributions with John Stachurski on the analysis of stochastic optimal growth models [*JET* 2005e; *Journal of Mathematical Economics* (2006o), with Ryszard Rudnicki; *JEDC* (2007f)].

This brief, and far from exhaustive, review of Kazuo Nishimura's outstanding contributions shows that he is clearly one of the few great economic theorists who have profoundly influenced our understanding of the dynamics of our economies. The profession has long recognized the importance of his contributions by honoring him repeatedly. Beyond his numerous editorial responsibilities, he was elected Fellow of the Econometric Society in 1992. He served as a Council Member of that Society in 1994–2001, and was program Chairman of its 1989 Far Eastern Meeting. In Japan, he has been the successful Director of the Kyoto Institute of Economic Research (KIER) for years, which became internationally very well known under his leadership. He was also elected Vice-President, and then President of the Japanese Economic Association in 1999–2001. He received in 2008 the Nikkei Prize for Excellent Books in Economic Science.

I would like also to mention that Kazuo Nishimura has been very influential in Japan and abroad by writing numerous papers and a book on the importance of teaching and learning mathematics in the education of young people. My understanding is that he got a well-deserved prize award from the Mathematical Society of Japan in 2005, honoring this book. My understanding is also that as a recognition of his action on this issue, he was elected in 2006, and has been serving since then, as President of the International Society for Education.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

Last but not least, I would like to testify that Kazuo Nishimura, beyond his great qualities as a scientist, is a wonderful, very lovable person. I think I am qualified to tell you this, for I enjoyed sharing many delightful moments with him, in particular during long evenings in Japanese restaurants in Kyoto or Tokyo, trying to compete (unsuccessfully) with him in drinking sake. . . .

The University of Aix-Marseille II has already celebrated Kazuo Nishimura's great scientific achievements by giving him an honorary doctoral degree in 2007. We are all here again in June 2011 in Marseille to tell him how much we admire and respect his scientific contributions, and to wish him a happy 65th birthday, hoping that he will be still around for the next 65 years, for the great benefit and pleasure of all of us.

MAIN SCIENTIFIC WRITINGS OF KAZUO NISHIMURA

BOOKS AND SYMPOSIUM ISSUES (EDITED IN ENGLISH)

Special Issue on Growth, Sustainability and Equilibria in Honor of Tapan Mitra (with Kaushik Basu and Mukul Majumdar). *International Journal of Economic Theory*, 2010a.

Special Issue in Honor of Jess Benhabib (with Roger Farmer). *International Journal of Economic Theory,* 2009a.

Equilibrium, Trade, and Growth; Selected Papers of Lionel W. McKenzie (with Tapan Mitra). Cambridge, MA: MIT Press, 2008a.

Special Issue in Honor of Takashi Negishi (with Makoto Yano). *International Journal of Economic Theory*, 2008b.

Special Issue on Nonlinear Macroeconomic Dynamics (with Makoto Yano). *International Journal of Economic Theory*, 2008c.

Handbook on Optimal Growth, 1—Discrete Time (with Rose-Anne Dana, Cuong Le Van, and Tapan Mitra). Berlin: Springer, 2006a.

Special Issue on Instability and Fluctuations in Intertemporal Equilibrium Models (with Cuong Le Van, Tapan Mitra, and Alain Venditti). *Journal of Mathematical Economics,* 2006b.

Special Issue on Intertemporal Equilibria, Aggregation and Sunspots in Honor of Jean Michel Grandmont (with Makoto Yano). *International Journal of Economic Theory,* 2006c.

Symposium Issue in Honor of Mukul Majumdar (with Charalambos D. Aliprantis, Tapan Mitra, and Roy Radner). *Economic Theory,* 2006d.

Symposium on Trade and Growth (with Makoto Yano). *Japanese Economic Review,* 2006e.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

Special Issue on Discrete-Time Dynamics in Economics (with Makoto Yano). *Journal of Difference Equations and Applications* 10 (5), 2004a.

Symposium on Intertemporal Equilibrium Theory: Indeterminacy, Bifurcations and Stability (with Tapan Mitra). *Journal of Economic Theory,* 2001a.

Optimization and Chaos (edited with Mukul Mujumdar and Tapan Mitra). Berlin: Springer, 2000a.

Symposium on Intertemporal Equilibrium Theory and Nonlinear Dynamics (with Harutaka Takahashi). *Japanese Economic Review* 50 (4), 1999a.

ACADEMIC PAPERS

Expectations-driven fluctuations and welfare loss under free trade in two-country models (with Alain Venditti and Makoto Yano). *International Journal of Economic Theory* 6 (1), 97–125, 2010b.

Indeterminacy and expectation-driven fluctuations with non-separable preferences (with Alain Venditti). *Mathematical Social Sciences* 60, 46–56, 2010c.

Multiple equilibria in two-sector monetary economies: An interplay between preferences and the timing for money (with Stefano Bosi and Alain Venditti). *Journal of Mathematical Economics* 46 (6), 997–1014, 2010d.

A homoclinic bifurcation and global indeterminacy of equilibrium in a two-sector endogenous growth model (with Paolo Mattana and Tadashi Shigoka). *International Journal of Economic Theory* 5 (1), 25–47, 2009b.

Equilibrium storage with multiple commodities (with John Stachurski). *Journal of Mathematical Economics* 45, 80–96, 2009c.

Global externalities, endogenous growth and sunspot fluctuations (with Harutaka Takahashi and Alain Venditti). In S. Elaydi, K. Nishimura, M. Shishikura, and N. Tose (eds.), *Advances in Discrete Dynamical Systems,* pp. 203–214. Tokyo: Mathematical Society Japan, 2009d.

Indeterminacy and business-cycle fluctuations in a two-sector monetary economy with externalities (with Stefano Bosi and Alain Venditti). *Journal of Difference Equations and Applications* 15, 1085–1096, 2009e.

Indeterminacy in aggregate models with small externalities: An interplay between preferences and technology (with Carine Nourry and Alain Venditti). *Journal of Nonlinear and Convex Analysis* 10, 279–298, 2009f.

On geometric ergodicity of the commodity pricing model (with John Stachurski). *International Journal of Economic Theory* 5 (3), 293–300, 2009g.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

Optimal growth and competitive equilibrium business cycles under decreasing returns in two-country models (with Alain Venditti and Makoto Yano). *Review of International Economics* 17 (2), 371–391, 2009h.

Bifurcation and sunspots in the continuous time equilibrium model with capacity utilization (with Jess Benhabib and Tadashi Shigoka). *International Journal of Economic Theory* 4 (2), 337–355, 2008d.

Characterization of equilibrium paths in a two-sector economy with CES production functions and sector-specific externality (with Miki Matsuo, Tomoya Sakagami, and Alain Venditti). In Takashi Kamihigashi and Laixun Zhao (eds.), *International Trade and Economic Dynamics,* pp. 421–431. Berlin: Springer, 2008e.

Detection of neural activity associated with thinking in frontal lobe by magnetoencephalography (with Yoshikazu Tobinaga and Mitsuo Tonoike). *Progress of Theoretical Physics,* Supplement 173, 332–341, 2008f.

Equilibrium dynamics in discrete-time endogenous growth models with social constant returns (with Kazuo Mino, Koji Shimomura, and Ping Wang). *Economic Theory* 34, 1–23, 2008g.

Specific factor models and dynamics in international trade (with Yunfang Hu and Koji Shimomura). In Sugata Marjit and Eden Yu (eds.), Contemporary and Emerging Issues in Trade Theory and Policy. *Frontiers of Economic and Globalization* 4, 191–207. Bingley, UK: Emerald, 2008h.

Time preference and two-country trade (with Been-Lon Chen and Koji Shimomura). *International Journal of Economic Theory* 4, 29–52, 2008i.

A two-country dynamic model of international trade and endogenous growth: Multiple balanced growth paths and stability (with Junko Doi and Koji Shimomura). *Journal of Mathematical Economics* 43 (3–4), 390–419, 2007a.

Indeterminacy in discrete-time infinite-horizon models with non-linear utility and endogenous labor (with Alain Venditti). *Journal of Mathematical Economics* 43 (3–4), 446–476, 2007b.

Instability and fluctuations in intertemporal equilibrium models: Introduction to the special issue (with Cuong Le Van, Tapan Mitra, and Alain Venditti). *Journal of Mathematical Economics* 43 (3–4), 231–235, 2007c.

Intertemporal substitution in consumption, labor supply elasticity and sunspot fluctuations in continuous-time models (with Jean-Philippe Garnier and Alain Venditti). *International Journal of Economic Theory* 3 (4), 235–259, 2007d.

School choice and the intergenerational poverty trap (with Lakshmi K. Raut). *Review of Development Economics* 11 (2), 412–420, 2007e.

Stochastic optimal policies when the discount rate vanishes (with John Stachurski). *Journal of Economic Dynamics and Control* 31 (4), 1416–1430, 2007f.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

Detection of thinking in human by magneto-encephalography (with Mitsuo Tonoike and Yoshikazu Tobinaga). In R. Magjarevic and J. H. Nagel (eds.), World Congress of Medical Physics and Biomedical Engineering 2006. *IFMBE Proceedings* 14, 2617–2621. Berlin: Springer, 2006f.

Duality with sector-specific externalities under social constant returns (with Koji Shimomura and Ping Wang). *Japanese Economic Review* 57, 467–475, 2006g.

Dynamic three-factor models of international trade (with Yunfang Hu and Koji Shimomura). *Asia–Pacific Journal of Accounting and Economics* 13 (2), 73–85, 2006h.

Endogenous fluctuations in two-country models (with Alain Venditti and Makoto Yano). *Japanese Economic Review* 57, 516–532, 2006i.

Endogenous fluctuations in two-sector models: Role of preferences (with Harutaka Takahashi and Alain Venditti). *Journal of Optimization Theory and Applications* 128 (2), 309–331, 2006j.

Foreword to the Symposium in Honor of Mukul Majumdar (with Charalambos D. Aliprantis, Tapan Mitra, and Roy Radner). *Economic Theory* 29, 249–250, 2006k.

Indeterminacy in a dynamic two-country model (with Koji Shimomura). *Economic Theory* 29, 307–324, 2006l.

Intertemporally dependent preferences and optimal dynamic behavior (with Tapan Mitra). *International Journal of Economic Theory* 2, 77–104, 2006m.

Parents' educational background, subjects "good-at" in schools affect income: An empirical study (with Junichi Hirata, Junko Urasaka, and Tadashi Yagi). *Japanese Economic Review* 57, 533–546, 2006n.

Stochastic optimal growth with non-convexities (with Ryszard Rudnicki and John Stachurski). *Journal of Mathematical Economics* 42 (1), 74–96, 2006o.

Sunspots and Hopf bifurcations in continuous time endogenous growth models (with Tadashi Shigoka). *International Journal of Economic Theory* 2, 199–216, 2006p.

Symposium on Trade and Growth: Introduction (with Makoto Yano). *Japanese Economic Review* 57, 455–456, 2006q.

Capital accumulation games with a non-concave production function (with Engelbert J. Dockner). *Journal of Economic Behavior and Organization* 57, 408–420, 2005a.

Indeterminacy in continuous-time two-sector models: An exposition (with Alain Venditti). *Keio Economic Studies* 42 (1–2), 73–81, 2005b.

Intertemporal complementarity and optimality: A study of a two-dimensional dynamical system (with Tapan Mitra). *International Economic Review* 46 (1), 93–131, 2005c.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

Production externalities and local dynamics in discrete-time multi-sector growth models with general production technologies (with Koji Shimomura and Ping Wang). *International Journal of Economic Theory* 1, 299–312, 2005d.

Stability of stochastic optimal growth models: A new approach (with John Stachurski). *Journal of Economic Theory* 122, 100–118, 2005e.

Asymmetric factor substitutability and indeterminacy (with Alain Venditti). *Journal of Economics* 83 (2), 125–150, 2004b.

Capital depreciation, factor substitutability and indeterminacy (with Alain Venditti). *Journal of Difference Equations and Applications* 10 (13–15), 1153–1169, 2004c.

Discrete time in economics: An introduction (with Makoto Yano). *Journal of Difference Equations and Applications* 10 (5), 449–451, 2004d.

Discrete time models in economic theory (with John Stachurski). *Cubo a Mathematics Journal* 6, 187–207, 2004e.

Indeterminacy and the role of factor substitutability (with Alain Venditti). *Macroeconomic Dynamics* 8, 436–465, 2004f.

Optimal topological chaos in dynamic economies (with Tadashi Shigoka and Makoto Yano). In *Proceedings of the Sixth International Conference on Difference Equations Augsburg, Germany 2001*, pp. 189–198. London: CRC Press, 2004g.

Strategic growth (with Engelbert Dockner). *Journal of Difference Equations and Applications* 10 (5), 515–527, 2004h.

Working and training: A nonlinear dynamic analysis of human capital development (with Tadashi Yagi and Makoto Yano). *Japanese Economic Review* 55 (2), 119–140, 2004i.

Studying mathematics and university education, labor income and career promotion: Empirical analysis on the Survey on the Effects of Education at Departments of Economics in Japanese Universities on Career Formation (with Junichi Hirata, Junko Urasaka, and Tadashi Yagi). *Social System Studies* 7, 1–24, 2003a.

Working on the brain and rationality in economic behavior (with Yoshikazu Tobinaga). In *Proceedings of the IJCNN 2003* (International Joint Conference on Neural Networks by the International Neural Network Society and the IEEE Neural Networks Society), pp. 2604–2608, 2003b.

Characterization of equilibrium strategies in a class of difference games (with Engelbert Dockner). *Journal of Difference Equations and Applications* 7, 915–926, 2002a.

Indeterminacy and cycles in two-sector discrete-time models (with Jess Benhabib and Alain Venditti). *Economic Theory* 20, 217–235, 2002b.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

Indeterminacy in a dynamic Heckscher–Ohlin model (with Koji Shimomura). *Journal of Economic Dynamics and Control* 27, 271–281, 2002c.

Intersectoral externalities and indeterminacy (with Alain Venditti). *Journal of Economic Theory* 105, 140–157, 2002d.

Trade and indeterminacy in a dynamic general equilibrium model (with Koji Shimomura). *Journal of Economic Theory* 105, 244–259, 2002e.

Capital depreciation, indeterminacy and cycles in two-sector economies (with Alain Venditti). In T. Negishi, R. V. Ramachandran, and K. Mino (eds.), *Economic Theory, Dynamics, and Markets*, pp. 189–197. Dordrecht, The Netherlands: Kluwer Academic Publishers, 2001b.

Chaotic equilibrium dynamics in endogenous growth models (with Michele Boldrin, Tadashi Shigoka, and Makoto Yano). *Journal of Economic Theory* 96, 97–132, 2001c.

Discounting and long-run behavior: Global bifurcation analysis of a family of dynamical systems (with Tapan Mitra). *Journal of Economic Theory* 96, 256–293, 2001d.

Equilibrium growth and nonlinear dynamics in continuous time models. *Japanese Economic Review* 52, 1–19, 2001e.

Dynamical systems arising from infinite time horizon optimization models (with Alain Venditti). *Journal of Difference Equations and Applications* 6, 753–773, 2000b.

Indeterminacy under constant returns to scale in multi-sector economies (with Jess Benhabib and Qinglai Meng). *Econometrica* 68, 1541–1548, 2000c.

Chaotic equilibria in a small open, ovelapping-generations economy with child–parent externality (with Koji Shimomura). *Review of International Economics* 7, 484–492, 1999b.

Chaotic solutions in infinite-time horizon linear programming and economic dynamics (with Makoto Yano). *Advances in Mathematical Economics* 1, 115–126, 1999c.

Indeterminacy arising in multisector economies (with Jess Benhabib). *Japanese Economic Review* 50, 485–506, 1999d.

Markov perfect equilibria for a class of capital accumulation games (with Engelbert Dockner and Manfred Plank). *Annals of Operations Research* 89, 215–230, 1999e.

Nonlinear dynamics in the Cournot model without full information (with Daniel Léonard). *Annals of Operations Research* 89, 165–173, 1999f.

Non-linear dynamics in the infinite time horizon model (with Gerhard Sorger). *Journal of Economic Surveys* 13, 619–652, 1999g.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

On the existence of chaotic solutions in dynamic linear programming (with Makoto Yano). *Mathematics and Computers in Simulation* 48, 487–496, 1999h.

Transboundary pollution in a dynamic game model (with Engelbert Dockner). *Japanese Economic Review* 50, 443–456, 1999i.

Indeterminacy and sunspots with constant returns (with Jess Benhabib). *Journal of Economic Theory* 81, 58–96, 1998a.

Interior optimal chaos with arbitrarily low discount rates (with T. Shigoka and M. Yano). *Japanese Economic Review* 49, 223–233, 1998b.

The role of capital depreciation in multi-sector models (with G. Baierl and M. Yano). *Journal of Economic Behavior and Organization* 33, 467–479, 1998c.

Endogenous growth, trade and specialization under variable returns to scale: The case of a small open economy (with N.V. Long and K. Shimomura). In B. Jensen and K. Wong (eds.), *Dynamics, Economic Growth and International Trade*. Ann Arbor: Michigan University Press, 1997.

Chaotic solutions in dynamic linear programming (with M. Yano). *Chaos, Solitons and Fractals* 7, 1191–1953, 1996a.

On the least upper bound of discount factors that are compatible with optimal period-three cycles (with Makoto Yano). *Journal of Economic Theory* 69, 306–333, 1996b.

Optimal cycles and chaos: A survey (with Gerhard Sorger). *Studies in Nonlinear Dynamics and Econometrics* 1, 11–28, 1996c.

Durable capital and chaos in competitive business cycles (with Makoto Yano). *Journal of Economic Behavior and Organization* 27, 165–181, 1995a.

External debt cycles (with Michihiro Ohyama). *Journal of Structural Change and Economic Dynamics* 6, 215–236, 1995b.

Non-linear dynamics and chaos in optimal growth: An example (with Makoto Yano). *Econometrica* 63, 981–1001, 1995c.

Non-linearity and business cycles in a two sector equilibrium model: An example with Cobb–Douglas production functions (with Makoto Yano). In T. Maruyama and W. Takahashi (eds.), *Nonlinear and Convex Analysis in Economic Theory*, pp. 231–245. Berlin: Springer-Verlag, 1995d.

Sustainable plans of social security with endogenous fertility (with Junsen Zhang). *Oxford Economic Papers* 47, 182–194, 1995e.

Ergodic chaos in optimal growth models with low discount rates (with Gerhard Sorger and Makoto Yano). *Economic Theory* 4, 705–717, 1994a.

Optimal chaos, nonlinearity and feasibility conditions (with Makoto Yano). *Economic Theory* 4, 689–704, 1994b.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

Social capital as public goods and oscillatory behaviour (with Makoto Yano). *Ricerche Economiche* 48, 185–193, 1994c.

Endogenous fertility and growth (with Jess Benhabib). In M. Boldrin, R. Becker, R. Jones, and W. Thomson (eds.), *General Equilibrium, Growth and Trade II*, pp. 237–247. New York: Academic Press, 1993a.

Endogenous real business cycles and international specialization (with Makoto Yano). In W. Ethier, E. Helpman, and P. Neary (eds.), *Theory, Policy and Dynamics in International Trade*, pp. 213–236. Cambridge, UK: Cambridge University Press, 1993b.

Interlinkage in the endogenous real business cycles of international economies (with Makoto Yano). *Economic Theory* 3, 151–168, 1993c.

Optimal chaos when future utilities are discounted arbitrarily weakly (with Makoto Yano). In T. Maruyama and W. Takahashi (eds.), *Researches in Nonlinear Analysis and Mathematical Economics*, Lecture Note Series. Institute of Mathematical Analysis. Kyoto, Japan: Kyoto University, 1993d.

Self-generated fertility waves (with Vijit Kunapongkul). In F. Casprini and R. Barbucchi (eds.), *The Development of Science for the Improvement of Human Life*, pp. 201–207. Siena, Italy: Siena University Press, 1993e.

The old-age security hypothesis revisited (with Junsen Zhang). *Journal of Development Economics* 41, 191–202, 1993f.

Business cycles and complex non-linear dynamics (with Makoto Yano). *Chaos, Solitons and Fractals* 2, 95–102, 1992a.

Factor intensity and Hopf bifurcations (with Harutaka Takahashi). In G. Feichtinger (ed.), *Optimal Control Theory and Economic Analysis* 4, pp. 135–149. Amsterdam, The Netherlands: North-Holland, 1992b.

Pay-as-you-go public pensions with endogenous fertility (with Junsen Zhang). *Journal of Public Economics* 48, 239–258, 1992c.

Economic growth and fertility rate cycles (with Vijit Kunapongkul). *Chaos, Solitons and Fractals* 1, 475–484, 1991.

Factor price equalization. In A. Takayama, H. Ohta, and M. Ohyama (eds.), *Trade, Policy and International Adjustments*, pp. 275–284. New York: Academic Press, 1990.

Endogenous fluctuations in the Barro–Becker theory of fertility (with Jess Benhabib). In Alois Wening and K. Zimmerman (eds.), *Demographic Change and Economic Development*, pp. 29–41. Berlin: Springer-Verlag, 1989a.

Optimal growth theory and dynamical systems. In Nobuo Aoki (ed.), *The Study of Dynamical Systems*, pp. 225–232. Singapore: World Scientific, 1989b.

Stochastic equilibrium fluctuations (with Jess Benhabib). *International Economic Review* 30 (1), 85–102, 1989c.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

On endogenous cycles in discrete time optimal growth models (with Jess Benhabib). In G. Feichtinger (ed.), *Optimal Control and Economic Analysis III*, pp. 3–10. Amsterdam, The Netherlands: North Holland, 1988a.

On the aggregated growth models with non-concave production function (with Takahiro Miyao). In G. Feichtinger (ed.), *Optimal Control and Economics Analysis III*, pp. 303–310. Amsterdam, The Netherlands: North Holland, 1988b.

The dynamics of efficient intertemporal allocations with many agents, recursive preferences and production (with Jess Benhabib and Saqib Jafray). *Journal of Economic Theory* 44,301–320, 1988c.

Global equilibrium dynamics with stationary recursive preferences (with Jess Benhabib and Mukul Majumdar). *Journal of Economic Behavior and Organization* 8, 429–452, 1987.

Competitive equilibrium cycles (with Jess Benhabib). *Journal of Economic Theory* 35, 284–306, 1985.

A path of optimal economic development (with Jess Benhabib). *Keio Economic Review* 20 (1), 1–22, 1984a.

Cyclical input demand and adjustment cost theory of investment (with Jess Benhabib). In R. M. Goodwin, M. Kruger, and A. Vercelli (eds.), *Non-linear Models of Fluctuating Growth*. Berlin: Springer-Verlag, 1984b.

Impatience and accumulation (with Michael Magill). *Journal of Mathematical Analysis and Applications* 98, 270–281, 1984c.

A complete characterization of optimal growth paths in an aggregated model with a non-concave production function (with Davis Dechert). *Journal of Economic Theory* 31, 332–354, 1983a.

Optimal development strategies in a labor-surplus economy with scale effects (with Takahiro Miyao). *Environments and Planning A* 15, 1151–1159, 1983b.

Stability of equilibrium in dynamic models of capital theory (with Jess Benhabib). *International Economic Review* 22 (2), 275–293, 1981.

Existence of Nash equilibrium in n-person games without quasi-concavity (with James Friedman). *International Economic Review* 22 (3), 637–648, 1981a.

Kuhn's intensity hypothesis revisited. *Review of Economic Studies* 43, 351–354, 1981b.

On the shape of the single-country and world commodity-substitution and factor-substitution surfaces under conditions of joint production (with Murray Kemp et al.). *Journal of International Economics* 10, 395–404, 1980.

On the uniqueness of steady states in an economy with heterogeneous capital goods (with Jess Benhabib). *International Economic Review* 20 (1), 59–82, 1979a.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press

On the uniqueness theorems by Arrow and Hahn. *Journal of Economic Theory* 21 (2), 348–352, 1979b.

The Hopf bifurcation and the existence and the stability of closed orbits in multisector models of economic growth (with Jess Benhabib). *Journal of Economic Theory* 21, 421–444, 1979c.

A further remark on the number of equilibria of an economy. *International Economic Review* 19 (3), 679–685, 1978a.

On the existence proofs of general equilibria. *Economic Studies Quarterly* 29 (3), 276–281, 1978b.

https://doi.org/10.1017/S1365100511000472 Published online by Cambridge University Press